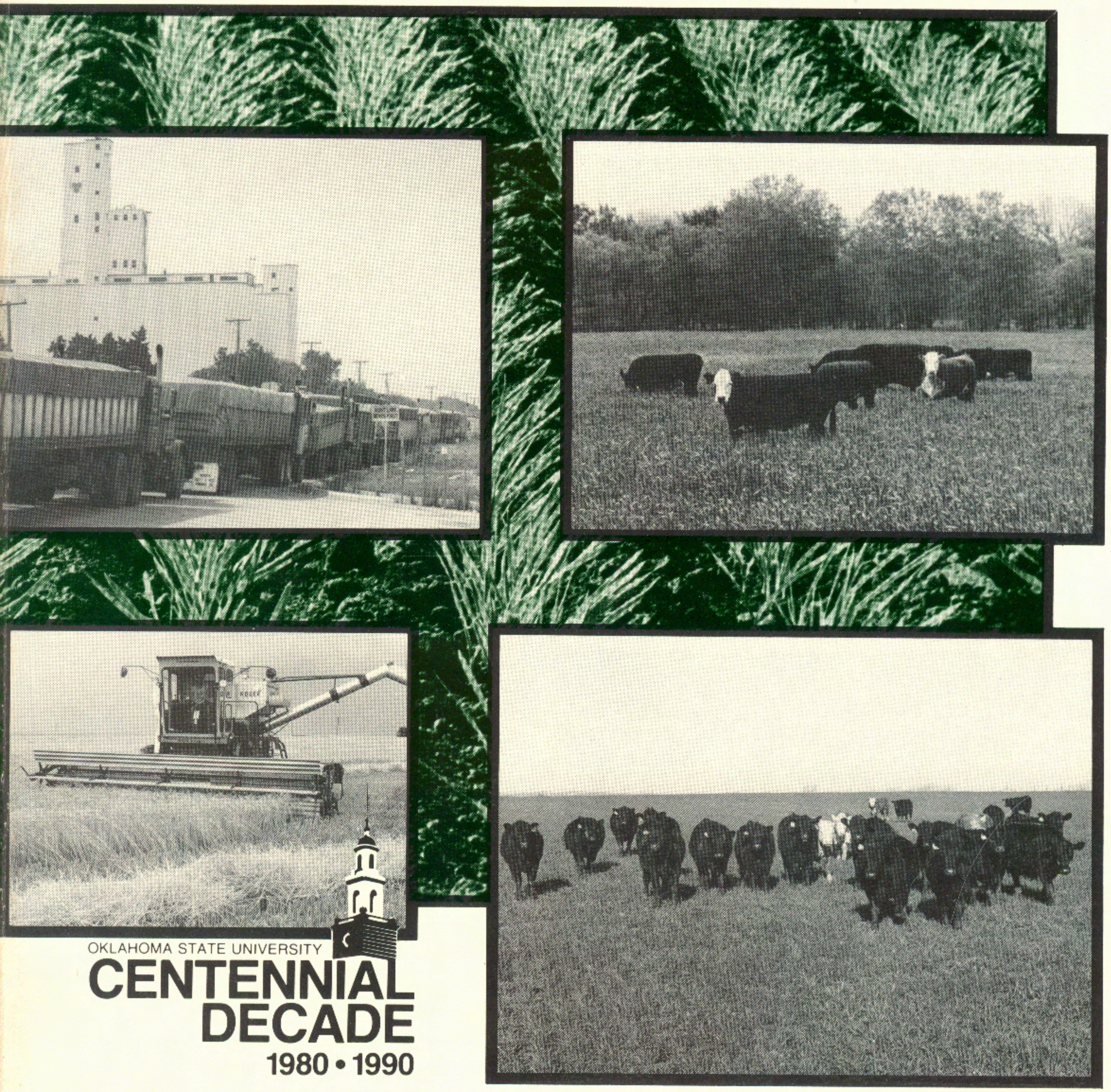
OCTOBER 24-25, 1983

NATIONAL WHEAT PASTURE SYMPOSIUM PROCEEDINGS



OKLAHOMA STATE UNIVERSITY
CENTENNIAL DECADE
1980 • 1990

Division of Agriculture Oklahoma State University MP-115

A Grant in Support of the Symposium from International Minerals and Chemical Corporation (Veterinary Products Division) is Gratefully Acknowledged.

Proceedings of the National Wheat Pasture Symposium

Edited by
Gerald W. Horn
Animal Science Department, Oklahoma State University,
Stillwater

Misc. Publication 115
Oklahoma Agricultural Experiment Station
Oklahoma State University
Stillwater

Published June 1984

A limited number of the Proceedings of the Symposium is available for purchase at a cost of $15 each.

Checks, payable to "Wheat Pasture Symposium" should be sent to Gerald W. Horn, Animal Science Department, Oklahoma State University, Stillwater, Oklahoma 74078

CONTENTS

Organizing and Program Committee iv

Preface v

Acknowledgements vi

I. AGRONOMIC CONSIDERATIONS TO MAXIMIZE FORAGE PRODUCTION

Cultural Practices for Maximizing Forage Production in Wheat 3
K.J. Donnelly and W.E. McMurphy

Variety and Species Effects on Forage Quantity, Forage Quality and Animal Performance 23
Lavoy I. Croy

Effects of Clipping and Grazing Termination Date on Grain Production 35
Lavoy I. Croy

Comments by Discussant (L.R. Nelson) 41

II. CHARACTERIZATION OF WHEAT FORAGE AND BASIC CONSIDERATIONS IN REGARD TO FORAGE UTILIZATION BY CATTLE AND METABOLIC DISORDERS

Chemical Composition of Wheat Pasture 47
F.P. Horn

Feeding Value of Wheat Silage and Hay as Wheat Crop Alternatives 55
Keith K. Bolsen

Utilization of the Energy and Protein Components of Forages by Ruminants - A United Kingdom Perspective 65
D.E. Beever

Mineral Composition of Wheat Forage as Related to Metabolic Disorders of Ruminants 99
D.L. Grunes, D.P. Hutcheson, F.P. Horn, B.A. Stewart and D.J. Undersander

Role of Magnesium, Potassium and Calcium in Normal Neuromuscular Function in Ruminants 115
James E. Breazile

Mechanisms of Tetany in Cows Grazed on Wheat Pasture 131
V.R. Bohman, F.P. Horn, W. Travis Littledike, J.G. Hurst and D. Griffin

Wheat Pasture Bloat of Stocker Cattle: A Comparison With Legume Pasture Bloat 145
R.E. Howarth and G.W. Horn

The Significance of Ruminal Motility in the Etiology of Bloat 165
H.W. Colvin, Jr. and G.W. Horn

Observations of Wheat Pasture Sudden Death Syndrome 197
Dee Griffin

Observations on Deaths of Stocker Cattle on Wheat Pasture 199
L.C. Hollis

III. GRAZING MANAGEMENT CONSIDERATIONS

Effects of Sward Structure on Forage Intake. Implications For Increasing Performance of Cattle on Wheat Pasture............207
T.D.A. Forbes
Forage and Grazing Effects on Intake and Utilization of Annual Ryegrass by Cattle..223
W.C. Ellis, J.P. Telford, H. Lippke and M.E. Riewe
Response of the Wheat Plant to Non-Animal Stresses....................235
Betty Klepper
Grazing of Wheat in the Vegetative Stage: Shoots.....................244
Scott Christiansen
Rooting Dynamics and Water Stress in Wheat: Potential Impacts of Grazing....................................257
Tony Svejcar
Rotation Grazing of Small Grain Pasture...............................265
R.L. Dalrymple
Comments by Discussant (M.M. Kothmann)................................293

IV. LIMIT-GRAZING COWS AND STOCKER CATTLE ON SMALL GRAINS FORAGES

Limit Grazing of Small Grain Pastures.................................297
Wadell Altom and T. Fred Schmedt
Limit-Grazing Cows and Stocker Cattle on Small Grains Forages: Rancher's Perspective and Data Needs.............................319
John L. Merrill

V. SUPPLEMENTATION PROGRAMS FOR WHEAT PASTURE STOCKER CATTLE

Supplemental Feeding of Grain and Protein for Stocker Cattle on Small Grains Pastures.................................327
Don Wagner, Robert Lowrey and Mark Grigsby
Effects of Ionophores on Grazed Forage Utilization and Their Economic Value for Cattle on Wheat Pasture.................343
W.C. Ellis, G.W. Horn, D. Delaney and K.R. Pond
Use of Implants of Anabolic Compounds for Growing Cattle on Small Grain Pastures..357
S.B. Laudert, G.W. Horn and J.W. McNeill
Feeding Low-Quality Roughages to Stocker Cattle on Wheat Pasture......365
G.W. Horn, T.L. Mader, W.A. Phillips and A.B. Johnson

VI. ECONOMIC EVALUATION OF WHEAT CROP ALTERNATIVES

Estimating Costs and Returns for Wheat Crop Alternatives in the Southern Plains -- Problems and Data Needs...................377
Wyatte L. Harman, John McNeill and G.B. Thompson
Linear Programming Analysis of Wheat Crop Alternatives................397
Orlan Buller
Microcomputer Analysis of Wheat Grain-Grazeout Alternatives Under the 1984 Government Program.................................413
Kim B. Anderson and Odell L. Walker

VII. FUTURE USE OF WHEAT PASTURE IN BEEF CATTLE PRODUCTION SYSTEMS

International Markets and the Wheat-Feed Grain Industries.............421
James S. Plaxico
Impacts of Government Policy Decisions on Production and Use (Grain Harvest Versus Grazing) of Wheat Pasture..................429
Kim B. Anderson and Luther Tweeten
Economics of the Meat Market and its Implications for the Future Use of Wheat Pasture in Beef Cattle Production Systems...435
James N. Trapp
Future Trends in the Beef Cattle Industry as Affected by Changes in Production Technology and Product Demand..............453
R.L. Preston

VIII. RESEARCH BRIEFS

Histamine Content of the Blood From Cows Affected With Tetany.........463
Rodney L. Preston
Grazing Winter Annuals...465
L.W. Lomas and J.L. Moyer
Sheep and Cattle Grazing Effects on Tillering Dynamics and Grain Yield of Winter Wheat.......................................467
Scott Christiansen, Tony Svejcar, W.A. Phillips, T.D.A. Forbes and J.D. Trent

ORGANIZING AND PROGRAM COMMITTEE

Gerald W. Horn, Chairman
Animal Science Department, OSU

Lavoy I. Croy
Agronomy Department, OSU

William A. Phillips
USDA/ARS, El Reno, Oklahoma

Odell L. Walker
Agricultural Economics Department, OSU

PREFACE

The National Wheat Pasture Symposium was held at Oklahoma State University on October 24 and 25, 1983. Program participants were from 11 states and 2 countries (England and Canada) other than the United States. Objectives of the symposium were to:

1. Review and consolidate the present knowledge base with regard to production and utilization of wheat pasture.

2. Identify, at the end of each paper, high-priority areas of needed research.

3. Explore future use of wheat pasture in livestock production systems.

A highlight of the Symposium was the presentation, "Utilization of the Energy and Protein Components of Forages by Ruminants - A United Kingdom Perspective", by David E. Beever of the Grassland Research Institute. The basic concepts of his paper challenge much of the traditional thinking with regard to utilization of high-quality small grain forage, and will provide inspiration for future research to improve the efficiency of production of ruminant livestock on small grain forages.

May 1984 G.W.H.

ACKNOWLEDGEMENTS

EDITORIAL ASSISTANCE

Papers presented at the symposium were submitted for peer review prior to preparation. The work of the following in coordinating the review of papers of certain sections of the Symposium is gratefully acknowledged.

Lloyd R. Nelson	Section I
David P. Hutcheson	Section II
William A. Phillips and M. M. Kothmann	Section III
Phillip L. Sims	Section IV
Odell L. Walker	Sections VI and VII

FINANCIAL SUPPORT

International Minerals and Chemical Corportation (Veterinary Products Division) provided the grant that served as the real spring-board for the Symposium. Thanks Jess.

SECRETARIAL SUPPORT

The Organizing and Program Committee would like to thank Mrs. Carolyn Gray for her excellent assistance in the organization and conduct of the symposium and in the preparation of this proceedings.

I. AGRONOMIC CONSIDERATIONS TO MAXIMIZE FORAGE PRODUCTION

CULTURAL PRACTICES FOR MAXIMIZING FORAGE PRODUCTION IN WHEAT

K. J. Donnelly and W. E. McMurphy[1/]

Summary

Continued expansion of the use of winter wheat for pasture in the Southern Great Plains has created a need for more information on how to enhance forage production, particularly in combination with grain production. Cultural practices for maximizing forage production often differ from those recommended for grain production. These differences include earlier seeding date, higher seeding rate, greater fertilizer needs, and greater attention to pest problems. Fall and winter forage production is most often limited and also is most responsive to proper management. Another critical cultural practice is management of grazing itself to maximize forage production without reducing grain yields. To assure adequate forage in northern areas, grazing must not start until plants are well established, and stocking rates must be adjusted to allow stockpiling of forage for winter months when growth slows. Rotational grazing systems may assist this effort and also increase forage yields, especially when grazing is continued on through spring (graze-out). For grain production, grazing must be terminated prior to elevation of the apical meristems to grazing height or yields will be drastically affected.

The primary area which needs further attention appears to be cultivar development for increased forage production. Current wheat breeding programs are designed primarily to increase grain yield potential, and no current cultivars consistently produce superior forage yields. Other areas needing further evaluation include additional descriptions of optimum seeding dates and rates for specific locations, benefits of narrower rows, irrigation scheduling, grazing with reduced tillage systems, development of effective pesticides without grazing restrictions, optimum grazing systems, and the establishment and acceptance of grazing termination guidelines based on plant development rather than calendar dates.

Introduction

Small grains have long been recognized as a valuable source of high quality forage for grazing livestock (Staten and Heller, 1949). Most of the extensive use of small grains pasture occurs in Texas, Oklahoma, and Kansas, where producers typically utilize winter wheat for grazing during its vegetative growth stage in fall, winter, and early spring. Livestock are then removed in spring shortly after floral initiation before rapid culm elongation begins (jointing stage) to allow reproductive development for grain production. If grazing intensity is not excessive and grazing is terminated before the apical

[1/] Assistant professor and professor, respectively, Oklahoma State University, Stillwater, OK 74078.

meristems reach grazing height, grain yields may not be greatly affected and may actually be increased under certain conditions (Croy et al., this publication). However, a considerable portion of winter wheat acreage is used exclusively for grazing on through spring until regrowth ceases and plants eventually mature (graze-out). Graze-out can result in approximately three times greater total forage yields (McMurphy, 1976), since winter wheat accumulates most of its total dry matter after floral initiation (Shanahan, 1982). With depressed grain prices in recent years, interest in the latter practice has increased. Interest has been particularly high during the past year since the Federal Government's payment-in-kind (PIK) program allowed graze-out on qualified acres as a method of removing those acres from grain production.

Most of the research on cultural practices for winter wheat has concentrated on grain production. Cultural practices for maximizing forage production in winter wheat, particularly for encouraging greater availability of fall and winter forage, are somewhat different than those recommended for maximizing grain production. The objectives of this presentation are to review some of the studies which have evaluated forage production and to summarize recommendations for cultural practices designed to maximize forage production in winter wheat. Emphasis will be placed on winter wheat due to its more extensive use and great ability to produce grain following termination of grazing, although other small grains such as rye, oats, barley, triticale, sterile wheat hybrids, and various small grain mixtures have also been evaluated, and some of them may provide more forage under certain conditions (Cook, 1968; Atkins et al., 1969; Denman and Arnold, 1970; Cowley et al., 1971; Malm et al., 1973; Finkner, 1974; McMurphy, 1976; Gardenhire and Wilkerson, 1980; Rommann et al., 1982). Species and variety effects on forage production are reviewed in more detail elsewhere in these proceedings (Croy, this publication). Major cultural practices which should be considered for forage production in winter wheat include: seeding date, seeding rate and row width, soil fertility management, irrigation management (where practiced), cultivar selection, grazing management (stocking rates, rotations, starting and termination dates), seedbed preparation, and pest control (weeds, insects, diseases). All of these practices will interact with two critical environmental factors, precipitation and temperature, to determine actual forage production. As a result of the importance of precipitation and temperature effects, results from one location or one year may not always apply to other locations or years.

Review of Literature

Seeding Date. The effect of seeding date on forage production has probably been studied more than any other cultural practice, and indeed it may be one of the most important management factors determining the potential for fall and winter forage. Studies conducted over several years in South Central Oklahoma near Ardmore (Bates, 1975-1983) have consistently shown an advantage to planting wheat and other small grains in mid-September or early-October compared to late-October or early-November for fall and winter forage production (through late-February or early-March). However, in most years, total forage production through May (simulated graze-out) has been slightly greater with the later planting date. These results indicate that spring forage production increased with later planting more than enough to offset the fall and winter advantage of earlier planting. Harper (1961) also showed that small grains planted in mid-September produced twice as much fall and winter forage as when planted in mid-October near Admore, Oklahoma.

Further north at Perkins, Oklahoma, Phillips (1975) showed that delayed seeding from August 22 resulted in a decrease in fall and winter forage which averaged over 500 lb/acre/week in 1972-73 (Table 1) and over 400 lb/acre/week in 1973-74 (Table 2). As in the reports of Bates (1975-1983), spring forage production following jointing was greater with the later planting dates. However, spring growth was unable to make up for the difference prior to jointing, such that total production (simulated graze-out) was decreased with delayed seeding by approximately 400 lb/acre/week in 1972-73 and 300 lb/acre/week in 1973-74 (Tables 1 and 2). Seeding date did not have a significant effect on grain yields in either unclipped control plots or in plots last clipped on March 17 in 1972-73. However, grain yield was reduced for all seeding dates by the March 17 clipping. In 1973-74, maximum grain yield for unclipped controls was produced with an October 17 planting date. This was expected, since the recommended seeding date for grain production in this area is October 1-15. However, Phillips (1975) also showed that the lower grain yields associated with planting on August 23 or September 18 in 1973-74 were increased to the levels of the unclipped control planted in October if fall forage was removed in December (Table 3). Thus, fall forage removal (simulated grazing) enhanced grain yields in the early seeded treatments.

Elder (1960) compared six planting dates over four seasons with clipping every 30 days using a winter pasture mixture of rye, wheat, oats, and vetch at Stillwater, Oklahoma. September 10, September 25, and October 10 seeding dates gave the same total forage production through May, but the September 10 seeding date produced twice as much forage before January 1 as the October 10 seeding date. Seeding after October 25 resulted in no measureable forage before March and also decreased total forage production.

In Texas, Holt et al. (1969) also found that September or early-October seeding was important for fall forage production with small grains at College Station but did not produce highest total forage yields for simulated graze-out. October 15 was the optimum date for total forage production. They suggested that the major problems with earlier planting are increased chance of drought and increased incidence of weeds and insects.

For irrigated wheat in Southeastern New Mexico, Malm et al. (1973) found two-thirds more forage production prior to jointing in March with September 1 or September 15 planting compared to October 1 planting. Planting October 15 or November 1 produced no measureable winter forage and considerably less forage prior to jointing (Table 4). The one month delay in planting from September 15 to October 15 decreased

Table 1. Accumulated wheat forage production as affected by seeding date at Perkins, Oklahoma, 1972-73 season.

Seeding Date	Accumulated Production Through:				
	Nov. 3	Dec. 1	Mar. 17	Apr. 26	May 23
	lb/acre				
Aug. 22	2170	2670	4770	6630	7380
Sept. 5		1510	3740	5920	6570
Sept. 19			2720	4660	5350
Oct. 3			1530	4360	4930

From Phillips (1975)

Table 2. Accumulated wheat forage production as affected by seeding date at Perkins, Oklahoma, 1973-74 season.

Seeding Date	Accumulated Production Through:				
	Oct. 26	Dec. 14	Mar. 25	Apr. 18	May 22
	lb/acre				
Aug. 23	1930	2500	4420	5510	6180
Sept. 18		1250	3160	4090	4870
Oct. 17			1400	2700	3310
Nov. 30				1160	1900

From Phillips (1975)

Table 3. Wheat grain yield as affected by seeding date and time of last forage harvest at Perkins, Oklahoma, 1973-74 season.

Last Forage Harvested On	Seeding Date			
	Aug. 23	Sept. 18	Oct. 17	Nov. 30
	bu/acre			
Never Harvested	13	19	27	24
Oct. 26	21	No. Hv.[1/]	No. Hv.[1/]	No. Hv.[1/]
Dec. 14	30	26	No. Hv.[1/]	No. Hv.[1/]
Mar. 25	19	16	21	No. Hv.[1/]
Apr. 18	0	2	3	4

[1/] Forage growth was insufficient to have a harvest at this early date after seeding or it was before seeding.

From Phillips (1975)

Table 4. Accumulated irrigated wheat forage production and grain yield following grazing as affected by seeding date in Southeastern New Mexico, 1970-71 and 1971-72 seasons.

Seeding Date	Accumulated Production Through:			Grain Yield
	December	February	March	
	lb/acre			lb/acre
Sept. 1	1680	2880	4540	1602
Sept. 15	1980	3400	5160	1874
Oct. 1	--	1280	2860	2105
Oct. 15	--	--	1280	2433
Nov. 1	--	--	680	1461

From Malm et al. (1973)

forage production prior to jointing by almost 4000 lb/acre. This is about double the rate of yield reduction with delayed planting reported by Phillips (1975) under non-irrigated conditions in Oklahoma. Grain yields following termination of forage harvests at jointing were greatest with the October 15 planting, and decreased for successively earlier dates or for the November 1 planting date (Table 4).

Fuehring (1981) also noted the importance of early planting for maximizing forage yields of irrigated wheat in the High Plains of New Mexico. Fall and winter forage yields were reduced drastically when planting was delayed past early-September. However, for simulated graze-out, planting date had only a small effect on total forage production. Grain yields were not greatly influenced by planting date. However, delaying the date of final forage harvest by approximately one-week intervals during March gradually increased forage yields but decreased grain yields.

Since these studies all indicate the necessity of seeding earlier than recommended for grain production to assure fall and winter forage production potential, we have initiated more detailed studies to further evaluate the optimum seeding date at five different locations throughout Oklahoma. Where adequate fall moisture was received in 1980-81 at Haskell, Oklahoma (East Central), seeding in mid-August resulted in highest accumulated forage yields throughout all forage harvests (Table 5). With lower fall moisture in 1982-83, a similar trend was observed, but the differences were not as large. Under irrigation at Goodwell, Oklahoma (Panhandle), optimum seeding date appears to be late-August or early-September. Maximum accumulated forage production for all clippings was greatest for the September 2 seeding in 1980-81 (Table 6) and the August 30 seeding in 1982-83 (Table 7). Mid-August planting was similar to mid-September planting for fall and winter production in 1980-81, but the latter produced 600 lb/acre more total forage by the end of May.

Unfortunately, fall moisture has been so limited at the other three locations during the first two years of this study that very little fall and winter forage was produced with any seeding date. Under these conditions, seeding date had little effect on spring forage production either, since all treatments were "evened-out" due to the slow establishment. These results simply point out the critical role of moisture in wheat forage production over which the non-irrigated producer has little control. Denman and Arnold (1970) and McMurphy (1976) both noted that limited fall moisture in Southwestern Oklahoma usually prevents early fall establishment of winter wheat for forage production. However, there may still be an advantage to early planting in dry soil in some situations, since later rainfall will allow germination and quick establishment. A potential problem is that enough rainfall to germinate seeds may be received, but not enough to keep seedlings alive, thereby resulting in a poor stand. Perhaps the problem is more likely with August planting when rainfall is often received in smaller increments than during later fall months.

Table 5. Accumulated wheat forage production as affected by seeding date at Haskell, Oklahoma, 1980-81 season.

Seeding Date	Accumulated Production Through:			
	November 20	February 27	April 1	April 23
	lb/acre			
Aug. 14	2151	3079	6630	6981
Aug. 28	1520	2511	6118	6486
Sept. 11	247	961	4254	4652
Sept. 25	--	311	3257	4062

Table 6. Accumulated irrigated wheat forage production as affected by seeding date at Goodwell, Oklahoma, 1980-81 season.

Seeding Date	Accumulated Production Through:					
	January 9	March 17	March 31	April 16	April 30	May 28
	lb/acre					
Aug. 18	2403	3605	4665	5192	5670	6460
Sept. 2	2436	3958	5243	6215	6560	7592
Sept. 17	1636	3278	4476	5356	5700	7060
Oct. 3	492	1887	3385	4289	4972	6218

Table 7. Accumulated irrigated wheat forage production as affected by seeding date at Goodwell, Oklahoma, 1982-83 season.

Seeding Date	Accumulated Production Through:					
	January 19	March 1	March 30	April 12	May 12	June 21
	lb/acre					
Aug. 30	798	1817	4765	5902	8333	10932
Sept. 17	--	378	2775	3586	6077	9262
Sept. 27	--	--	2273	3355	5999	9097
Oct. 11	--	--	835	1666	4733	8094

Seeding Rate and Row Width. Only a few studies have reported on the effects of seeding rate and/or row width on forage production. However, recommendations for small grain forage production have often suggested seeding rates 50 to 100% higher than normally recommended for grain production (Fribourg, 1973). Holt (1959) found forage production of oats by January 3 at Crystal City, Texas, was increased by 1300 lb/acre with 96 lb of seed per acre compared to 48 lb per acre. However, accumulated forage production by March 18 was only 500 lb/acre greater with the higher seeding rate. Small advantages to higher seeding rate have also been reported in other studies in Texas by Holt et al. (1969). They found less advantage to 100 lb seed/acre vs. 50 lb seed/acre for wheat compared to oats or rye at College Station.

Shipley and Regier (1972) showed a much greater response to higher seeding rate for irrigated wheat in the Texas High Plains. The difference in fall and winter forage production (August 30 to March 1) (Figure 1) was much greater than the difference in spring forage production (March 1 to June 4) (Figure 2). There was no effect of seeding rate without irrigation. In another year, 90 or 120 lb of seed per acre resulted in more fall and winter forage under irrigation than did 60 lb of seed per acre. Grain yields were not influenced by seeding rate in these studies.

Rao et al. (1969) found no difference in winter forage yield for 60, 75, or 95 lb seed per acre in winter wheat at College Station. However, averaged over all seeding rates, 6-inch rows gave a significant increase (11%) over 9- or 12-inch rows. Bishnoi (1980) also showed an advantage of 5-inch row width over 10-inch row width for winter forage production of wheat and rye in Northern Alabama. Seeding rates of 75 or 100 lb per acre also resulted in higher forage production than 50 lb per acre. However, seeding at 50 lb per acre produced highest grain yields whether plots were clipped for winter forage or not. Holt et al. (1969) found no advantage to broadcast seeding over 12-inch rows.

Thus, it appears that higher seeding rate and narrow row spacing may be advantageous for early fall forage production, especially under high moisture or irrigation with early seeding dates. However, as Holt et al. (1969) noted, the tillering characteristic of small grains tends to compensate for low plant populations and row width differences, such that little forage benefit from higher seeding rate or narrower rows is observable by spring. Indeed if grain is also to be produced, high seeding rate may be a disadvantage, since too high plant population may lead to decreased numbers of spike-bearing tillers (Puckridge and Donald, 1967).

Soil Fertility Management. The primary nutrient usually associated with limiting potential small grain forage production is nitrogen (N). The basis for the high N demand for forage production is a matter of simple arithmetic. Winter wheat forage containing 25% crude protein will contain approximately 4% N. Thus, one ton of dry forage will contain 80 lb of N. A reasonable forage production goal for graze-out in Oklahoma is 2-3 tons/acre, which would require 160-240 lb N/acre. Oklahoma Cooperative Extension Service soil test recommendations (Johnson and Tucker, 1982) base N requirements on yield goal and in-

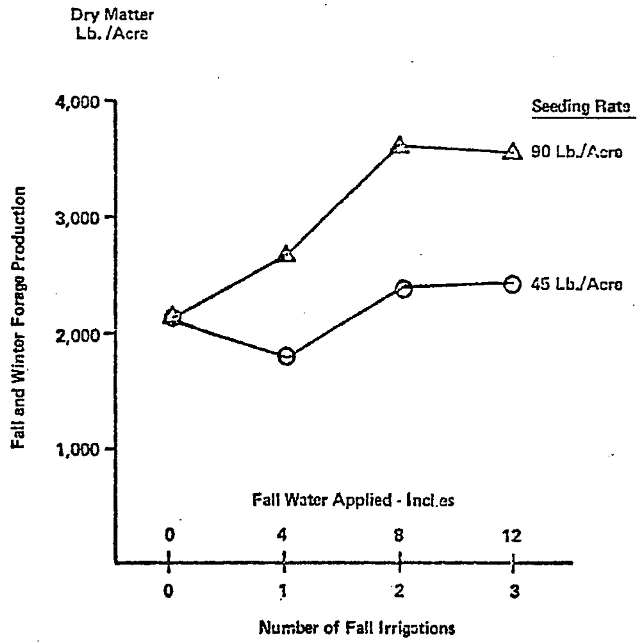


Figure 1. Forage production of irrigated winter wheat from emergence on August 30 to March 1, irrigated wheat grazing study, North Plains Research Field, Etter, Texas, 1970-71. (From-Shipley and Regier, 1972).

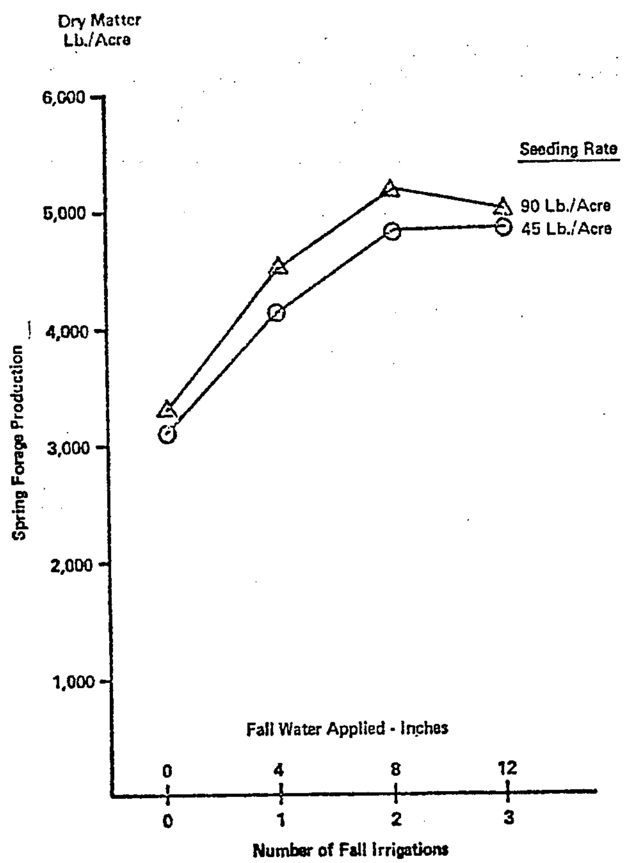


Figure 2. Forage production of irrigation winter wheat from March 1 to June 4, irrigated wheat grazing study, North Plains Research Field, Etter, Texas, 1970-71. (From-Shipley and Regier, 1972).

dicate 60 lb N/acre required per ton of forage for grazing small grains. In addition, 2 lb N/acre per bushel of grain yield goal is required, if both forage and grain are produced. Nitrogen fertilization according to yield goal and forage removal seems to be the best approach, since actual comparisons of small grain forage yields to fertilizer application have produced varied responses. Nitrogen fertilization appears to have little effect on forage quality in Oklahoma (Denman and Arnold, 1970).

In actual fertilization studies, Holt et al. (1969) reported increases of 1200 to 1500 lb of forage per acre for 120 vs. 60 lb N/acre at Mt. Pleasant, Texas. This would be consistent with the 80 lb N per ton of forage suggested earlier. Fall and early winter growth increased as pre-plant N increased from 30 to 120 lb N/acre. However, at College Station, responses were not as great. In Georgia, Morris and Gardner (1958) found 120 lb N/acre increased forage yields by March 15 only 750 lb per acre compared to 60 lb N/acre. Phillips (1975) compared 60 lb N/acre at planting to 180 lb N/acre split among planting, November 8, and March 15 at Perkins, Oklahoma. The high N increased total forage production averaged over four seeding dates from 5310 to 6062 lb per acre (Table 8). However, the greatest increase was in fall and winter production (611 lb/acre) compared to the increase during spring (142 lb/acre). The lack of consistency in N responses is probably related to differences in organic matter, temperature effects on mineralization of N, moisture interactions, other nutrient levels, and other factors.

Split application of N has been suggested to increase forage yields of small grains for grazing (Fribourg, 1973). Holt et al. (1969) reported increased yields in response to split application between planting and winter (December or January) at several locations in Texas. Two post-planting applications were of no advantage, however. Atkins et al. (1969) indicated a small response to an additional 30 lb N/acre in mid-winter at College Station. In Oklahoma, Elder (1967) found no advantage to split application of N between fall and spring. It appears that the principle advantage of split application would be the ability to adjust N needs to forage removal, since unpredictable environmental factors make it difficult to estimate total N needs at planting. If conditions are favorable for heavy grazing removal in fall and/or spring, then additional N may be needed, especially if a grain crop is to be taken. For early forage production, sufficient N for a reasonable forage yield goal should be applied at planting or before.

Phosphorus (P) is also critical and has been shown to have an even greater effect than N on fall forage production under some conditions in Oklahoma (Edler, 1967). Cook (1968) showed that P alone did not increase forage yields significantly, but a combination of N and P resulted in higher yields than either alone. Cook's results averaged over five years at Temple, Texas, are summarized in Table 9. Baker and Tucker (1971) showed that the potential for NO_3-N accumulation in wheat forage was reduced by P application. Oklahoma Cooperative Extension Service recommendations (Johnson and Tucker, 1982) for P and K on winter wheat are based on soil test levels and are equivalent for forage and/or grain production.

Table 8. Effect of seeding date and nitrogen fertilization on forage yields of Centurk wheat at Perkins, Oklahoma, 1972-73 season.

Seeding Date	Forage Production Through March 17	After March 17	Total
	lb/acre		
Low Nitrogen (60 lb N/acre)			
Aug. 22	4254	2342	6596
Sept. 5	2909	2766	5675
Sept. 19	2256	2793	5049
Oct. 3	905	3015	3920
Mean	2581	2729	5310
High Nitrogen (180 lb N/acre)			
Aug. 22	4774	2610	7384
Sept. 5	3739	2832	6571
Sept. 19	2723	2629	5352
Oct. 3	1530	3411	4941
Mean	3192	2871	6062
$LSD_{(P=.05)}$	396	439	392

From Phillips (1975)

Table 9. Average effects of combinations of nitrogen and phosphorus on small grain forage yields at Temple, Texas, 1963-67 season.

N (lb/acre)	P_2O_5 (lb/acre) 0	30	60	Average
	lb/acre			
0	2700	2900	3050	2880
15	3040	3510	3630	3330
30	3450	3960	3990	3800
60	3520	3910	4040	3820
90	3790	4050	4180	4010
Average	3300	3660	3780	

From Cook (1968)

Irrigation management. Although a considerable portion of the irrigated winter wheat acreage in the High Plains is grazed, only limited studies of irrigation practices for optimizing forage production either in combination with grain production or for graze-out have been completed. At the North Plains Research Field at Etter, Texas, Shipley and Regier (1972) evaluated irrigation management effects on forage production using both clipping and grazing trials. In 1970-71, they compared one, two, or three fall irrigations of 4 inches each to no irrigation. Maximum total clipped forage yields for simulated graze-out were produced with 90 lb seed/acre and two fall irrigations. There was a significant increase in forage yields with two irrigations compared to one, but there was no advantage to a third fall irrigation (Figure 3). Greater effects of irrigation on forage production were observed during spring compared to fall and winter and at the 90 lb seeding rate compared to the 45 lb seeding rate (Figures 1 and 2). In 1971-72, the optimum date for the second fall irrigation was evaluated. Seeding date was September 1, and the first irrigation was November 1. Highest total forage yields were obtained with the second irrigation on January 15 compared to December 15, January 1, February 1, or February 15.

In the grazing trials, at the 90 lb seeding rate over three years, grain yields were increased by fall and winter grazing compared to ungrazed, irrigated control plots planted September 1. However, grain yields were as much as 30% lower than ungrazed wheat planted in October during two of the years. There was only a slight reduction in grain yield with different grazing termination dates from March 1 through April 10, but later termination dates greatly depressed yields. Within grazing treatments, grain yields following grazing were not affected by seeding rate or irrigation schedule, provided at least one fall irrigation was applied.

Cultivar selection. In general, although differences among cultivars for forage production have been noted within years at different locations, no consistent advantages of particular cultivars of winter wheat for forage production have been found during extensive testing in Oklahoma (Denman and Arnold, 1970; McMurphy, 1976; Rommann et al., 1976-1982). Most of the popular cultivars selected for grain production have shown the ability to produce good forage yields under favorable conditions. Cowley et al. (1971) reported similar inconsistent results from year to year when comparing wheat and other small grain varieties at Bushland, Texas. Malm et al. (1973) suggested an advantage for sterile wheat hybrids for graze-out since they exhibit delayed senescence. McMurphy (1976) noted that the most important consideration is selection of a cultivar which is capable of rapid fall growth since fall and winter forage is usually limiting in Oklahoma. Since most producers are primarily interested in grain production, winter wheat cultivars are usually selected on the basis of grain yield potential rather than forage yield potential as noted by Holt et al. (1969). Additional notes on cultivar and species effect on forage quantity and quality are reported herein (Croy, this publication).

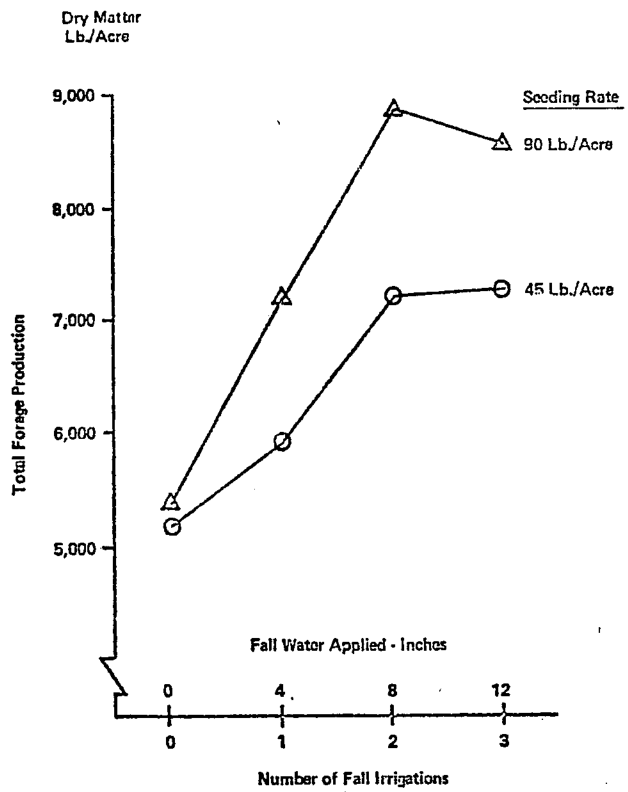


Figure 3. Forage production of irrigated winter wheat from emergence on August 30 to graze-out on June 4, irrigated wheat grazing study, North Plains Research Field, Etter, Texas, 1970-71 (From-Shipley and Regier, 1972).

Table 10. Effect of foliage removal in fall and winter on wheat forage production following planting on August 23, 1972, at Perkins, Oklahoma.

Harvest Dates	Harvest Treatment		
	3 harvests	2 harvests	1 harvest
	----------- lb/acre -----------		
Oct. 9	1790	No Clip	No Clip
Dec. 1	989	2370	No Clip
Mar. 15	2300	1962	4008
Total	5079	4332	4008

From Phillips (1975)

Grazing Management. The effects of grazing management on grain yields following termination of grazing are of major concern to producers using winter wheat for forage plus grain. It is well established that grazing must be terminated prior to elevation of apical meristems on potential spike-bearing tillers to grazing height to avoid serious grain yield reductions (Dunphy et al., 1982). Effects of grazing management during the grazing period on grain yields are less well defined and relate to factors such as starting date, grazing intensity, continuous grazing vs. rotation or limit grazing, the specific timing of grazing termination based on a recommended "safe" calendar date compared to actual plant development which varies from year to year, and interactions with environmental factors. More detailed discussions of some of these factors are included elsewhere (Croy et al., this publication).

Grazing management also has a significant impact on forage production and utilization, whether using graze-out or forage plus grain systems. Since an entire session of this symposium has been devoted to this area, only a brief reference will be made here. Holt et al. (1969) summarized work in Texas on grazing management and related the importance of delaying first grazing until small grain plants were well established with 8-10 inches of topgrowth and sufficient root development to resist uprooting by grazing, then managing subsequent grazing either to maintain residual leaf area or allow a recovery period between grazings. Clipping oat forage each time plants reached 4-6 inches produced only half as much forage as clipping at 10-12 inches.

In southern portions of the wheat grazing area, forage production can be expected to continue throughout the winter months. However, further north when temperatures drop below 40^{o}F, wheat makes very little growth (Holt, 1962). Therefore, forage must be stockpiled to carry the livestock through January and February (Rommann et al., 1975-1982). Forage growth occurs at a faster rate during the spring, and two-thirds of the total production occurs after jointing in Oklahoma. Thus, producers should expect to be able to graze the same number of livestock on one-half of the acreage during spring graze-out compared to that needed for fall and winter. If sufficient fall forage is produced, Phillips (1975) showed that total forage production was increased by removing fall forage which reached 8-10 inches in height (Table 10). Fall forage removal also enhanced grain yields of early seeded wheat as previously indicated (Table 3). However, once jointing occurred, forage removal in spring actually decreased potential forage yield by removing apical meristems and slowing growth. These results probably help explain why rotational grazing increased carrying capacity by 15-20% in the spring but not in the fall in East Central Oklahoma (Elder, 1967).

Seedbed Preparation. Little research on specific seedbed preparation techniques for enhancing forage production has been conducted. However, a major proglem which limits fall forage production of winter wheat under non-irrigated conditions in most of the Southern Plains is the frequent lack of available soil moisture for seed germination and plant establishment at the desired August or early-September seeding dates (McMurphy, 1976). Therefore, a primary concern in seedbed preparation during the entire fallow period from previous crop harvest to planting should be moisture conservation. As such, tillage should be performed only as needed to control weed growth and produce a suitable seedbed. The development of reduced tillage systems which may result in better moisture conservation during the fallow period may seem attractive. However, recent emphasis on developing reduced tillage systems for winter wheat grain production in Oklahoma have not evaluated grazing as a part of the systems (E.G. Krenzer, pers. comm.). Research in Texas (Unger, 1971) has shown that grazing small grain crops leads to increased soil compaction measured by bulk density or soil penetrometer. Effects were greatest in the top three inches of the soil profile and when soil water content was near field capacity. The primary tillage operation immediately following termination of grazing (graze-out) or grain harvest in conventional tillage systems is usually moldboard plowing which breaks up compact surface layers. One potential problem with reduced tillage systems is that moldboard plowing as a primary tillage step is eliminated. This may limit the effectiveness of such systems in combination with grazing where surface soil compaction is likely.

Pest Control. Pest problems (diseases, insects, weeds) in winter wheat are similar whether the crop is used for forage, grain, or both. However, management practices used to promote forage production may alter the potential for damage by certain pests. Although most of the specific discussion here applies to Oklahoma, the same principles may apply to other pest problems at different locations.

Holt et al. (1969) noted that diseases are less of a problem in forage production than in grain production because most diseases seldom become serious until early spring after major forage needs have been met. As a result, disease problems in winter wheat grown for both forage and grain are of greater conern than in that grazed out. However, warm soils and high temperatures associated with early planting for forage production in either system are more favorable for development of several diseases such as seedling blights caused by the root rot pathogens Helminthosporium and Fusarium (Williams et al., 1980). Forage yield reductions of 77% have been reported in root rot infested areas due to stand losses. Thus, fungicide seed treatment for control of seedling diseases is very critical with early seeding. Another disease which is more prevalent in Oklahoma with early planting, especially when volunteer wheat is not adequately controlled, is wheat streak mosaic (Williams and Young, 1977). The vector (wheat curl mite) and virus survive during the fallow period on volunteer wheat. Although symptoms may not appear in the fall, early planting allows a longer time in the fall for the disease to be transmitted and develop. Powdery mildew is a disease which may be more prevalent with lush fall growth following early seeding and high fall moisture, but a good method of control is grazing itself to remove the excess vegetative growth. Fall grazing is also a method of reducing leaf rust (Williams, 1978). For most other disease problems in Oklahoma, management for grazing probably has no different effect than management for grain (R.A. Johnston, pers. comm.). However, selection of resistant cultivars and following recommended cultural practices to reduce incidence of any disease should benefit both grain and forage yield potential.

Insect problems which may be intensified by grazing management include the false wireworm, which is most likely to damage seed which is planted early in warm, dry soil and does not germinate immediately. Early seeded wheat also may be a target for infestations of fall armyworms and greenbugs during some years in Oklahoma (R.A. Johnston, pers. comm.). In Kansas, the importance of delyaed seeding to reduce the potential for damage by Hessian fly has long been recognized (Laude et al., 1955) and creates a potential problem of reduced grain yields for susceptible cultivars seeded early to promote fall forage production.

Several concerns related to weed control problems with wheat pasture should be mentioned. Of primary importance are the grazing restrictions which exist on many herbicides. For example, no effective herbicides for wild oats ("Hoelon", "Fargo", etc.) are registered for use due to full season grazing restrictions. The extensive use of winter wheat for grazing in Oklahoma and Texas make it difficult to even get effective products with grazing restrictions labelled for grain production in these states (T. Peeper, pers. comm.). There are also restrictions related to crop development which may interfere with grazing use. For example, "Sencor" can be used for cheat control on certain wheat varieties, but it cannot be applied until wheat plants are well tillered, then there is an additional 14 day grazing restriction. This delay may cut into potential grazing time. Small grain pasture mixtures have often been promoted (Elder, 1960), but a potential weed problem may appear when the producer wants to return the area to a single species and has grown a pasture mixture containing rye or vetch which then volunteer readily. Another problem with use of soil-applied herbicides followed by grazing is maintaining a uniform distribution of a herbicide layer against the trampling action of the livestock which re-distribute soil and herbicides, especially when the soil is too wet (T. Peeper, pers. comm.). Grazing small grains also reduces the ability of the crop to shade weeds as it normally does without grazing. This may lead to increased weed development, especially with graze-out systems. On the positive side, grazing animals may graze some weedy species and retard their development compared to ungrazed conditions. These examples have been given simply to show that grazing may create some different pest problems which the producer should be prepared to address.

Conclusions

This summary of the literature on studies relating to cultural practices for enhancing forage yields in winter wheat has provided some general guidelines which should be followed. Most of the benefits due to proper management are apparent in fall and winter forage production rather than in spring forage production. This is critical since fall and winter forage is more limited for most producers. In addition, management is more critical for combination grazing-grain systems than for graze-out systems.

Seeding 4 to 6 weeks earlier than recommended for grain production is usually beneficial for fall and winter forage. Seed treatment for insects and diseases and careful monitoring of potential disease, insect, and weed problems are more critical with earlier seeding. Doubling the seeding rate over that normally recommended for grain production is advantageous with early planting, especially under irrigation. Narrower rows may produce small benefits, but they may not be practical if they require a change in planting equipment. Although nitrogen is the fertilizer nutrient most frequently needed, a balanced soil fertility program should be emphasized for maximum forage production. For example, reports have shown response to nitrogen may be limited by low levels of soil available phosphorus. Thus, fertilizer recommendations should be based on soil test results, and nitrogen rates should be adjusted for yield goals of both forage and grain. Split application of nitrogen has produced variable responses. However, its major advantage is that it provides a good method of adjusting nitrogen fertilizer needs to actual forage production and utilization throughout the season.

Early seeding of wheat often results in reduced grain yields since excessive fall growth may lead to high fall water use or increased disease or insect problems. However, fall forage utilization by grazing of early seeded wheat may prevent grain yield reductions and help control foliar diseases. Therefore, once plants are well established in fall, grazing of excess forage is generally beneficial for maintaining grain yield potential. In addition, total forage production has been shown to increase with removal of fall forage which reaches 8-10 inches in height. To assure adequate winter forage in northern areas, stocking rates must be adjusted to allow stockpiling of forage for winter months when growth slows. Rotational grazing systems may help meet these objectives and also increase forage yields, especially when grazing is continued on through spring for graze-out. For grain production, grazing must be terminated prior to elevation of the developing spikes to grazing height to prevent serious grain yield reductions. Additional concerns relating to grazing management on forage and grain production are reviewed elsewhere in these proceedings.

Areas of Needed Research

This literature review has revealed several potential areas for which additional information would be helpful. These additional research needs on cultural practices for winter wheat forage production include the following:

(1) Selection of cultivars for both forage and grain yield potential, since selection for cultivars under current breeding programs emphasizing grain yields has apparently not produced any cultivars with superior forage yield potential.

(2) Integration of grazing management with reduced tillage systems for winter wheat production.

(3) Development of effect weed control herbicides for grassy weeds without grazing restrictions.

(4) Effects of grazing termination date on grain yields based on plant development related to variable environmental factors rather than a calendar date.

(5) Further development of grazing systems which result in optimum production and utilization of fall and winter forage.

(6) A more accurate analysis of the specific optimum early seeding dates for specific locations, including effects on both forage production and grain yield response following grazing.

(7) Further evaluation of row-width effects which may be more important than seeding rates.

(8) Further evaluation of optimum irrigation scheduling in view of decreasing water supplies.

(9) Additional studies on effects of soil fertility status on forage yields, particularly on potassium and liming to correct soil pH which have not been adequately addressed.

Literature Cited

Atkins, I. M., O. G. Merkle, and P. E. Pawlisch. 1969. Influences of growth habit, fertility levels and clipping treatments on production of grain, winter forage and silage of small grain varieties. Texas Agr. Exp. Sta. Prog. Rep. 2652.

Baker, J. M. and B. B. Tucker. 1971. Effects of rates of N and P on the accumulation of NO_3-N in wheat, oats, rye and barley on different sampling dates. Agron. J. 63:204-207.

Bates, R. P. 1975-1983. Comparison of planting dates for rye, oats, wheat, barley, and triticale varieties and strains. The Samuel Roberts Nobel Foundation Leaflets, Ardmore, OK.

Bishnoi, U. R. 1980. Effects of seeding rates and row spacing on forage and grain production of triticale, wheat, and rye. Crop Sci. 20:107-108.

Cook, E. D. 1968. Small grain fertilizer tests, Temple, Texas, 1963-67. Texas Agr. Exp. Sta. Prog. Rep. 2612.

Cowley, C., R. C. Thomason, G. L. Peterson, and W. W. Watson. 1971. Small grain forage production on the High Plains of Texas. Report of Symposium on Grazing Small Grains, USDA Southwestern Great Plains Research Center, Bushland, TX.

Croy, L. I. 1983. Variety and species effects on quantity and quality of forage produced and animal performance. Proceedings of the National Wheat Pasture Symposium, Oklahoma State University, Stillwater, OK.

Croy, L. I., L. R. Nelson, F. M. Rouquette, Jr., D. J. Undersander, and S. R. Winter. 1983. Effects of clipping and grazing termination date on grain production. Proceedings of the National Wheat Pasture Symposium, Oklahoma State University, Stillwater, OK.

Denman, C. E., and J. Arnold. 1970. Seasonal forage production for small grain species in Oklahoma. Oklahoma Agr. Exp. Sta. Bull. 680.

Dunphy, D. J., M. E. McDaniel, and E. C. Holt. 1982. Effect of forage utilization on wheat grain yield. Crop Sci. 22:106-109.

Elder, W. C. 1960. Grazing characteristics and clipping response of small grains. Oklahoma Agr. Exp. Sta. Bull. 567.

Elder, W. C. 1967. Winter grazing small grains in Oklahoma. Oklahoma Agr. Exp. Sta. Bull. 654.

Finkner, R. E. 1974. Grain and forage production from fall-planted small grains on the High Plains. New Mexico Agr. Exp. Sta. Bull. 621.

Fribourg, H. A. 1973. Summer annual grasses and cereals for forage. In Heath, M.E., D. S. Metcalfe, and R. E. Barnes (ed.). Forages. 3rd edition. Iowa State Univ. Press, Ames, IA.

Fuehring, H. D. 1981. Effect of date of planting and clipping of irrigated Centurk winter wheat on forage and grain yields. New Mexico Agr. Exp. Sta. Res. Rep. 453.

Gardenhire, J. H. and E. C. Wilkerson. 1980. Forage production of small grains at Dallas, 1974-78. Texas Agr. Exp. Sta. Misc. Pub. 1458.

Harper, H. J. 1961. Grazing and clipping experiments with small grain pasture in south central Oklahoma. Oklahoma Agr. Exp. Sta. Bull. 585.

Holt, E. C. 1962. Growth behavior and management of small grains for forage. Agron. J. 54:272-275.

Holt, E. C. 1959. Small grains for forage. Texas Agr. Exp. Sta. Bull. 411.

Holt, E. C., M. J. Norris, and J. A. Lancaster. 1969. Production and management of small grains for forage. Texas Agr. Exp. Sta. Bull. 1082.

Johnson, G., and B. Tucker. 1982. O.S.U. soil test calibrations. Okla. State Univ. Coop. Ext. Fact Sheet No. 2225.

Laude, H. H., J. A. Hobbs, F. W. Smith, E. G. Heyne, A. L. Clapp, and J. W. Zahnley. 1955. Growing wheat in Kansas. Kansas Agr. Exp. Sta. Bull. 370.

Malm, N. R. 1973. Forage production from winter small grains in Southeastern New Mexico. New Mexico Agr. Exp. Sta. Bull. 607.

McMurphy, W. E. 1976. Small grain and rye grass forage variety tests in Oklahoma. Oklahoma Agr. Exp. Sta. Bull. 726.

Morris, H. D., and F. P. Gardner. 1958. The effect of nitrogen fertilization and duration of clipping period on forage and grain yields of oats, wheat, and rye. Agron. J. 50:454-457.

Phillips, L. J. 1975. Small grain production: Seeding dates and clipping frequency. M.S. Thesis. Oklahoma State University, Stillwater, OK.

Puckridge, D. W., and C. M. Donald. 1967. Competition among wheat plants sown at a wide range of densities. Aust. J. Agric. Res. 19:191-211.

Rao, S. C., O. G. Merkle, and I. M. Atkins. 1969. Effects of seeding rates and row spacing on forage production, grain yield and yield components. Texas Agr. Exp. Sta. Prog. Rep. 2656.

Rommann, L. M., W. E. McMurphy, F. E. LeGrand, and R. A. Johnston. 1976-1982. Forage production from small grain. Oklahoma State Univ. Coop. Ext. Current Reports 2002, 2010, 2021, 2055, 2060, 2073.

Shanahan, J. F. 1982. Tiller age, survival, and morphology relative to grain yield in winter wheat. Ph.D. Dissertation. Colorado State University. Univ. Microfilms. Ann Arbor, MI. (Diss. Abst. Int. 43:588-B).

Shipley, John, and Cecil Regier. 1972. Optimum forage production and the economic alternatives associated with grazing irrigated wheat, Texas High Plains. Texas Agr. Exp. Sta. Misc. Pub. 1068.

Staten, H. W., and V. G. Heller. 1949. Winter pasture for more feed and better feed at lower cost. Oklahoma Agr. Exp. Sta. Bull. 333.

Unger, P. W. 1971. Soil compaction as affected by grazing. Report of Symposium on Grazing Small Grains, USDA Southwestern Great Plains Research Center, Bushland, TX.

Williams, E., Jr. 1978. Leaf rust and stem rust of wheat. Okla. State Univ. Coop. Ext. Fact Sheet No. 7609.

Williams, E., Jr., and H. C. Young, Jr. 1977. Wheat streak mosaic. Okla. State Univ. Coop. Ext. Fact Sheet No. 2202.

Williams, E., Jr., L. L. Mingleton, and C. C. Russell. 1980. Wheat root rots. Okla. State Univ. Coop. Ext. Fact Sheet No. 7622.

Variety and Species Effects on Forage Quantity, Forage Quality and Animal Performance

Lavoy I. Croy

I wish to make a few general statements related to the production and utilization of small grain forage. Since there is also interest in use of tall fescue and ryegrass by some people in the audience, these will be included in some cases.

There are three sets of circumstances in which a cereal crop may be grazed (Holliday, 1956):

1) Grazing only - crop will be grazed out completely without the harvest of a grain crop.
2) Grazing and grain - planted early enough to obtain grazing with animals being removed to permit grain harvest.
3) Grain production - grazing is only opportunistic when forage is excess. May occur when excess vegetation would cause lodging and/or moisture loss.

Southern Great Plains represents a unique set of climatic conditions which permit the production of excess forage. Some other areas of the world graze wheat but not nearly in the magnitude of that in the Hard Red Winter Wheat area.

Acreage of graze-out wheat obviously varies from year to year and the data on number of acres are poor. Production statistics do show acres abandoned and many of these acres are grazed out. In Oklahoma this has a long time average of 18%. Other states also experience some abandonment.

Determination of any acreage planted early for forage is equally elusive. A five year average from 1975-1980 showed the following in Oklahoma:

10% planted by September 12
20% planted by September 20
30% planted by September 27

In years when moisture is favorable, up to 40% of the wheat acreage in Oklahoma can be planted by September 30 (Okla. Agricultural Statistics). A major limitation for early seeding to obtain fall forage is inadequate moisture for early germination and growth. Timely operations (having seed bed ready and planting on limited moisture or dusting in part of the acreage) can improve the potential for fall grazing.

Management for forage production include some practices which can permit high forage production, while permitting the harvest of a grain crop. Early seeding is absolutely essential to obtain high fall forage production and can begin when the soil temperature is 85°F or lower at seeding depth. Increased seeding rate and proper fertility for the expected production is necessary. Overgrazing in the fall can lead to reduced forage and in the spring can reduce grain production. Grazing can be deferred in the fall and forage stockpiled for winter grazing. Problems which may limit early seeding are soil moisture, plant diseases and weed control. Advantages which exist are the reduction in costs of production: different options are available; i. e., a part of the forage can be grazed out in place of taking a grain crop, efficiency of the farm operations can be increased and the risk can be spread over the forage as well as the grain crop.

Species and Varieties

Each species of cool season plants has certain advantages and disadvantages (McMurphy, 1983). Using a mixture of more than one species may extend the grazing season since different species have different periods of production. For example, wheat and ryegrass may provide a better balanced production system than either alone. However, many wheat grain producers do not want their fields contaminated by other species and will use only wheat.

Rye will grow at a cooler temperature and thus will often provide more fall and winter forage than any other small grain. It excels on sandy soils. However, the disadvantages are the very early termination of growth in May and the possibility of volunteer rye in wheat grain fields. Wheat will produce forage for at least two weeks longer than rye in the spring. In the Oklahoma Panhandle with irrigation and a mid-August seeding date, wheat has been just as productive as rye for fall and winter forage. Since wheat has a longer growing season in the spring, it is more productive in the spring than rye. Varietal selection of a wheat is far less important than the cultural practices of early seeding and high nitrogen fertilization for forage production.

Oats are a good forage species for southern Oklahoma, Texas and in other areas where winterkill is not a problem. Ryegrass is a valuable species for southern and eastern areas of the U.S. The big advantage of ryegrass is that growth continues later in the spring long after wheat or rye stops producing forage. Adequate precipitation and mild winter temperatures are necessary for dependable production.

Triticales do not appear to be as productive as other species at this time. They may produce well in some areas but still not produce forage quantities equal to the best wheats.

In the southern part of the region (Fig. 1), oats will produce more total forage than wheat or rye which have very similar yields. Differences among wheat varieties in yield and digestibility are not great (Table 1, Horn, et al., 1981).

As we look across the region climate influences the time of forage production and grazing season. The information obtained in one area may need to be modified for use in another. In this short paper, it is difficult to address these variations adequately.

Tall fescue, a perennial does not have to be planted each year and removes the need for yearly seedbed preparation and planting. Table 2 presents some yields from Muskogee, Oklahoma and the response to added nitrogen fertilizer. Both production and crude protein can be increased with added nitrogen.

Fertilization

Forage containing 25% crude protein (4% N) will have 80 pounds of N per ton of dry matter (McMurphy, 1983). Thus 2 to 3 tons of forage will contain 160 to 240 pounds of nitrogen per acre (Gardenhire and Wilkerson, 1980). If one obtains 70% efficiency of the applied nitrogen, then 230 to 340 pounds of soil and applied nitrogen per acre are needed for forage production. If a grain crop is to be harvested, nitrogen must also be available for the expected yield. When the yield goals are not realized, then the fertilizer application can be adjusted the following year on the basis of the soil test. A soil test is very important to assure that nutrients (nitrogen, phosphorus, potassium) are not limiting production.

Rotation Grazing

No advantage in total forage yield for rotation grazing was realized in the fall and winter months. In spring months, rotation grazing permitted 15 to 20% higher stocking rates and produced more gain per acre than continuous grazing (Elder, 1967). Rotation in the spring permitted more plants to retain their growing points for a longer time period which increased production under graze-out systems.

Fall Stocking Rates

Early grazing or clipping before plant establishment greatly lowered yields. In grazing studies at Muskogee, Oklahoma on small grains mixtures (Fig. 2), heavy (1.2 head/acre) stocking rate gave a 2% increase in gain per acre over a light (0.7 head/acre) rate for November and December (Elder, 1967). Production was lower for the remainder of the season for the heavy stocking rate than for the light stocking rate. In a like manner, early mechanical clipping of forage in the fall months before plants were well established lowered yields greatly.

In grazing studies in Kansas plants from moderately grazed areas had more robust crowns and less top growth than ungrazed plants; however, plants which were severely grazed were much smaller and had fewer tillers than either of the other grazing treatments (Swanson and Anderson, 1951).

Wintering Dry Cows

High quality wheat forage can be combined with dry forage in a limited grazing system for dry cows (Elder, 1967). Data in Table 3 show a grazing pattern in which wheat forage can provide cows their protein supplement--as the winter progresses and quality of dry grass declines, the cows are permitted to graze the wheat more often.

This grazing pattern was adequate to maintain dry cows with a 5% weight loss through the winter and calving which was quite acceptable. In a two year study, cows gained weight in November and December, had a slight loss in January and February, and had the greatest loss in March when the calf was born. Also, calves can be given access to small grains thru creep gates to provide high protein forage to supplement their mother's milk.

Chemical Composition

The cool season forages are some of the highest quality forage available and animal gains are often superior to that obtained on warm season forages. In wheat forage, crude protein content of 25 to 30% are common, calcium and magnesium are low and phosphorus and digestibility is high and rapid. Animal gains of 1.5 pounds per day are obtained for the grazing season with 2.0 pounds possible in spring. Six to eight pounds of forage will often produce one pound of beef gain.

The biological and chemical determinants of quality were measured for a number of forage species in Minnesota at stages where these would be made into silage (Cherney and Marten, 1982). IVDMD ranged from 80% for two varieties of wheat at pre-boot (when the flag leaf collar was about two inches above the collar of the preceding leaf) to 59% at 28 days after head emergence from the boot (Fig. 3). Cell wall constituents 48%, ADF 32%, ADL, 4.6% and crude protein, 17.7% were at acceptable levels. Average mineral contents were K - 2.8%, Ca - 0.56%, P - 0.38%, and Mg - 0.22% (Fig. 4). Individual plant parts were also examined and the leaf blade, the head, and the sheath had higher CP and IVDMD than the stem (Cherney and Marten, 1982b).

Wheat, barley and oat silages were made over a number of years in a study at Kansas (Oltjen and Bolsen, 1978). Wheat and barley cut at the early-dough contained about 60 to 65% moisture and could be ensiled without problems with regard to moisture. Since the cereal stems are hollow and filled with air, fine chopping and good packing were important to exclude entraped air. Table 4 shows that protein content was at an acceptable level and IVDMD was quite good. There were only small differences among the varieties which largely reflected the differences in the maturity. In finishing trials where the small grain silages were compared with corn silage as sources of roughages only small differences were observed in the performance of the animals.

Summary

Wheat forage is one of the highest quality forages which can be produced in the southern Great Plains and is important in livestock systems. Protein content (about 25%) is high in the young plant and is acceptable (about 10%) at a silage stage.

Some management practices are necessary if fall forage is to be produced consistently when moisture is adequate--early seeding, high seed rate, high fertility applications, and proper stocking rate. Grazeout of a portion of the wheat acreage (about 1/3) would have an impact on the grain prices, provide an option on time of sale of animals and provide another means of weed control.

Literature Cited

Cherney, J. H. and G. C. Marten. 1982a. Small grain crop forage potential: I. Biological and chemical determinants of quality, and yield. Crop Sci. 22:227-230.

Cherney, J. H. and G. C. Marten. 1982b. Some grain crop forage potential: II. Interrelationships among biological, chemical, morphological and anatomical determinants of quality. Crop Sci. 22:240-244.

Elder, W. C. 1967. Winter grazing small grains in Oklahoma. Oklahoma Agr. Exp. Sta. Bul. B-654.

Gardenhire, J. H. and E. C. Wilkerson. 1980. Forage production of small grains at Dallas, 1974-78. Texas Agr. Exp. Sta. MP - 1458.

Holliday, R. 1956. Fodder production from winter sown cereals and its effect upon grain yield. Field Crops Abstr. 9:129-135; 207-213.

Horn, G. W., W. E. McMurphy, R. L. Mitchell. 1981. Forage production and digestibility of small grains forage. Oklahoma Agr. Exp. Sta. MP-108.

Hughes, H. D., M. E. Heath, and D. S. Metcalfe. 1962. Forages, 2nd Ed. p. 340-345. Ia. State Univ. Press. Ames IA.

Leonard, W. H. and J. H. Martin. 1963. Cereal Crops. p. 344-346. MacMillan, Co. N.Y.

McMurphy, W. E. 1976. Small grain and ryegrass forage variety tests in Oklahoma. Oklahoma Agr. Exp. Sta. Bul. B-726.

McMurphy, W. E. 1983. Unpublished data Oklahoma Agr. Exp. Sta.

Oltjen, J. W. and K. K. Bolsen. 1978. Wheat, barley, and oat silage for beef cattle. Kansas Agr. Exp. Sta. Bul. 613.

Schlehuber, A. M. and B. B. Tucker. 1967. Culture of wheat. p. 160-168. In Wheat and wheat improvement, Amer. Soc. of Agron. Monograph 13, ed. K. S. Quisenberry and L. P. Reitz.

Swanson, A. F. and K. Anderson. 1951. Winter wheat for pasture in Kansas. Kansas Agr. Exp. Sta. Bul. B-345.

Table 1. In vitro digestible dry matter (IVDMD) and yield for wheat varieties.

Variety	IVDMD, % 3-18-80	Yield lb/A 11-13-79	Yield lb/A 3-18-80
Newton	74.5a	334bc	933ab
Triumph 64	72.0ab	623a	750bc
Osage	69.9bc	227c	664c
TAM-101	68.4c	280bc	1129a

Table 2. Dry matter (DM) yield and crude protein (CP) for tall fescue in response to fertility levels at Muskogee, Oklahoma.

N	P_2O_5	K_2O	D.M.	C.P.%
------------pounds/acre-------------				
0	0	0	1113	9.8
80	40	40	3200	13.6
80	80	80	3289	13.5
160	80	80	4692	16.1
320	80	80	6422	20.2
640	160	160	7310	23.1

Table 3. A winter supplementation program for dry beef cows utilizing small grain as a supplement for dry grass at Stillwater, Oklahoma.

Dates	Ratio of days grazing on Small Grains	to Dry grass
November, December	1	5
January, February	1	4
March	1	3
Total Days	32	118

Table 4. Dry matter (DM), crude protein (CP) and in vitro dry matter digestibility (IVDMD) for wheat silage at 3 stages of maturity in Kansas.

Stage	D.M. %	CP %	IVDMD %
Boot	15.8	15.1	61.2
Milk	30.4	10.5	57.7
Dough	37.5	9.2	57.4

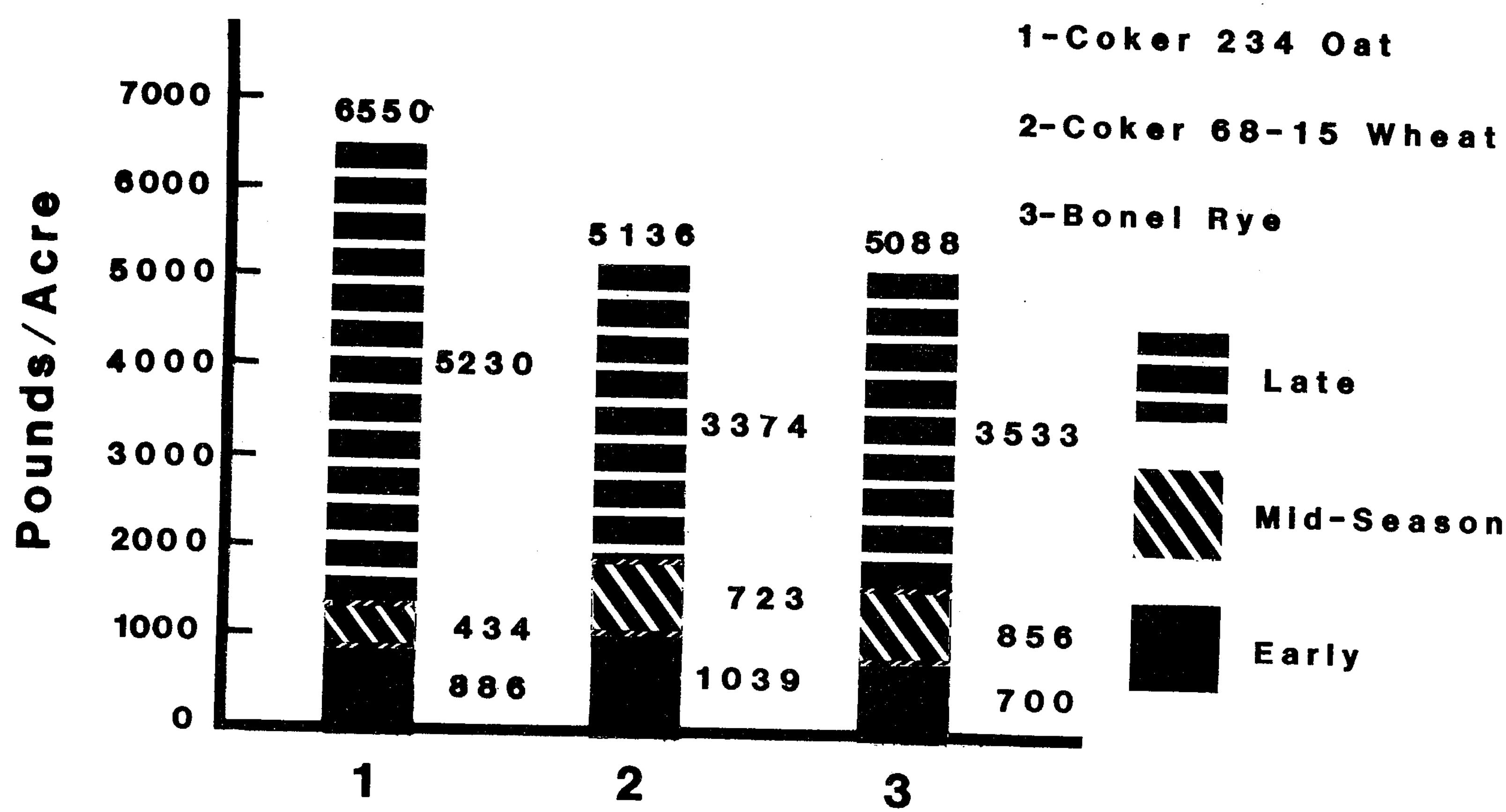


Fig. 1 Yields of wheat, oats, and rye at Dallas, Texas, 1974-78.

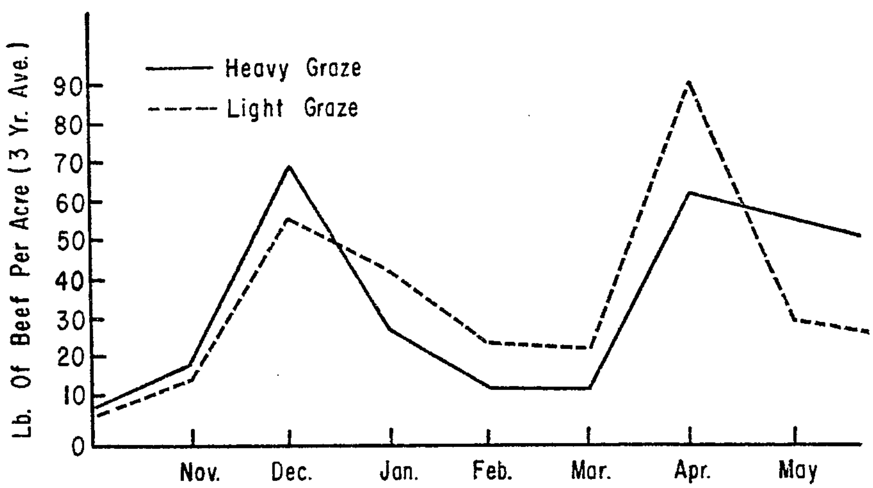


Fig. 2. Heavy stocking rates in November and December lowered stocking rates and beef production for January through April compared with a lighter rate.

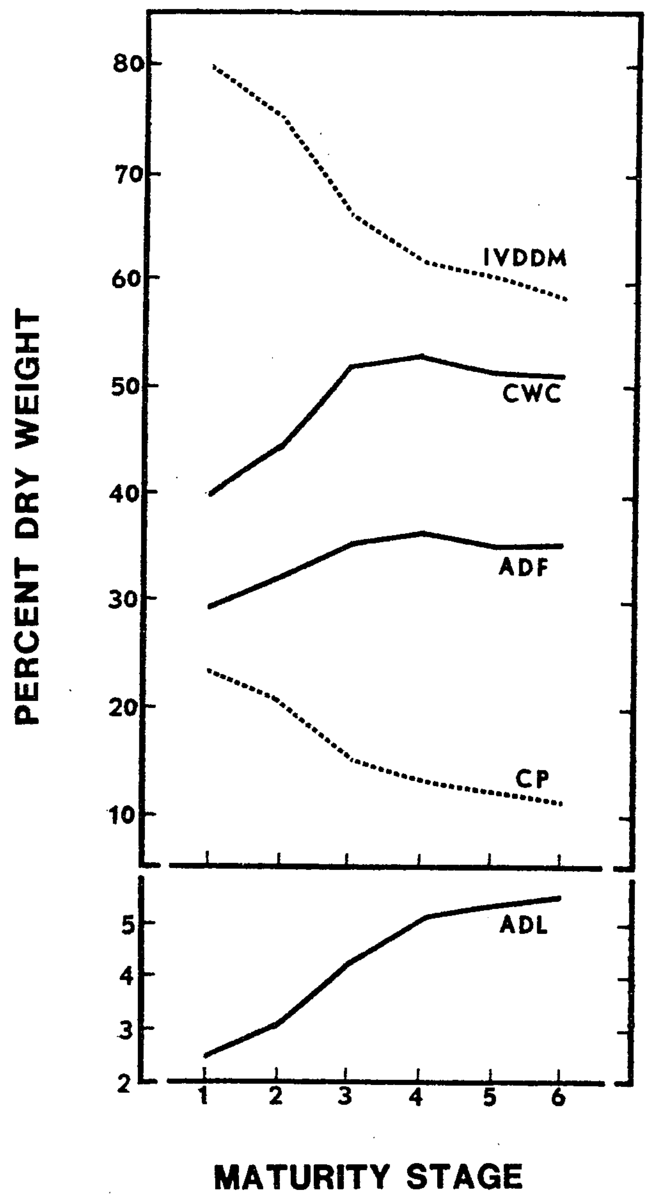


Fig. 3. In vitro digestible dry matter (IVDDM), acid detergent lignin (ADL), crude protein (CP), cell wall constituents (CWC), and acid detergent fiber (ADF) concentration changes for wheat. Maturity stages, (1) collar of flag leaf 2 inches above preceeding collar, (2) spike emergence, (3) 7, (4) 14, (5) 21, and (6) 28 days after spike emergence.

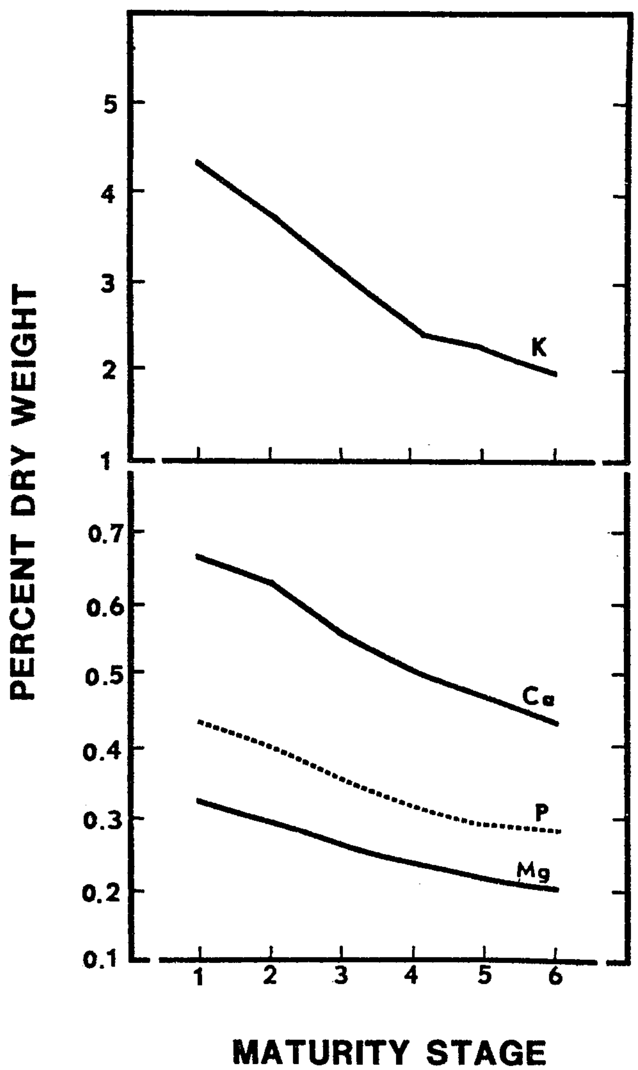


Fig. 4. Potassium (K), calcium (Ca), phosphorus (P), and magnesium (mg) for wheat. Maturity stages as in Figure 3.

Effects of Clipping and Grazing Termination Date on Grain Production

Lavoy I. Croy

Physiology of Growth

Small grains tend to produce more tillers and leaves than are necessary for maximum grain production. In the southern Great Plains much research has been conducted indicating that some of this plant tissue can be grazed with little or no yield penalty.

Leaf growth and tillering or stooling are markedly influenced by climatic conditions (temperature, light intensity, day-length, rainfall) and nutritional status under which the plants are growing (Evans, 1975). Leaves formed prior to floral induction originate close to the crown, and after induction the stem internodes elongate and the leaves are separated permitting more effective light distribution within the canopy. The rate of tillering is maximal at 77°F, but a larger number of tillers are often found at lower temperatures since the duration of tillering is longer.

With the onset of stem elongation the head or growing point is elevated from near ground surface to a height that the grazing animal can remove them from the plant. Stem elongation is also very much under climatic control and is related with varietal maturity. Dates for removal of the grazing animals will be different for various varieties, localities and years. The primary tillers usually have the largest heads and thus will have a strong effect on yield reduction if they are grazed off.

Grazing and Clipping Studies

Literature is definitely not in agreement on the benefits or damage of grazing on grain production if animals are removed before stem elongation. There is literature showing that yields will be reduced if grazing continues after stem elongation. There may be some apparent reasons for the various results.

Research at Overton, Texas shows considerable difference in forage yields existed between the two years (Table 1) and indicates the effect climate can have on yields from year to year.

Grazing or clipping of wheat in East Texas (Nelson, et al., 1982) increased the yields of some varieties, had no effect on others, and decreased the yields of others (Table 2). The two years of the study show about 4 bushels grain loss per 1,000 pounds of forage. Since the forage is important for grazing, it is advantageous to look at the rate of gain or days of grazing relative to grain yield loss. In 1980-81, an average daily gain of 1.06 pounds was obtained for 89 days and 1.50 pounds of daily gain in 1981-82 for 87 days. Animal gain per acre was 112 pounds in 1980-81 and 150 pounds in 1981-82. There was about 26.5 pounds of gain or 22 days grazing per bushel loss in 1981 and 19.5

pounds of gain or 6.7 days grazing per bushel loss in 1982. In one year of the study, diseases and ryegrass reduced the yields.

A clipping trial at College Station, Texas (Dunphy, et al., 1982) showed that clipping at the early joint had little or no effect on grain yield while clipping at mid to late joint reduced yields (Table 3). Tiller number was not significantly reduced by clipping treatments, but seeds per head were reduced. This would indicate that younger tillers reached maturity and seed initials are being laid down during these stages so clipping could be removing leaves which reduces photosynthate available for seed initiation.

Jointing dates varied as much as a month among cultivars and years, and this response raises the question of the value of a set calender date for livestock removal from wheat (Table 4). While clipping might be different from a grazing situation, dates of morphologic development of the plants would be the same.

In a grazing study in the Texas Panhandle (Shipley and Regier, 1972) animals gained an average of 1.4 pounds per day during fall and early spring. With the initiation of rapid spring-growth gains of 2.2 pounds per day were obtained. Heading dates were delayed and yields were reduced after March 30 in response to later dates of termination for grazing (Table 5).

Planting and clipping date effects on forage and grain yields were evaluated at Clovis, New Mexico (Fuehring, 1981). Data in Table 6 show that the highest forage yields were obtained from August 15 seeding and the highest grain yields from September 13 seeding. Clipping through March 22 did not significantly reduce grain yields although there was a slight decline in grain yield. He concluded that grazing through March produced a decrease of 26 pounds of grain per acre per day in 1979, a wet year and only seven pounds in 1980, a dryer year.

A wheat grazing study has been initiated at Bushland, Texas (Winter, 1982). In 1981-82, it was necessary to terminate grazing on early-planted wheat February 1, six weeks prior to the commonly recommended date to prevent a yield reduction. Grazing was severe in 1982 and this could account for the fact the later termination dates did not allow the plants time to grow the leaf area necessary for high yields.

Research in Nebraska (Kiesselbach, 1925) demonstrated that the grazing or mowing of wheat which had the potential to lodge could increase yields; however in years when there was no lodging, grazing delayed the maturity and reduced yields.

Summary

Grazing would appear to favor increased yields or not reduce yields when 1) fertility was adequate, 2) wheat was not grazed severely, 3) forage and water use was reduced, and 4) lodging was reduced. Grazing could reduce grain yields when 1) nutrients were limiting, 2) grazing was too severe, 3) there was little or no water limitation, 4) lodging was not a problem, and (5) wet conditions permitted plants to be trampled into the ground.

Animals must be removed before floral initiation or jointing to prevent yield reductions. Floral initiation dates are influenced by temperature, fertility and variety so any set calender date for an area must be sufficiently early to represent a large number of years. Determination of jointing is not difficult, but does take some close observations and is something which farmers can do. It would be necessary to have an enclosure for observations to be sure that animals are not grazing off heads before jointing is observed. The value of grazing versus the grain yields may warrant accepting some yield reductions in exchange for the increased animal gains.

Literature Cited

Dunphy, D. J., and M. E. McDaniel, and E. C. Holt. 1982. Effect of forage utilization on wheat grain yield. Crop Sci. 22:106-109.

Evans, L. T. 1975. Crop Physiology. p. 105-108. Cambridge Univ. Press.

Fuehring, H. D. 1981. Effect of date of planting and clipping of irrigated Centurk wheat for forage and grain yields. New Mexico Agr. Exp. Sta. Research Report 453.

Kiesselbach, T. A. 1925. Winter wheat investigations. Nebraska Ag. Exp. Sta. Research Bul. 31 p.112-117.

Nelson, L. R., F. M. Rouquette, Jr. and R. D. Randel. 1983. Cash wheat in a wheat-ryegrass grazing system. Texas Agr. Exp. Sta. B1452.

Shipley, J. and C. Regier. 1972. Winter wheat grazing and irrigation water management, northern high plains. Texas Agr. Exp. Sta. Progress Report 3030.

Winter, S. E., E. Thompson and J. Barnes. 1983. Wheat Grazing. Texas Agr. Exp. Sta. Unpublished data.

Winter, S. R. 1982. Response of winter wheat to grazing. Agron. Abstr. p. 130.

Table 1. Forage yields on plots mechanically clipped until February 16 for two years at Overton, Texas.

	Clipping Date			
	Dec. 12	Jan. 23	Feb. 16	Total
	Dry weight, pounds per acre			
1980-81	542	297	148	987
1981-82	1879	1052	322	3252

Table 2. Grain yields (bushels/Acre) of wheat over 2 years under 3 forage treatments at Overton, Texas

Variety	Forage treatment		
	Grain Only	Clipped to Mid-February	Grazed to Mid-February
		1980-81	
Tx 73-93	59	59	57
McNair 1003	52	53	47
Coker 85-15	55	48	32
Tx 72-9	40	45	42
Arthur 71	31	43	38
Mean	47	50	43
		1981-82	
Tx 73-93	46	42	30
McNair 1003	38	24	28
Coker 68-1	32	23	17
Northrup King	31	20	14
TAM W-106	25	25	16
Mean	34	27	21

Table 3. Wheat forage and grain yields at different stages of harvest at College Station, Texas.

Stage	Sturdy	Coker 68-15
	Forage Yield, pounds/acre	
Early joint	1547	1618
Mid joint	1869	1830
Late joint	2268	2179
	Grain Yield, bushels/acre	
Not cut	33.0	43.0
Early joint	27.8	34.2
Mid joint	18.5	28.9
Late joint	13.3	21.8

Table 4. Effect of forage removal at different stages of growth on dates of jointing and plant maturity at College Station, Texas.

Treatment	Sturdy			Coker 68-15		
	1977	1978	1979	1977	1978	1979
			Date of jointing			
Not cut	2-29	1-26	2-24	2-5	1-6	1-15
Early joint	2-19	3-17	3-5	2-5	1-23	2-13
Mid joint	2-26	3-25	3-12	2-14	3-1	2-27
Late joint	3-2	3-29	3-19	2-26	3-10	3-5
			Date of maturity			
Not cut	5-6	5-14	5-15	5-2	5-10	5-10
Early joint	5-7	5-15	5-16	5-4	5-12	5-16
Mid joint	5-12	5-17	5-17	5-6	5-13	5-17
Late joint	5-13	5-21	5-22	5-13	5-13	5-16

Table 5. Effect of grazing date removal on dates of heading and grain yields at Etter, Texas.

Grazed Date	Headed	Yield, Bushels/Acre
Not grazed	May 6	--
March 1	May 11	48.1
March 20	May 15	49.1
March 30	May 18	42.8
April 10	May 20	43.6
April 30	May 23	20.1

Table 6. Forage and grain yields of wheat by planting date (average over 5 clipping dates) and by clipping date (average over 5 planting dates) at Plains Br. Station, Clovis New Mexico in 1979 and 1980.

Date of Plant	Date of Clip	Forage Yields Pounds/Acre	Grain Yield Bushels/Acre
August 15		8180	65.1
August 30		7726	66.7
September 13		5688	73.0
September 29		3212	68.5
October 16		1563	66.8
	December 21	3770	74.3
	March 2	4547	70.7
	March 13	5296	70.6
	March 22	5952	63.9
	March 30	6579	63.0
LSD .05		819	10.1

COMMENTS BY DISCUSSANT

L. R. Nelson
Texas A&M Research and Extension Center
Overton, Texas 75684

SUMMARY

The presentations on agronomic practices for optimum wheat forage production were well conceived and discussed most of the research reported during the past 20 years. This indicates two main points. First, very little research on agronomic practices to increase forage production of wheat has been reported in the past 20 years. Second, there is a need for research to increase forage yields of wheat. This is particularly true with the new germplasm presently available and also with irrigation management.

INTRODUCTION

I will discuss several main topics presented by Dr's Croy and Donnelly and point out areas where further research is needed.

Seeding date: It is generally agreed that early planting is best for increasing forage yields, particularly when moisture is present. I see a need for an increased plant breeding effort to improve seedling vigor under high temperature and moisture stress. The semi-dwarf wheats are here to stay and these wheats generally have less seedling vigor and will not emerge from a soil depth greater than 2 inches. Therefore, there is a need to select for seedling vigor and emergence at a greater depth within the semi-dwarf germplasm.

Seeding rates and row widths: This area has been studied in great detail and addressed very well. My comment is, during the next few years many new commercially produced varieties and hybrid varieties will be released. What will this mean to forage production? Higher seed costs are probable and to be expected. This may result in lower seeding rates which would likely reduce fall and winter forage production. Further, little or no forage research is presently underway with the development of new varieties or hybrids. More research is needed on the effect of heterosis on forage yields of wheat and other winter annuals.

Soil fertility management: Optimum use of nutrients can provide management options for both forage and grain production. To make a profit with wheat, it is often necessary to harvest both a forage and a grain crop. Furthermore, the forage should be efficiently harvested by appropriate livestock. Nitrogen should be applied in split applications for efficient use by the plants. Potassium is removed in large amounts, since it is concentrated in vegetative parts, and they are removed. Holt (1) reported a favorable interaction between high N and P fertilization for high forage yield in oats. On acid soils, dolimitic or Ag limestone is necessary, and will improve yields and increase calcium and magnesium on the forage.

Irrigation management: This area needs to be emphasized in research programs because of present and anticipated water shortages. We need more information relating grazing to optimum forage yields and water use.

Cultivar selection: Wheat varieties are released because of their grain potential and disease resistance. These two traits may not be closely related to high forage yields (most diseases attack wheat late in the spring). As commercial varieties and hybrids become more popular, the emphasis on forage may even be less. Commenting as a plant breeder, we need to develop varietiies which have high tillering capacity, good seedling vigor and superior forage production. This may require more efficient screening methods for selecting superior types from segregating populations of wheat. Other areas that further research is needed are insect and disease tolerance. Also new varieties need to be tested for ability to withstand grazing pressure and regrowth potential after grazing. Nutritional quality of forage of new small grain varieties should be tested before varieties are released.

Grazing management: The use of dual purpose wheat (forage-grain) requires good management. Management decisions on put on date, take off date, number of animals per acre, and rotational grazing have all been addressed. Holt (1) reported that the maximum forage yield will be obtained from a single harvest at the end of the growing season (such as a silage harvest). Frequent clippings reduced forage yields, reduced number of tillers, reduced size of the crown and also root production.

Seedbed preparation: Generally the amount of tillage required for small grains is related to moisture conservation (such as fallowing during the summer). At present, much of our wheat acreage is double cropped or some type of minimum tillage is used in planting wheat. Our observations in East Texas are that planting in sods greatly reduces early fall and winter forage production. More research is needed to understand interactions between method of planting, varieties, weed problems, diseases and insects.

Pest control: Normally diseases are not a problem on wheat utilized for forage, although later in the season diseases such as leaf rust or powdery mildew may occur. The use of systemic fungicides, insecticides or herbicides is gaining in popularity and grazing should not occur unless the chemicals are labeled for grazing. Wild oats and ryegrass are serious weed problems in wheat and can be controlled with products such as Hoelon, Glean or Fargo. Of these products, only Glean has a label or clearance for grazing. We need to find safe pesticides or apply chemicals after cattle have been removed from the forage in the spring. Our studies of herbicides applied to wheat in late February to control ryegrass have been unsuccessful due to phytotoxicity to wheat or lack of weed control. Other pests which may attack wheat are wire worms, false wire worms, aphids, green bugs, hessian fly and barley yellow dwarf virus.

<u>Variety and species effect on quality and quantity</u>: Each of the small grain crops has a growth production curve for yield during the growing season. This will also vary between varieties within species. Mixtures will overcome the peaks and valleys on the growth curves and also reduce the risk of forage loss from winterkilling. A question that occurs from time to time is what is the value of a pound of forage in December versus a pound of forage in April? Perhaps the use of models in conjunction with economics could be utilized to better demonstrate which species should be planted for highest profitability.

LITERATURE CITED

1. Holt, E. C., M. J.Norris and J. A. Lancaster. 1969. Production and management of small grains for forage. Texas A&M Agri. Exp. Sta. Bulletin B-1083.

II. CHARACTERIZATION OF WHEAT FORAGE AND BASIC CONSIDERATIONS IN REGARD TO FORAGE UTILIZATION BY CATTLE AND METABOLIC DISORDERS

CHEMICAL COMPOSITION OF WHEAT PASTURE

F. P. Horn

U.S. Department of Agriculture, El Reno, Oklahoma 73036

Summary

Wheat forage is high in moisture and soluble constituents and, because of this, cattle may at times be unable to meet their daily dry matter (DM) requirement. But the nutrients in wheat pasture are readily available and rapidly digested. The crude protein (CP) content of wheat is notably high (at times in excess of 30% of DM) and at times non-protein nitrogen (NPN) levels approach toxicity. Properly managed, wheat is an effective protein supplement; there is evidence that the crude protein in wheat is highly soluble and highly available.

The fiber content of wheat forage is low with most acid detergent fiber (ADF) values falling below 30% of DM and most neutral detergent fiber (NDF) values falling below 50% of DM. Lignin values range from 2.5 to 5% of DM for most of the grazing season.

From a nutritional standpoint, it is important to note that the Ca:P ratio is not ideal; wheat forage is low in Ca resulting in an average ratio of 1 to 1.1. Also, Mg levels are marginal to low for cows through most of the grazing season.

Introduction

Wheat provides lush and highly nutritious forage which can support various classes of grazing livestock wherever it can be grown and grazed. Either alone or in combination with other small grains, perennial grasses or legumes, it can serve as the "mainstay" of major segments of the livestock industry as it does with beef stockers; or it can provide an economical supplement to enhance and extend less nutritious winter forages.

It is estimated that 10 million hectares of winter wheat are grown in the southern Great Plains area and that as many as 6 million stocker cattle graze this forage crop annually. High quality forages associated with cereal grain production meet or exceed the nutrient requirements of grazing livestock regardless of class or species. With speculation about the long term trend toward reduced availability of feed grains for livestock, there is growing interest in high quality forages for production of "finished" beef.

Review of Literature

Research on the chemical composition of winter wheat has been concerned with factors responsible for metabolic disorders, especially grass tetany (Mayland et al., 1976; Horn, 1980; Stewart et al., 1981; Bohman et al., 1983) and bloat (Bartley et al., 1975; Horn et al., 1977a, 1977b; Stewart et al., 1981). In addition, Belyea et al. (1978) reported on the chemical and mineral composition of ungrazed wheat as a harvested forage with potential for dairy cattle feed.

Because of the dual role of wheat in pasture and grain production, most wheat fields are intensively managed. The principle fertilizer need of small grains is normally nitrogen. If the cereal is to be used for forage, a fall application of N is especially critical (Burton and Prine, 1958; Dev et al., 1979). While responses to fertilizer are variable depending on the myriad of factors associated with uptake of plant nutrients, the most common fertilization practice on small grains pasture involves application of nitrogen (N), phosphorus (P) and potassium (K) at planting time, and top dressing with N in winter and/or spring (Holt et al., 1969; Fribourg, 1973). Fertilization and season have been shown to influence the chemical composition of the forage; particularly the nitrogen fraction.

"Field dry matter" values for 1972-73 samples from unrinsed-grazed, rinsed-grazed, unrinsed-ungrazed and rinsed-ungrazed plots are presented in figure 1 (Horn et al., 1984). Patterns of change were similar among samples collected during the grazing season. Soil contamination did not appear to be a consistent problem in sampling with the exception that in mid-winter (February) unrinsed samples from grazed plots tended to be higher in apparent field DM because of soil contamination.

Seasonal changes in in vitro dry matter digestibility (IVDMD) and chemical composition of wheat forage from 4 years at the US Livestock and Forage Research Laboratory, El Reno, OK were pooled and analyzed and they are presented in figure 2. The patterns represent the cubic regression of nutrient composition on days from November 1.

Peak levels of IVDMD occurred in fall and spring during periods of most rapid growth. Changes in CP followed a similar pattern. The CP (or N) content of wheat and other small grains forages has been shown by others to be high (Patel and Nishimuta, 1978; Stewart et al., 1981; Bohman et al., 1983) and both ammonia toxicity and nitrate toxicity have been suggested as potential problems in animals grazing wheat pasture (Clay, 1973; Horn et al., 1977a).

Both neutral detergent fiber (NDF) and acid detergent fiber (ADF) increased in fall with advancing age of the plant. In addition, the slowing of growth during winter coupled with continuous defoliation by grazing resulted in an increased proportion of stem. Acceleration of plant growth with increasing temperatures in February led to decreases in the proportion of fiber, but with the onset of tillering and seed head formation in April, the fiber content rose. Similar trends in fiber content have been reported by others (Horn et al., 1977b; Johnson et al., 1973), but it should be noted that compared to other vegetative cool season grasses, the fiber content of wheat is low.

The calcium (Ca), phosphorus (P) and magnesium (Mg) contents of wheat forage have been studied at great length because of their importance in wheat pasture poisoning. Indeed, mineral nutrition of grazing livestock will be discussed at length in other papers in this symposium. From the nutritional standpoint, then, we show (figure 3) that the Ca content of the forage is low and the proportion of Ca to P is, on average, approximately 1 to 1.1 rather than the recommended 2 to 1 (NRC, 1976). The Mg content of the forage is also low and conducive to tetany during much of the grazing season.

Conclusions

1. During some periods in the grazing season, the high moisture content of the wheat plant may make it impossible for the animal to satisfy daily dry matter requirements.

2. Wheat pasture is very high in readily available protein. This may, under certain circumstances, cause toxic levels of ammonia to be formed in the rumen.

3. Wheat pasture herbage is very highly and rapidly digested. Undoubtedly, gas formation in the rumen is extensive and there is potential for bloat problems.

4. The Ca:P ratio in wheat pasture herbage may not be acceptable for optimum performance.

5. The Mg content of wheat pasture herbage is low and the forage is conducive to tetany.

Areas of Needed Research

With the increasing emphasis on quality forages for systematic approaches to livestock production, a better understanding of the utilization of small-grains pasture, and of the hazards intrinsic in grazing these forages is essential. Researchable problems of most importance include:

1. Understanding the etiology of bloat in grazing stocker calves.

2. Understanding the relationships between defoliation by grazing and forage utilization on subsequent grain yield.

3. Determining effective means of supplementing the forage with selected minerals and available energy sources so as to optimize health, performance and ultimately profitability of the wheat grazing enterprise.

Literature Cited

Bartley, E. E., G. W. Barr and R. Mickelsen. 1975. Bloat in cattle. XVII. Wheat pasture bloat and its prevention with poloxalene. J. Anim. Sci. 41:752.

Belyea, R. L., F. A. Martz, R. E. Ricketts, R. R. Ruehlow and R. C. Bennett. 1978. In vitro dry matter digestibility, detergent fiber, protein and mineral content of wheat forages as a dairy cattle feed. J. Anim. Sci. 46:873.

Bohman, V. R., F. P. Horn, B. A. Stewart, A. C. Mathers, D. L. Grunes. 1983. Wheat pasture poisioning. I. An evaluation of cereal pastures as releated to tetany in beef cows. J. Anim. Sci. 57:(in press).

Burton, G. W., and Prine, G. M. 1958. Forage production of rye, oats and ryegrass as influenced by fertilization and management. Agron. J. 50:260-2.

Clay, B. R. 1973. Stocker cattle losses on small grains pasture. Okla. Vet. 25:15.

Dev, G., N. S. Dhillon and T. Singh. 1979. Effect of rates, sources and timings of nitrogen application on yield and quality of forage oats. Indian J. Dairy Sci. 32:1979.

Fribourg, H. A. 1973. Summer annual grasses and cereals for forage. In M. E. Heath, D. S. Metcalf and R. F. Barnes, eds, Forages, Ed 3, Iowa State Univ Press, Ames, IA, 344-57.

Holt, E. C., Norris, M. J., and Lancaster, J. A. 1969. Production and management of small grains for forage. Tex. Agr. Exp. Sta. Bull. B-1082.

Horn, F. P. 1980. Metabolic disorders of cattle grazing wheat pasture. In Proc. John Lee Pratt Int. Symp. Role of magnesium in animal nutrition. Blacksburg, VA. In press.

Horn, F. P., G. W. Horn and H. R. Crookshank. 1977a. Effect of short-term fasting and refeeding on weight and blood components of steers grazing wheat pasture. J. Anim. Sci. 44:288.

Horn, F. P., A. D. Tillman and S. W. Coleman. 1984. Changes in the chemical and mineral composition of wheat pasture forage during the grazing season. In preparation.

Horn, G. W., B. R. Clay and L. I. Croy. 1977b. Wheat pasture bloat of stockers. Oklahoma Agric. Exp. Sta. Res. Rep. MP-101:26.

Johnson, R. R., M. McGeehon, E. Williams and H. C. Young, Jr. 1973. Studies on the nutritive value of wheat pasture. Oklahoma Agric. Exp. Sta. Res. Rep. MP-90:13.

Mayland, H. F., D. L. Grunes and V. A. Lazar. 1976. Grass tetany hazard of cereal forages based upon chemical composition. Agron. J. 68:665.

N.R.C. 1976. Nutrient Requirements of Domestic Animals, No. 4. Nutrient Requirements of Beef Cattle. Fifth Revised Ed., National Academy of Science - National Research Council, Washington, D. C.

Patel, G. A. and J. F. Nishimuta. 1978. Comparative nutritive value of wheat, rye and triticale forages in a beef finishing program. Alabama Agric. Mich. Univ. Annual Res. Rep. 7:189.

Stewart, B. A., D. L. Grunes, A. C. Mathers and F. P. Horn. 1981. Chemical composition of winter wheat forage grown where grass tetany and bloat occur. Agon. J. 73:337.

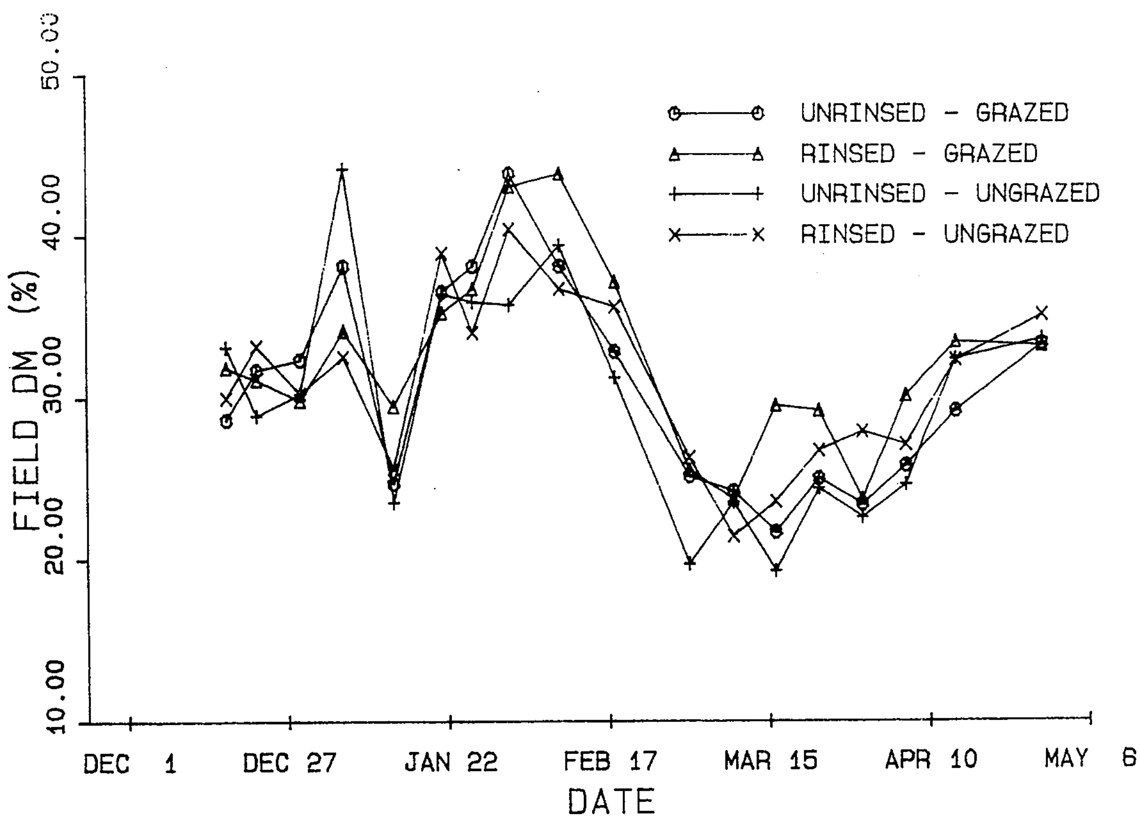


Figure 1. Seasonal changes in the moisture content of rinsed and unrinsed; grazed and ungrazed.

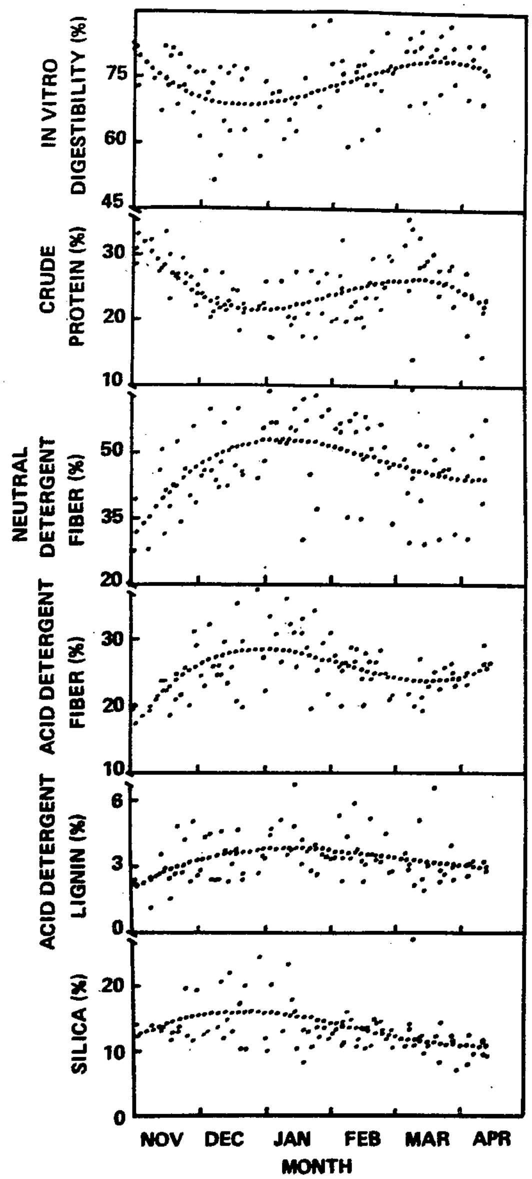


Figure 2. IVDMD and chemical composition of wheat forage.

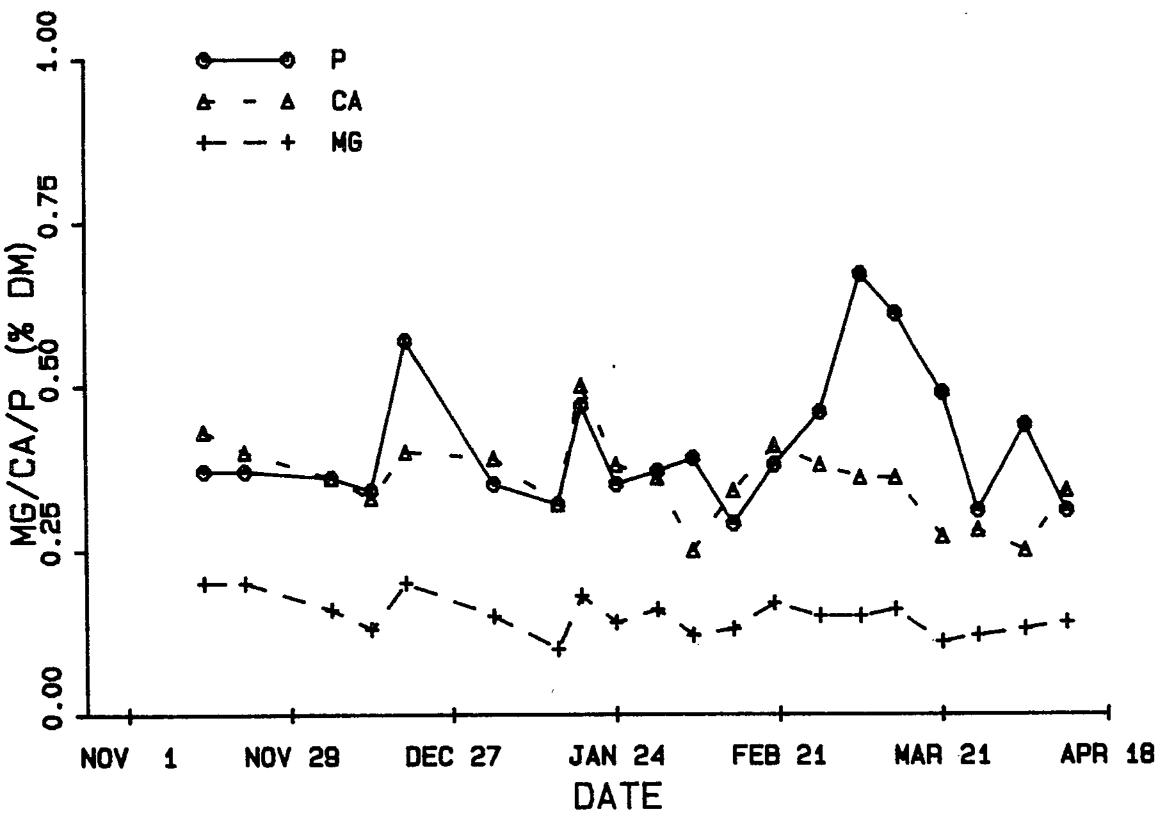


Figure 3. Phosphorus, calcium and magnesium concentrations in winter wheat forage.

FEEDING VALUE OF WHEAT SILAGE AND HAY AS WHEAT CROP ALTERNATIVES

Keith K. Bolsen

Kansas State University, Manhattan, 66506

SUMMARY

The yield and nutrient content of wheat forage are greatly influenced by stage of plant maturity at cutting. As wheat matures from boot to dough stages, forage dry matter tonage/hectare increases but forage % crude protein decreases. These variations mean that a representative sample of silage or hay should be analyzed for nutrient content if diets containing wheat forage are to be formulated accurately.

Wheat silage and hay probably have similar harvesting, storing, and feeding losses. Making wheat hay has greater weather risks than silage but hay, which has much less moisture and is more stable in air than silage, has greater marketing flexibility. Wheat silage normally has a 30 to 50% larger shrink in the silo when compared with corn silage and wheat silage usually heats more quickly when exposed to air.

Nutritionally, wheat silage has about a 10 to 20% higher feeding value than wheat hay. When fed to growing cattle in high silage diets: (1) the feeding value of wheat silage is directly related to its grain content; (2) dough stage wheat silage supports 80 to 90% the level of performance as does corn silage; (3) combining wheat silage and corn silage improves the value of wheat silage; (4) wheat silage diets usually require less supplemental protein than corn silage diets; and (5) small amounts of urea can be fed effectively with wheat silage. Dairy cattle research results with all of the cereals have been less consistent than beef cattle results, but it is generally recommended that wheat forage be harvested for dairy feed in the boot to early head stages.

INTRODUCTION

Winter wheat is becoming a commonly used forage in beef and dairy cattle production, particularly where rainfall is seasonal and limited and irrigation is expensive (Bolsen et al., 1976 and Sansoucy, 1981). There are several advantages for harvesting wheat silage or hay which include increased total nutrients per hectare; harvesting equipment and storage facilities are utilized more completely; earlier harvest means land may be double-cropped more effectively; earlier harvest decreases the risk of crop loss from rain, wind, or hail; and drought conditions are less likely to occur during the wheat growing season. There are some disadvantages which include investment in harvest equipment or storage facilities; more labor than for grain production; a short harvest period since wheat matures rapidly; and a less liquid asset which is normally marketed through cattle.

The feeding value of wheat forage is affected primarily by these factors: (1) stage of maturity at cutting; (2) method of harvest and storage (ie. silage or hay); (3) type of cattle fed (ie. dairy or beef); and (4) amount of wheat forage in the diet. It is the objective here to review these four factors and to identify areas for future research which will lead to better wheat silage and hay utilization.

COMPOSITION AND YIELD OF WHEAT FORAGE

Wheat varieties mature at various rates, depending on location grown, soil fertility, climatic conditions, etc. The chemical composition and dry matter (DM) yield change rapidly as the wheat plant matures during the growing season. Oltjen and Bolsen (1978) reported that winter wheat contained 15 to 17% DM in the boot stage; 23 to 30%, in the milk stage; and 35 to 47%, in the dough stage. Corresponding crude protein values (DM basis) were 15 to 16% in the boot stage; 10.5 to 11.5% in the milk stage; and 9.2 to 10.4% in the dough stage. These workers also showed that as wheat matured from the boot to the dough stage, total DM and digestible DM yields increased by 1.8 and 1.65 times, respectively.

FEEDING VALUE OF WHEAT FORAGE

Wheat or corn silages were fed to beef cattle in seven trials from 1972 to 1982 (Oltjen and Bolsen, 1978; Bolsen et al., 1981; and Bolsen et al., 1982). The wheat forages were whole plant and were harvested in the dough stage, except as indicated. Silages were made in concrete stave silos (3 x 15 m). When necessary, water was added to provide a moisture content of at least 60% in the ensiled forage. Wheat silage varieties included soft red winter, awnless wheats (Blue Boy, Blue Boy II, and Arthur) and hard red winter, awned wheats (Parker, Eagle, Sage, and Newton).

Results of these trials are shown in table 1. Cattle fed corn silage outperformed those fed wheat silage but this was expected since the corn silages had higher grain contents and lower fiber values. The reduced feeding values of the wheat silages were due to their lower DM intakes and digestibilities. The relative wheat silage performance in these trials averaged 81% of corn silage performance (table 2). This comparison is somewhat misleading because, when the two poorest wheat silages are omitted (Parker in trial 2 and Blue Boy II in trial 3), the relative performance of wheat goes up to 85% of corn. The average gain and feed conversion for wheat silage in these seven trials were .84 kg/day and 9.2 kg of DM/kg of gain and both are acceptible in most cattle enterprises.

The lower gain and DM intake associated with wheat silage can be overcome by several means. Feeding one to two kg of additional grain daily should rise the energy value of wheat silage diets to values comparable to corn silage diets. The DM intake of wheat silage was increased by combining it with corn silage or alfalfa haylage. Daily gains were improved with the corn silage diet (table 1; trial 2) but not with the haylage diets (table 1, trials 6 and 7).

Wheat silage, with its higher crude protein content, requires less supplemental protein than corn or sorghum silages. By using a small amount of urea, supplements for wheat silage diets can be formulated much cheaper than most other growing diet supplements. Results in table 1 (trial 3) show that yearling steers fed wheat silage with .03 kg of urea daily gained the same as steers fed the soybean meal supplement.

Wheat varieties differed in silage feeding value (table 1). It was not a simple difference of hard red winter versus soft red winter or awned versus awnless. Differences existed among hard red winter, awned varieties. For example, Eagle had a higher feeding value and was consumed in greater amounts than Parker. Likewise, in the awnless soft red winters, Arthur had a higher feeding value than Blue Boy II. Oltjen and Bolsen (1980) showed that these differences were explained by grain to forage ratio and fiber content (especially acid detergent fiber) which differed among wheat silage varieties. They concluded that a variety which produces a high grain yield will likely give a silage with a high feeding value.

In digestion trials with lambs, Bolsen and Berger (1976) showed that DM and crude protein digestibilities of hard and soft winter wheat and winter barley silages were not affected by stage of maturity at cutting (table 3). However, crude fiber digestibility decreased and nitrogen-free extract (NFE) digestibility increased as maturity advanced from boot to dough stage.

Although cereal forages are used satisfactorily in dairy cattle diets, they often do not support levels of milk production equal to good quality alfalfa hay and silage or corn silage. Stage of maturity at cutting has inconsistently affected DM intake of cereals, particularly when conserved as silage. McCullough and Sisk (1966) found that dairy cows consumed 20% more boot stage wheat silage DM than milk or dough stage silage dry matter. Fisher et al. (1972) reported that dairy cows consumed less barley milk stage silage DM than boot or dough stage silage dry matter. However, Miller et al. (1967) and Polan et al. (1968) observed that dairy cows consumed less DM when barley was ensiled in the boot stage than when ensiled in the milk or dough stages. Martz et al. (1958) reported that dairy cows receiving 2 kg of alfalfa hay and 1 kg of grain per 6 kg of milk produced consumed more oat dough stage silage than boot or milk stage silage when silages were offered ad libitum.

Based upon crude protein and estimated net energy of lactation values, Belyea et al. (1978) concluded that the optimum stages to cut wheat forage for dairy cows were boot to early heading.

Only a limited number of research trials have compared cereal silages to cereal hays. Wheat silage and hay trials have usually been conducted with dairy cattle or sheep. Oltjen et al. (1977) reported that feeder lambs fed wheat or oat silages gained faster and more efficiently than lambs fed the corresponding hays (table 4). Silages had slightly higher crude protein, lower crude fiber, and greater digestibility than their companion hays. For dairy cattle, Fisher et al. (1972) found milk stage barley silage superior to hay.

MANAGING WHEAT HAY AND SILAGE

Wheat hay quality and losses are affected more by unpredictable late spring weather than is silage. The 2 to 4 days drying time before baling increase the risk of losing nutrients to leaching due to rainfall. Raking and baling can result in 10 to 20% leaf loss or higher, depending on the extent of weathering. Outside storage and feeding losses in large hay packages can be extensive unless these bales are managed properly (Martin, 1980).

Ensiling losses can only be minimized if proper techniques are used and the forage is chopped at the correct moisture (Zimmer, 1980). If wheat is ensiled in the boot stage, it should be field-wilted to 25 to 30% DM for storage in conventional tower or horizontal silos. Wheat ensiled in the milk or dough stages should be direct-cut and the DM content not allowed to exceed 40% if stored in conventional silos. The shrink loss of properly made wheat dough stage silage will likely be greater than that of properly made corn silage. In two comparisons, wheat silages had an average shrink loss of 19% compared with 10% for corn and 13% for forage sorghum (table 5). Wheat silage had a similar shrink loss as 68% moisture alfalfa silage but a greater loss than 62% moisture alfalfa. Two characteristics of wheat are responsible for most of this additional storage loss: (1) it has a hollow stem which entraps more air when ensiled and (2) wheat silage usually heats quickly when exposed to air during feedout.

AREAS OF FUTURE RESEARCH

After reviewing the current management practices and the past literature concerning the feeding value of wheat silage and hay, research is needed in these five areas:

(1) Select wheat varieties which have both grain and forage production potential. This should allow the farmer more flexibility in planning his crop and livestock programs.

(2) Reduce the weather risks and excessive field losses often incurred with wheat hay systems. This could be done by accelerating the forage drying time in the swath or by baling at higher moisture with the aid of preservatives.

(3) Increase the conservation efficiency in wheat silage systems. Practices which reduce the entrapped air (ie. finer chopping), increase fermentation efficiency (ie. additives), or minimize surface waste when the silage is fed should also reduce the "shrink" loss.

(4) Extend the effective harvest season for dough stage wheat silage. This might be accomplished by selecting two (or more) varieties of wheat which do not mature at the same rate and time or by incorporating other crops into the wheat silage system (ie. winter barley, triticale, or rye; spring oats; or alfalfa).

LITERATURE CITED

Belyea, R.L., F.A. Martz, R.E. Ricketts, R.R. Ruehlow, and R.C. Bennett. 1978. In vitro dry matter digestibility, detergent fiber, protein and mineral content of wheat forage as a dairy cattle feed. J. Anim. Sci. 46:873.

Bolsen, K.K. and L.L. Berger. 1976. Effects of type and variety and stage of maturity on feeding values of cereal silages for lambs. J. Anim. Sci. 42:168.

Bolsen, K.K., L.L. Berger, K.L. Conway and J.G. Riley. 1976. Wheat, barley and corn silages for growing steers and lambs. J. Anim. Sci. 42:185.

Bolsen, K.K., H.J. Ilg, and M. Nuwanyakpa. 1981. NaOH and Ensila Plus additives for wheat silage and alfalfa haylage for growing steers. Rpt. of Prog. 394, Kansas Agri. Exp. Sta.

Bolsen, K.K., H.J. Ilg, M. Nuwanyakpa, and J. Hoover. 1982. NaOH wheat silage and alfalfa haylage for growing steers and heifers. Rpt. of Prog. 413, Kanas Agri. Exp. Sta.

Fisher, L.J., J.R. Lessard and G.A. Lodge. 1972. Whole crop barley as conserved forage for lactating cows. Can. J. Anim. Sci. 52:497.

Martin, N.P. 1980. Harvesting and storing of quality hay. American Forage and Grassland Council Proc. p. 177.

Martz, F.A., C.A. Noller and D.L. Hill. 1958. The feeding value of oat silage for milking cows. Purdue University Agr. Exp. Sta. Mimeo Rep. DH-72.

McCullough, M.E. and L.R. Sisk. 1966. Influence of stage of maturity at harvest and level of grain feeding on intake of wheat silage. J. Dairy Sci. 50:705.

Miller, C.N., J.T. Huber, R.E. Blaser, R.A. Sandy and C.E. Polan. 1967. Nutritive value and yields of barley silage at three stages of growth. J. Dairy Sci. 50:616.

Oltjen, J.W. and K.K. Bolsen. 1978. Wheat, barley and oat silages for beef cattle. Bull. 613, Kansas Agri. Exp. Sta.

Oltjen, J.W., K.K. Bolsen, H.J. Ilg, P. Sowers. 1977. Wheat and oat hay or silage for growing lambs. Rpt. of Prog. 300, Kansas Agri. Exp. Sta.

Oltjen, J.W., K.K. Bolsen. 1980. Wheat, barley, oat and corn silages for growing steers. J. Anim. Sci. 51:958.

Polan, C.E., T.M. Starling, J.T. Huber, C.N. Miller and R.A Sandy. 1968. Yields, composition and nutritive evaluation of barley silage at three stages of maturity for lactating cows. J. Dairy Sci. 51:1801.

Sansoucy, R. 1981. Silage from whole-crop forage cereals for cattle feeding. World Anim. Rev., 37:25-30.

Zimmer, E. 1980. Efficient silage systems. Forage Conservation in the '80's. Brighton, England. Occ. Sym. No. 11, British Grassland Society.

TABLE 1. PERFORMANCE OF GROWING CATTLE FED WHEAT OR CORN SILAGES[1]

Silage	Avg. daily gain, kg	Daily feed intake, kg[2]	Feed/kg of gain, kg[2]	Silage DM, %	Silage CP, %[2]	Forage harvest date
	Trial 1 (122 days)					
Corn	.87	6.9	8.1	33.4	8.7	--
Blue Boy wheat-head[3]	.69	6.5	9.5	35.7	13.6	June 11
Parker wheat-head	.65	6.1	9.5	36.6	13.2	June 9
	Trial 2 (100 days)					
Corn	1.09	8.4	7.5	40.9	8.3	--
Arthur wheat	.95	7.9	8.5	36.9	7.5	June 8
Parker wheat	.70	6.7	9.6	34.6	7.4	June 6
Parker wheat-head	.79	6.7	8.1	41.2	9.9	June 7
Corn+Parker wheat-head	1.02	8.2	8.1	--	--	--
	Trial 3 (90 days)					
Corn	1.28	8.8	6.8	34.8	9.1	--
Corn + urea	1.28	8.9	6.9	--	--	--
Arthur wheat	.87	6.8	7.9	32.2	11.2	June 5
Arthur wheat + urea	.87	7.1	8.2	--	--	--
Blue Boy II wheat	.70	6.5	9.5	36.9	11.2	June 5
Eagle wheat	.87	7.4	8.5	34.3	9.6	June 5
	Trial 4 (87 days)					
Corn	1.11	8.5	7.7	37.8	7.8	Aug. 29
Arthur wheat	1.05	8.3	7.9	36.9	10.8	June 13
Eagle wheat	.96	7.7	8.1	37.8	8.4	June 14
Eagle wheat-milk stage	.89	7.3	8.2	33.8	9.9	June 5
	Trial 5 (89 days)					
Corn	1.14	8.7	7.6	37.2	8.3	Aug. 20
Arthur wheat	.93	8.5	9.1	39.2	11.2	June 7
Sage wheat	.89	8.7	9.9	41.2	8.3	June 9
	Trial 6 (78 days)					
Newton wheat	.97	6.8	7.1	42.0	9.5	June 14
Wheat + alfalfa haylage	.96	8.3	8.4	--	--	--
	Trial 7 (80 days)					
Newton wheat	.73	5.4	7.5	41.9	11.1	June 9
Wheat + alfalfa haylage	.71	6.6	9.3	--	--	--

[1] All diets were 85 to 87% silage (DM basis) and all were supplemented with soybean meal except where urea was fed in trial 3. Wheat was grown under dryland conditions at Manhattan.

[2] 100% DM basis.

[3] Upper one-half of the plant.

TABLE 2. RELATIVE FEEDING VALUES OF WHEAT AND CORN SILAGES.[1]

Silage	Relative value
Corn	100
Wheat (dough stage)	81 (range: 64 to 96)

[1]Feeding values established from rate and efficiency of gain data in the feeding trials (table 1).

TABLE 3. EFFECT OF STAGE OF MATURITY AT CUTTING ON DIGESTIBILITY OF CEREAL SILAGES BY LAMBS.[1,2]

	Apparent digestibility			
Stage of maturity	DM	Crude protein	Crude fiber	NFE
Boot	61.4	67.5	68.0[a]	63.2[b]
Milk	60.3	66.9	60.1[b]	64.2[b]
Dough	61.7	69.2	52.2[c]	69.2[a]

[1]Mean of hard and soft winter wheat and winter barley silages.

[2]Eighteen observations per mean.

[a,b,c]$P<.05$.

TABLE 4. PERFORMANCE OF GROWING LAMBS FED WHEAT OR OAT SILAGES AND HAYS.[1]

Item	Trio oats hay	Trio oats silage	Lodi oats hay	Lodi oats silage	Arthur wheat hay	Arthur wheat silage
Avg. daily gain, kg	.08	.09	.08	.09	.13	.16
Daily feed intake, kg[2]	.90	.95	.95	.95	1.13	1.22
Feed/kg of gain, kg[2]	12.5	10.6	12.7	11.2	8.8	7.7
DM, %	91	30	92	33	92	40
	% of the forage DM					
Crude protein	11.2	12.6	10.0	10.7	9.7	11.0
Crude fiber	32.7	31.8	31.0	29.4	26.4	23.0
In vitro DM digestibility, %	54.2	55.4	55.1	59.1	59.2	60.9

[1] 50 days.
[2] 100% DM basis.

TABLE 5. FERMENTATION, STORAGE, SPOILAGE, AND FEEDOUT LOSSES FOR WHEAT, CORN, FORAGE SORGHUM, AND ALFALFA SILAGES.[1]

Silage crop	Crop DM, %	Feedable DM recovery	Top spoilage loss	Fermentation, storage, and feedout loss
		% of the DM ensiled		
Wheat	41	80	5	15
Corn	36	93	2	9
Sorghum	34	90	2	8
Alfalfa	38	85	4	11
Wheat	42	82	6	12
Corn	33	87	2	11
Sorghum	42	84	4	12
Alfalfa	32	82	5	13

[1] Silages made in 3 x 15 m concrete stave silos.

UTILIZATION OF THE ENERGY AND PROTEIN COMPONENTS OF FORAGES BY RUMINANTS - A UNITED KINGDOM PERSPECTIVE

D. E. Beever

The Grassland Research Institute, Hurley, Nr. Maidenhead, Berkshire

INTRODUCTION

The purpose of this review is to consider the overall efficiency of conversion of the energy and protein components of forage into meat and milk products by ruminant livestock. Such a review will recognize that this conversion is influenced by a number of important processes occuring within the animal and the relative importance of these will be identified. The interdependence of energy and protein at all levels within the animal will be illustrated, although specific consideration of the utilization of forage protein will be emphasized. This paper will attempt to consider the utilization of both grazed and conserved forages, and the important differences between grasses and legumes will be highlighted.

Forage Production in the United Kingdom

Of the total agricultural area in the United Kingdom, approximately 70% comprises "grassland" (Marsh, 1981) and this can be classified as temporary grassland (15% of total grassland) permanent grassland (37%) and rough grazing (48%). The levels and seasonality of forage production from such grassland will vary considerably and be influenced by environmental and managerial factors. However, it is reasonable to conclude that temporary and permanent grassland will make the largest contribution to the total forage production in the UK. These leys are characterized by a high content of Perennial and Italian ryegrass, which may represent approximately 75% of the sown grass species (Hopkins & Down, 1981), whilst the use of other grass species (e.g., Timothy or Cocksfoot) is limited and in general declining.

The major use of legume seed is in grass mixtures, with the favored species being white clover, along with some limited use of red clover. Overall, the proportion of legumes in total seed sales has remained fairly constant at between 6 and 8% since 1967 (Hopkins & Down, 1981), with white clover representing almost 80% of this total, whilst the establishment of pure swards of lucerne or red clover has been restricted to a few specific soil and environmental types in the country.

Consequently, it follows that forage production in the UK is dominated by grass, and in response to this trend, Down & Lazenby (1981) reported that fertilizer N application to grassland has increased dramatically over the last 10 years or so and by 1979 (last available data) was equivalent to averages of 150 and 90 kg N/ha/year for temporary and permanent grassland, respectively.

From the annual production of forage in the UK, which is either consumed in situ or as a conserved product, it has been estimated that 76% of the energy requirements of the total UK ruminant population are met. This varies from a value of 97% of the total energy requirement for sheep, where the use of cereals and other feeds is minimal, to 79% for all beef production systems and approximately 60% for dairy production, the latter being a system of production which over the last few years has seen an increased dependence on cereal feeding.

Against this background of forage production in the UK it must be recognized that, with only few exceptions the active period of grass growth is from mid April to mid September, with a large portion of the annual production occurring by the end of May. Consequently, it is general practice throughout the country to conserve grass as silage during the period mid-May to mid-June, with a small amount of silage being produced from mid-summer or autumn regrowths. Field-cured hay is made, weather permitting, during the period late May - mid July, but recent data reveal that of total conserved forage DM, the proportion represented as silage has steadily increased and now constitutes over 55%. Most grass which is destined for silage receives quite liberal applications of N fertilizer; the use of precision-chop harvesters is now commonplace, but the choice between direct-cut (or minimum wilt) and additive, against heavy wilted (to 30% DM) material remains divided. In this context, the preparation and subsequent feeding has become more highly mechanized, and equally, through the choice of different maturing varieties, the strategic use of additives and better ensiling technology, the overall efficiency of the ensiling process has been dramatically improved, with a substantial reduction in losses (McDonald, 1981). Virtually all silage is made in clamps, the use of cropstores for high DM silage being negligible.

NUTRITIVE VALUE OF FORAGES

In discussing the nutritive value of forages, whether grazed or consumed as conserved products, it is recognized that the physical and chemical characteristics of the forage will have a major effect on the quantity and quality of the material consumed by the animal. This applies specifically in the grazing situation, where the choice of the forage grown, the rate and pattern of fertilizer application, the age of the forage at the time of grazing and the stocking density, along with obvious seasonal and locational effects, will have a major effect on the quality and quantity of forage available. Additionally, the grazing ruminant's accepted ability to select the forage it consumes further complicates the picture in regard to understanding the overall efficiency of conversion of available forage to animal products.

With respect to conserved forages, clearly the harvesting of large quantities of forage at specific times allows the farmer more control over the composition of the harvested material, but as pointed out by McDonald (1981), the processes of silage fermentation can vary considerably and the resulting silages may differ markedly in nutrient profile, according to the efficacy of the ensiling techniques employed.

1. GRAZED FORAGE

Whilst this is the most difficult area of forage evaluation to examine, it is nevertheless more appropriate to commence an investigation at this point.

In any grazier's mind, the provision of adequate material of an appropriately high digestibility to sustain his livestock units, and optimization of the yield of utilized metabolizable energy (UME)/unit of land area, are paramount. Consequently, such factors as sward height and forage acceptability appear to be most crucial and attention to a more detailed assessment of nutritive value is almost coincidental. Thus, in grazing studies with dairy cattle, Le Du et al. (1981) reported that for a perennial ryegrass sward grazed at 4 weekly intervals, OM digestibility ranged from only 0.72 to 0.80, yet total N content was found to vary between 13 and 30 g N/kg dry matter (DM). Similarly Losada et al. (1981) who examined both primary and 4-week regrowths of perennial ryegrass offered to grazing cattle (200 kg average weight), found OM digestibility (from *in vitro* - *in vivo* derived relationships) to vary little from a mean value of 0.79, yet total N content ranged from 19 to 28 g N/kg DM and water soluble carbohydrate content from 107 to 181 g/kg DM.

Legumes are characterized by high N contents, and Losada et al. (1981) and Cammell et al. (1982) observed that variations in N content of white clover (40-44 g/kg and 43-47 g/kg DM, respectively) were generally much less than those reported earlier for grasses. On the other hand, legumes such as lucerne and red clover are generally characterized by lower OM digestibilities (0.54 - 0.68) although in this context, white clover appears to be an exception with few reported values falling below 0.75, and generally much closer to 0.80.

At the other end of the scale, the N content of poor hill grazing in the UK is generally much lower (6 - 25 g/kg DM), with associated OM digestibilities of 0.5 - 0.78 (HFRO, 1978); whilst in a recent paper Mayes and Lamb (1982) reported a heather/agrostis pasture to have an N content of 12 g/kg DM and an OM digestibility of 0.49.

In addition to the overall composition of the forage on offer, the animals' ability to select will influence the composition of the diet consumed. This was amply demonstrated by Curll (1981) who, with mature sheep grazing a ryegrass:white clover sward, reported that the grass:clover ratio in the offered crop was 3.6:1, but found that the ratio in the ingested material, obtained by examination of oesophageal fistulae samples, was closer to 1.8:1, clearly demonstrating the animals' positive selection of the legume component. Equally, the animals' ability to select positively for leaves rather than stems, and their negative selection of faecal and urine contaminated pasture, will further distort the composition of the ingested material compared with the material on offer.

1a. DIGESTION OF FRESH FORAGES

In order to understand more fully the overall efficiency of conversion of nutrients to animal products, it is essential to consider the consequences of the processes of digestion, absorption and metabolism which occur within the animal, as outlined by Beever (1979).

To this end, considerable research effort has been seen in the area of ruminant digestion. Some of the earliest studies on the digestion of fresh forages were conducted at Newcastle University in collaboration with the Grassland Research Institute, and a brief summary of the data is presented in table 1. All three studies used mature sheep fed at maintenance plus levels, and in the first two studies, the forage was frozen at the time of harvesting and fed later in the thawed state. It can be seen from table 1 that duodenal N flow represented between 0.85 and 0.97 of N intake, and the quantity of N absorbed from the small intestine ranged from 0.53 to 0.61 of N intake. These low values for N absorption from the small intestine were recorded in contrast to high overall N digestibility values, suggesting that only between 0.69 (Beever et al., 1976) and 0.81 (Beever et al., 1971) of total digestible N was absorbed from the small intestine. This low N absorption despite high digestible N intakes was developed further by Thomson and Beever (1980) who, on recalculating the data of Proud (1972) for experiment 1 showed amino N absorption from the small intestine to be equivalent to only 0.41 and 0.55 of total N and digestible N intake.

In addition to feeding frozen (to represent fresh) grass in experiment 2 (table 1), Beever et al. (1976) also prepared several dried forms from the same crop and these, in turn, were fed to the same mature sheep. The major response of dehydration was to increase both the duodenal flow and the small intestinal absorption of nitrogen and from an examination of the % of the total dietary N soluble in acid pepsin (S), Beever et al. (1976) developed a significant negative relationship, viz. TNR = 165 - 1.13S ($r = -0.98$), where TNR was equivalent to g total N entering small intestine/g N intake. Clearly, this relationship, although obviously limited in its applicability, demonstrated the importance of dietary N solubility in relation to duodenal N flow. However, the study of Beever et al. (1976) did not distinguish duodenal N into respective microbial and undegraded feed N components and consequently they could only speculate on the likely mechanism associated with the increased flow. On the other hand, in the study with fresh grass, Beever et al. (1974) reported that microbial N synthesis was low on the fresh forage (16 g/kg OM apparently digested in the rumen (OMADR)) and this was found to be significantly increased by dehydration of the forage prior to feeding (32 g/kg OMADR), leading the authors to conclude that both enhanced microbial N synthesis and undegraded feed protein flow to the duodenum could contribute to the overall enhanced duodenal N flows observed on dried vs fresh (frozen) forages.

In accord with these earlier studies in UK, MacRae and Ulyatt (1974) and Ulyatt & MacRae (1974) evaluated a series of temperate forages in New Zealand. Using perennial ryegrass (R), short rotational ryegrass (M) and pure white clover (C), all fed in the fresh state to mature sheep, they observed that duodenal N flow was consistently less than N intake

(R 0.66, M 0.88, C 0.74), with small intestinal NAN absorption equivalent to 0.37 (R), 0.57 (M) and 0.47 (C) g/g N intake. On all three diets, overall N digestibility exceeded .80 and so it may be shown that small intestinal NAN amounted to only 0.47 (R), 0.72 (M) and 0.58 (C) of digestible N intake.

From these two separate studies, albeit conducted with mature sheep, it became clear that with fresh forage diets, varying and quite often large quantities of dietary N failed to reach the duodenum in any form whatsoever. This fraction was presumed to be lost from the rumen as ammonia by absorption across the epithelium, with the net consequence being a reduction in the quantity of amino N absorbed from the small intestine. Additionally, the studies of MacRae & Ulyatt (1974) demonstrated that substantial between-forage differences with respect to N digestion did exist. However, in attempting to explain the cause of such differences, MacRae & Ulyatt (1974) were not particularly successful. They drew attention to the importance of balancing the supplies of ruminally degradable carbohydrate with degraded N levels, and to the high levels of soluble N and pectin in clover diets, whilst earlier, Ulyatt (1971) had shown that the readily fermentable to structural carbohydrate ratio varied from 0.57 (R) to 0.79 (M) for the grasses compared with a value of 1.22 for clover.

In contrast, in a further study by Ulyatt & Egan (1979) where four fresh forages were fed hourly (as opposed to twice daily in the study of MacRae & Ulyatt, 1974) to sheep, the data showed duodenal N flow for two ryegrasses and sainfoin (a tannin-containing legume) to more or less equate with N intake and only with white clover was duodenal N flow found to be consistently less than N intake (0.88 g/g). These results were surprising in relation to the earlier findings and led Ulyatt & Egan (1979) to suggest that the use of diets having higher OM digestibilities than those used by MacRae & Ulyatt (1974) and the adoption of frequent feeding may have been responsible for the effects noted.

The nil response to N digestion on the sainfoin diet, as reported by Ulyatt & Egan (1979) is equally surprising. In any earlier study, Thomson et al. (1971) fed low temperature dried sainfoin and lucerne, of similar N contents to mature sheep and demonstrated a substantial improvement in total N flow to the duodenum and total amino acid absorption from the small intestine for sheep on the sainfoin diet. From the studies of Jones et al. (1973) and Reid et al. (1974) it would appear that such differences were due to the presence of tannins in sainfoin which are known to bind with dietary proteins, so rendering them less or more slowly available for digestion in the rumen. To investigate this pheonomenon further, Siddons, Beever & Thomson (unpubl. obs.) considered the digestion of fresh (daily harvested) sainfoin and red clover fed alone or in mixtures, to mature sheep. The objective of the study was to further examine the protein protection potential of sainfoin tannins and to consider the possible effect that a small addition of sainfoin may have on the digestion of a non tannin containing legume such as red clover.

The results of this study are presented in table 2. Both crops had over 3% N in the total dry matter (red clover 10% greater than sainfoin) but the sainfoin was characterized with much lower soluble N contents.

The two mixtures gave intermediate values for soluble N contents which suggested that there was no interaction between the two contrasting legumes. Rumen proteolytic and deaminative activities were found to be lowest on the all sainfoin diet compared with the red clover, whilst the values noted on the two mixtures tended to be similar to those noted on the red clover and no indication of any positive interaction due to the presence of dietary tannins was evident. In line with these changes, the in vivo digestion data revealed that total duodenal amino acid supply to the small intestine in relation to total amino acid intake was 0.83 on the sainfoin diet compared with values ranging from 0.65 to 0.75 on the other three diets. Similarly, when microbial amino acid contribution to the small intestine of sheep fed the four diets was assessed, the data showed quite clearly that overall efficiency of microbial synthesis was highest on the all sainfoin diet, with yet again no obvious effect on any interaction. Thus, whilst this study failed to demonstrate any positive interaction between the sainfoin and red clover with respect to N digestion, it confirmed the earlier finding of Thomson et al. (1971) and showed that enhanced microbial activity made a large contribution to the effects noted with respect to duodenal amino acid flow.

Against this background of information on the digestion of cut fresh forages, there have been surprisingly few attempts to investigate the use of energy or "protein" supplements. The study of Mayes & Lamb (1982) attempted to investigate the use of a starch/urea mixture as a supplement to a poor quality heather/agrostis diet fed indoors to housed sheep. On the basal diet, NAN absorption amounted to 0.56 of N intake (= 3.6 g NAN/d) whilst the addition of urea and starch (total 3.5 g N/d) increased duodenal NAN flow and absorption by 3.4 and 1.4 g/d, respectively. Microbial N flow was increased by 2.1 g N/d (= to 0.60 of added urea N) whilst microbial N efficiencies were similar on both diets (control 34, supplemented 31 g N/kg OMADR). However, whilst the overall effect of supplementation was to increase total ME supply, absorbed NAN/MJME on the supplemented diet (0.94 g/MJ) was found to be approximately 10% less than the value recorded on the control diet (1.03 g/MJ).

In the mid seventies, Corbett and his colleagues in Australia directed their efforts towards the design of equipment suitable for the measurement of digestion in sheep at pasture and this work resulted in the successful development of a portable pump for the intraruminal infusion of markers (Corbett et al., 1976). Subsequently, work at the Grassland Research Institute led to the development of a further infusion pump (Evans et al., 1981a) and an automatic duodenal sampler (Evans et al., 1981b), both of which could be easily attached to the harness of grazing cattle. More recently, the duodenal sampler proposed by Evans et al. (1981b) has been successfully modified for use with grazing dairy cows.

Following these developments, several attempts to evaluate grazed pastures have been undertaken. At the GRI, the first study (Ulyatt et al., 1980) involved a limited evaluation of five forages comprising pure perennial ryegrass and pure white clover at three and two stages of growth, respectively. All forages were offered to growing cattle at a rate of 5.6 kg forage DM/100 kg live weight/d, with a fresh allocation being given each day. It was intended that all forages should have similar OM digestibilities (0.78 - 0.80) and this was achieved except for the primary white clover which had an OM digestibility of 0.74. A summary of the data is presented in table 3. Despite similar forage allowances, OM and NAN flow to the small intestine on the grass diets declined as the season advanced, although the overall effect on duodenal NAN flow/estimated ME intake was negligible (mean 2.32 g/MJ). On the other hand, the flow of OM and NAN on the 2 clover diets appeared to be unaffected by stage of growth. OM flow (mean 13.2) was similar to that seen for the early grass, whilst the level of NAN flow (0.78) was intermediate between the early grass and the two regrowths. However, the consequence in relation to overall nutrient supply was a 38% improvement in NAN/ME supply on the clover (mean 3.22 g/MJ) compared with the grass diets (2.32 g/MJ).

In the subsequent year, Losada et al. (1982) extended this evaluation of grazed perennial ryegrass and pure white clover to cover a greater part of the growing season. Using a total of 20 intestinally-cannulated growing cattle, he examined a total of 7 grasses and 6 white clover diets. All forages were designed to have OM digestibilities in excess of 0.75. The grasses had total N contents varying from 19 to 33 g/kg DM, whilst the clovers had values ranging from 39 to 45 g/kg DM. In addition to determination of duodenal flow based on the use of ruthenium phenanthroline and chromium EDTA, estimates of voluntary food intake were derived from calculation of faecal OM output (with Ru as an indigestible marker) and measurement of the OM digestibility of the crop on offer (*in vitro* - *in vivo* derived relationships). These data are summarized in table 4 for cattle offered either ryegrass or white clover at 2 levels of forage allowance, viz. 3 and 6 kg DM/100 kg body weight. It can be seen that maximum intake on the grass diets approached 2.4 kg OM/100 kg body weight but these intakes were only seen from the end of May onwards. Prior to this time, OM intakes at either allowance level were considerably reduced and particularly poor with the first crop evaluated in mid May (mean 1.43 kg/100 kg body weight). With the exception of this diet, the level of intake achieved on the low level of allowance was on average 92% of that recorded on the highest allowance. Against these low intakes, the data on the clover diets were much more interesting. Overall, intakes were some 18% higher than the average value recorded for grasses at the corresponding time (clovers 2.60 kg/100 kg body weight, grasses 2.20 kg/100 kg) with the mean OM intake for the high clover allowance reaching almost 2.72 kg/100 kg.

Against these marked variations in estimated OM intakes, data relating to the flow of NAN to the small intestine (expressed per 100 kg body weight) are illustrated in figure 1. For convenience, the data obtained at the 2 levels of allocation for each forage have been pooled to provide a mean value for each diet. It can be seen from figure 1 that for the grass fed animals the value ranged from 47 to 68 g/100 kg body weight with large fluctuations being noted in early May - coinciding with the low recorded intakes, and in late June when the lowest concentration of nitrogen in the forage dry matter was recorded. Against this, the values obtained for the clover diets were consistently higher and showed little variation between 74 and 80 g/100 kg body weight. When, however, these results were expressed in relation to estimated digestible organic matter intakes, a large part of this variation was found to disappear although a mid season superiority of white clover was still evident.

In considering this data overall, Losada et al. (1982) found that in 8 of the diets examined, NAN flow to the duodenum was less than estimated N intake and based on the nitrogen content in the forage OM, these authors produced the following relationship:
NR = 1.54 - 0.019 NO (r = - 0.89) where NR = NAN flow/N intake (g/g) and NO = N content in the forage OM (g/kg). This suggested two aspects. Firstly, that within the body of data collected by Losada et al. (1982) it appeared that the clovers and the grasses adhered to one single relationship and secondly, that with diets containing more than 28 g N/kg OM net losses of N between mouth and duodenum could be expected, with some of the high N containing clover diets sustaining ruminal N losses equivalent to 40% of N intake. In conjunction with these findings, Losada et al. (1982) reported quite marked variations in rumen NH_3 concentrations. Thus on the grass diets, mean daily concentrations varied between 4 and 10 mg NH_3-N/100 ml during May, June and July, and it was only with the last crop examined in early August that mean daily values approaching 20 mg NH_3-N/100 ml were recorded. On the other hand, the mean daily values on the clover diets all exceeded 20 mg/100 ml and in mid August mean daily values approaching 40 mg/100 ml were observed.

In an attempt to obtain more information on the digestion of fresh forages by growing cattle, in a subsequent experiment Cammell et al. (1983) used housed cattle, fed zero grazed ryegrass or white clover harvested daily. The main findings of this experiment are presented in tables 5 and 6. Each crop was examined on three separate occasions to represent early (primary) growth and mid and late season regrowths. The data presented in table 5 show that, as found previously, mean daily rumen NH_3 concentrations in the early and mid season grass were surprisingly low (compared with similar N contents in the two crops of 23 mg/g DM) and only with the late harvested material (N content = 28 mg/g DM) were significantly higher rumen NH_3 concentrations observed. Against this, the clover diets which all had N contents between 43 and 47 mg/g DM, gave mean daily rumen NH_3 values which were 28 mg/100 ml in early season rising to 34 and finally 60 mg/100 ml in mid and late season, respectively. Examination of individual VFA molar proportions revealed no marked forage or seasonal effects, whilst measurements of water fractional outflow rate and rumen volume identified some interesting seasonal effects but no consistent differences between the 2 forage types.

From table 6 it can be seen that all diets had an <u>in vivo</u> OM digestibility of at least 0.80 except for mid season clover where a value of 0.76 was recorded. However, when the proportion of the digestible OM intake apparently digested in the rumen was determined, values for the 3 grass diets averaged 0.66 compared with a much lower mean value of 0.46 on the three clover diets. This would suggest that proportionally less digestion of the ingested OM was occurring in the rumen on the clover diets. However, the evidence of an accelerated rate of passage out of the rumen on these diets was not seen in the water fractional outflow rates noted in the previous table. Reconciliation of this apparent anomaly, however, lies in the ruminal digestion and synthesis of N occurring on these diets.

The data in table 6 indicate that on the grass diets, NAN flow was between 0.95 and 1.36 of N intake whilst values of 0.83 to 0.94 were seen on the clover diets. Partition of duodenal NAN into microbial N and undegraded feed N by use of ^{15}N tracer studies revealed that in all situations the amount of undegraded feed N flowing to the small intestine was less than 0.20 of N intake with mean values for the grass and clover of 0.13 and 0.18 respectively. On the other hand, the efficiency of microbial N synthesis on all diets, and in particular the clover diets, was high and it was this considerable flow of microbial OM to the small intestine that was artificially depressing the apparent digestion of OM in the rumen. In the light of this finding, Losada calculated that the proportion of digestible organic matter intake truly fermented in the rumen amounted to 94% on the grass diet and 85% on the clover diets, so dispelling this previous suggestion that considerable quantities of ingested OM may escape degradation on clover diets. To confirm this finding, brief consideration of some rumen in situ digestion studies carried out by Losada (1983) revealed that the grass diets had mean rates of OM and N degradation of 0.07 and 0.11 h^{-1} compared with 0.13 and 0.16 h^{-1} for the clover diets, and this led Losada to conclude that the supply of degraded nutrients (i.e., N/OM ration) was markedly affected by the forages offered.

Comparable data on the extent of feed protein degradation of fresh forages is remarkably limited. Earlier values obtained with housed sheep gave inconclusive results with a range from 50% (Beever et al., 1974) for perennial ryegrass to 70% (Ulyatt et al., 1975) for short rotational ryegrass and 74% (Hume and Purser, 1974) for subterranean clover. However, data presented by Corbett et al. (1982) for sheep grazing a variety of forages appears to be much more consistent; for Phalaris and lucerne (both early and late season) and native pasture (early season) estimates of apparent feed protein degradabilities ranged from 0.82 to 0.98 of protein intake and only with the later grazed native pasture was a significantly lower degradability observed (0.69). These results are in agreement with the generally high rumen ammonia concentrations observed by Corbett et al. (1982) and the considerable loss of N which may occur during the ruminal digestion of fresh forages. On the other hand, and in further agreement with the data presented earlier, Corbett et al. reported microbial N efficiencies ranging from 27 to 49 g/kg OMADR, which are higher than accepted values.

Following the indoor feeding experiment reported by Cammell et al. (1983), a general review of the information obtained in conjunction with previously available data revealed several important issues with respect to fresh forage feeding. In particular, with high N containing diets, this substantial net loss of N between mouth and duodenum was of considerable interest. In a following experiment, Beever et al. (1984a) proposed that the net loss was due to the rapid proteolysis and deamination of forage protein known to occur in the rumen on fresh forages coupled with an imbalanced degraded energy supply in relation to degraded N supply so preventing maximum utilization of the degraded N. In attempting to consider ways of preventing this loss, two options became apparent. Firstly, the use of a readily available energy supplement was obvious, but Beever et al. (1984a) dismissed this option in favour of attempting to control the rate of proteolysis and/or deamination. In considering ways of achieving this, two possible methods were considered. Firstly, the application of formaldehyde to the crop prior to feeding was proposed, whilst on the basis of evidence that the feeding of monensin may reduce ammonia concentration in the rumen (Dinius et al., 1976), the use of monensin in conjunction with the basal forage was examined. In total three crops, viz. primary growths of perennial ryegrass and white clover and a regrowth white clover were examined by feeding zero grazed forage to housed cattle (mean body weight 320 kg) at a rate equivalent to 22 g/kg body weight. A summary of the data obtained is presented in table 7.

As seen previously, the mean ruminal NH_3 concentrations on the two clover control diets (42 and 45 mg NH_3 N/100 ml) were considerably greater than the level noted on the grass diet (19 mg/100 ml). With the grass diet, however, monensin and formaldehyde treatment both appeared to have similar effects on NH_3 concentration equivalent to an approximate 20% reduction compared with the control. On the primary clover, monensin appeared to reduce NH_3 concentration to a lesser extent (12% reduction) whilst formaldehyde treatment caused a 30% reduction, and these effects were more marked with the regrowth clover where monensin had virtually no effect (7% reduction) and formaldehyde halved rumen NH_3 concentration. In this study no estimates of overall digestibility were made, but by expressing ruminal digestion of OM against OM intake it can be seen that monensin had no effect whereas formaldehyde caused apparently greater reductions in line with the larger effects on NH_3 concentration mentioned earlier. Against this finding, however, the authors observed that ruminal digestion of cellulose was not affected by any of the treatments imposed (overall means, control 0.77, monensin 0.77, formaldehyde 0.77 of cellulose intake). On the other hand, formaldehyde treatment markedly increased NAN flow to the small intestine in relation to N intake by +19%, +18% and +31%, for the three diets, respectively, whilst the responses to monensin were +8%, +2% and +4% only (all related to corresponding control diet). With the 2 clover diets, Beever et al. (1984a) were able, by use of ^{15}N to estimate microbial N yields, and the results indicated that the major response to formaldehyde was an increase in total microbial N synthesis with such accounting for at least 75% of the increased duodenal NAN flow observed. On the primary growth clover, feed N degradability appeared to be unaffected by either treatment, whilst on the regrowth there was indication of a small decrease from 0.84 to 0.80.

From this study, Beever and his colleagues were able to conclude that with high N containing fresh forages, it was possible to increase duodenal NAN flow and reduce ruminal loss of N by treatment of the diet prior to feeding with formaldehyde (6 hr exposure) and that, surprisingly, a large part of this effect was due to an increased synthesis of microbial N.

1b. UTILIZATION OF FRESH FORAGES

Until recently, it was widely accepted that grazed forages of average to high quality in terms of broad indices such as intake potential and digestibility, would supply sufficient protein to meet the production potential of all classes of ruminant livestock. However, in the light of the data presented in the preceding section, where NAN supply to the animal in relation to N intake or ME intake may be less than previously thought, it is advisable to reconsider this general opinion.

In this respect, there are several experimental reports to support the view that protein supplementation of animals receiving fresh forages may give rise to production responses of both biological and economical significance. In an earlier study Gordon et al. (1974) fed concentrates containing either 90 or 210 g crude protein/kg DM to dairy cows consuming fresh grass and reported milk yield increases of 0.6 and 0.8 kg/kg concentrate fed, respectively. Alternatively, Rogers et al. (1980a) fed either untreated or formaldehyde treated casein (1 kg/day) to cows grazing grass of high digestibility and N content and reported milk yield responses of 0.5 and 2.0 kg/day, respectively. To consider both energy and protein supplementation of fresh grass, Penning & Treacher (1982) fed lactating ewes on fresh grass plus either a high energy supplement (barley plus maize starch) or one of three protein supplements (viz. soyabean, fish meal or a mixture of the two proteins). Energy supplementation increased total OM intake by 23% but there was only a 4% increase in milk yield. On the other hand, the protein supplements increased milk yields by 12, 25 and 24%, respectively, whilst Orr et al. (1982) with suckling ewes grazing ryegrass, demonstrated by using lamb growth as an assay of milk yield, that fishmeal supplementation increased output by 12 and 19%, respectively, at two herbage allowances for the ewes. With energy supplementation, a performance response of +11% was only observed on the high herbage allowance animals.

To examine this effect under more controlled conditions, Barry et al. (1982) used abomasal infusions of casein and methionine with growing lambs receiving a zero-grazed ryegrass/white clover diet. The level of protein supplementation was fixed to increase small intestinal absorption of protein by an estimated 40 g/d (control 60 g/d, infused 99 g/d) and this was found to be associated with a 25% increase in live-weight gain (control 79 g/d, infused 99 g/d) and a 70% increase in total protein deposition (12.6 v 21.0 g/d) with an associated 10% reduction in the level of fat deposition. Consequently, Barry et al. (1982) concluded that protein infusion had the overall effect of increasing the proportion of energy retention present as protein from 0.27 to 0.41.

In attempting to explain these differences, Barry et al. (1982) were unable to detect any differences in whole body protein synthesis and glucose irreversible loss rates. However, a marked increase in thyroxine concentration was observed along with smaller increases in insulin and glucagon levels, and this led Barry et al. (1982) to conclude that the animal response to protein supplement which indicated an inadequacy in protein supply on the basal diet was due in part to an increased supply of total or essential amino acids, whilst induced changes in the endocrine system may have been equally as important.

In a similar experiment, Black et al. (1979) showed abomasal infusions of casein to young lambs at pasture to enhance live-weight gain and wool growth by 34 and 1.9 g/d, respectively. On the other hand, abomasal infusions of glucose gave no improvement in either parameter.

Thus it would appear that in many situations protein supplementation of fresh pasture may markedly enhance animal performance. However, recourse to protein concentrates can be expensive and two alternative approaches are worthy of consideration. Firstly, by a careful choice of forages species it would appear that protein supply to the animal can be improved, and it is in this context that the strategic use of grass: legume swards, or in some situations pure legume swards, may be desirable. Rogers et al (1979) offered ryegrass or white clover at ad libitum feeding levels to lactating dairy cows and noted a 30% improvement in milk yield on the clover fed cows, with an important component of this improved performance being due to an increased voluntary consumption of white clover compared with the ryegrass. However, when levels of white clover consumption were restricted to those observed on the ryegrass diet, a 10% improvement in milk yield on the clover diet was still observed. In a subsequent experiment, Rogers et al. (1980) found that cows offered white clover or a 50:50 white clover:ryegrass mixture consumed more DM than cows receiving ryegrass only and improvements in milk yield of 3.6 and 2.2 kg/d, respectively, were noted.

Similarly, in a recent experiment conducted at this Institute, Thomson et al (1983) examined the milk yield between weeks 4 and 18 of lactation from Friesian cows grazing either ryegrass or white clover, offered at a rate sufficient to permit ad libitum intake. From this study, in which no energy or protein supplements were offered, Thomson et al found that the clover-fed cows increased milk yield at a faster rate post parturition and attained their peak milk yield (27.6 kg/d) approximately 15 d earlier than the ryegrass-fed cows (peak 25.2 kg/d). In addition, they found that the milk from clover-fed cows had a higher protein (31.8 v 30.3 g/kg) content and a lower fat content (38.7 v 42.2 g/kg).

Reference was made earlier to the digestion studies with sheep carried out by MacRae & Ulyatt (1974) to compare three distinct forage types. In conjunction with this study 2 lamb growth experiments were undertaken and in attempting to explain the production responses noted, MacRae & Ulyatt (1974) were able to report a strong positive correlation between live-weight gain noted in grazing lambs and predicted amino acid supply from the small intestine (table 8). On the other hand, no such relationship with total VFA energy supply was observed, whilst it can be seen that the overall consequence of changing forage type was to increase the proportion of total absorbed energy represented as protein from 0.22 (diet R) to a mean of 0.31 for diets M & C.

The second alternative to stimulate protein supply to the animal on high N-containing diets is to manipulate rumen fermentation along similar lines to that considered by Beever et al. (1984). In this context Monensin does not look promising, whilst the use of protein protectants such as formaldehyde does, although this finding does not offer an easy practical solution to the problem. The benefits to be obtained from reducing protein loss in the rumen should, in addition to increasing small intestinal protein supply, reduce net ammonia absorption from the rumen. On the bais of ARC (1980) it can be calculated that with dairy cows consuming up to

18 kg DM/d of a fresh forage containing between 30 and 35 g N/kg DM, ruminally degradable N supply may exceed the extent of microbial N capture by up to 300 g/d. If all of this excess is lost from the rumen as ammonia, then it would suggest a mean rate of appearance of ammonia in the pre-hepatic tissues of the animal approaching 13 g NH_3-N/hr. In this context, Symonds et al. (1981) in a series of ammonia infusion studies, reported that the liver of dairy cows successfully removed up to 12.6 g NH_3-N/hr, whilst above this level arterial NH_3 concentrations rose, with quite severe chemical changes occurring in the cows until at net ammonia absorption rates of 23 g NH_3-N/hr the animals became recumbent. On the bais of these data from an unrelated experiment it is difficult to assess the consequence of high NH_3 absorption from fresh forages on the animal, although the possibility of impaired intake and consequently reduced animal performance cannot be ruled out.

On the other hand, from work carried out by Dr. Chalmers at the Rowett Research Institute, it appears that subclinical or clinical NH_3 toxicity of cattle grazing high N-containing pastures should not be a problem. Unless rumen pH rises above 7.0 for sustained periods of time it is doubtful that significant ammonia absorption from the rumen will occur. Furthermore, in high-yielding cows grazing high N-containing fresh grass, Dr. Chalmers recorded jugular vein NH_3 concentrations of less than 3 mg N/1, which were considerably lower than the hepatic vein or carotid artery NH_3 concentrations noted by Symonds et al. (1981) at which clinical toxicity symptoms were detected. On the other hand, the studies of Ulyatt et al. (1980), Losada (1982) and Beever et al. (1984) clearly demonstrate that on high N diets, significant quantities of the ingested N may fail to reach the duodenum in any form whatsoever. An early resolution of this apparent incompatability is urgently required.

2. SILAGES

Grass and grass:legume mixed swards make the largest contribution to the total forage ensiled annually in the UK for winter feeding to ruminant livestock, with a limited quantity of forage maize being grown in the southern part of UK for ensiling normally during October/November. With respect to grass silage, the current options appear to favour either direct cut and harvested material, which is normally ensiled with an additive, or partially wilted material where use of an additive is generally more restricted and is often only used when poor weather conditions prevail. Consequently, research into the digestion and utilization of grass silages has reflected the procedures being adopted in practice.

2a. DIGESTION OF SILAGES

Until quite recently most UK data on the digestion of silages was derived using mature sheep. In the experiment of Beever et al. (1971) and Proud (1972) cited earlier, in addition to examining fresh grass, both wilted and direct cut (non additive) silage were prepared from the same sward and fed to sheep. Subsequently, Thomson and Beever (1980) expressed the data for amino acid N flow and absorption from these diets in relation to the N content of the original crop prior to conservation.

The data are presented in table 9 and show large differences between the three diets. Thus the wilted silage gave very low values both for amino acid N flow and absorption (only 31% of N intake) whilst unwilted silage gave an intermediate value for amino acid N flow (0.54) and a value for amino acid N absorption equivalent to that found on the fresh grass, where duodenal amino acid N flow was 0.63 of N intake. Additionally, Proud (1972) reported that microbial N synthetic efficiency was 53 g N/kg OMADR on the fresh diet, declining to 41 and 39 g/kg on the unwilted and wilted silages, respectively. In attempting to explain these differences, Beever (1980) calculated that whilst the fresh grass and wilted silage had similar total degraded N levels (24 g/d), the amount of degraded carbohydrate was almost 40% greater on the fresh diet. Consequently, the degraded carbohydrate to degraded N ratio was higher on the fresh grass (13.6 g/g) than the wilted silage (9.8 g/g) and it was this difference which contributed to the higher microbial yield and the higher apparent microbial capture of the degraded N on the fresh diet (0.89 g/g degraded N) compared with the wilted silage (0.69 g/g). On the unwilted silage, both degraded carbohydrate and degraded N levels were reduced, and although the high ratio of degraded substrates (15.0 g carbohydrate/g N) permitted high efficiency of capture of the degraded N (0.89 g/g), the overall synthesis of microbial N was restricted by degraded N supply.

Subsequent studies have confirmed reduced flows of N and amino acids into and absorption from the small intestine of sheep fed direct cut (Beever et al., 1977) or wilted (non additive) grass silage (Siddons et al., 1979). Both studies indicated that feed protein degradability within the rumen was at least 85% with microbial protein synthetic efficiency being almost 50% higher on the direct cut silage (167 v 113 g amino acid/kg OMADR) whilst on the wilted silage, duodenal amino acid N supply and small intestinal amino acid N absorption were only 0.60 and 0.42 of total ingested N.

Several reports on the use of formic acid as a silage additive and its possible effect on protein digestion and absorption have appeared in the literature (Kelly et al., 1978; Møller and Thomson, 1977). In general, these studies concluded that protein supply was still quite poor with only some indication that N losses across the rumen were reduced in response to the use of formic acid. None of these studies, however, permit a full assessment of the benefits of formic acid with respect to protein digestion and, whilst Møller and Thomson (1977) reported reductions in feed N degradability, and bacterial N synthetic efficiency along with lower duodenal N supplies on formic acid compared with non additive silage, this area of nutrition still requires further elucidation.

On the other hand, the effect of using additives containing formaldehyde is much better understood. At an application rate of 6 g HCHO/100 g crude protein to ryegrass at the time of harvesting, Beever et al. (1977) reported a 33% increase in total amino acid flow to the small intestine of sheep with a marked reduction in feed protein degradation in the rumen (control 0.85 g/g feed protein, HCHO 0.22 g/g) and a dramatic decline in microbial protein synthesis (control 167 g/kg OMADR, HCHO 66 g/kg). Changing the overall composition of duodenal amino acid with an increased contribution from undegraded feed protein caused a small reduction in apparent availability of duodenal amino acid in the small intestine (control 0.75 g/g, HCHO 0.67 g/g) with the net outcome of HCHO treatment being a 13% improvement in amino acid uptake from the intestines.

More recently, Siddons et al. (1979) examined this aspect further using a reduced formaldehyde application rate of 3.5 g HCHO/100 g crude protein on a primary growth ryegrass. The silages were subsequently fed to sheep and the HCHO treated material was found to have a much lower rumen ammonia concentration (control 24.1 mg NH_3-N/100 ml, HCHO 10.7 mg/100 ml). However, even under these conditions, microbial N synthesis was not depressed, but the reduction in feed protein degradability from 0.86 (control) to 0.43 (HCHO) led to a marked increase in the flow of amino acid N to the small intestine. In this study, no reductions in small intestinal N availability were recorded and the overall effect of HCHO treatment was to increase small intestinal N absorption from 0.35 g/g N intake to 0.68 g/g, virtually a 100% increase.

In a more recent study with growing cattle, Thomson et al. (1982) examined perennial ryegrass which was partially wilted (21% DM) before ensiling with either formic acid or a mixture of formic acid and formaldehyde (50 g HCHO/100 g crude protein). Formaldehyde was shown to have no effect on the ruminal digestion of organic matter, cellulose or neutral detergent fibre, but increased duodenal amino acid supply from 123 to 164 g/kg organic matter intake was recorded. Further examination showed that whilst mean rumen NH_3 levels were more than halved as a consequence of HCHO treatment, microbial protein synthesis was unaffected and a large increase in the flow of undegraded dietary protein to the small intestine was observed. On the basis of other determinations, it was concluded from this study that the overall effect of HCHO treatment was to increase the supply of metabolizable protein/MJ estimated ME intake from 7.5 to 10.5 g/MJ. Variation in this index of nutritive value was further demonstrated by Beever (1980) who showed, for a series of forage diets with N contents varying from only 21 to 32 g/kg DM, metabolizable protein values ranged from 5.7 (wilted silage) to 12.0 g/MJ ME (oven dried ryegrass).

Additional studies (Hvelpund and Møller, 1976; Brett et al., 1979; Thomas et al., 1980a; Overend et al., 1982) have confirmed the results cited earlier, and in a recent review, Thomas et al. (1980b) reported that for a range of silage only diets, mean microbial N synthesis was 22 g/kg OMADR, a value which appears to be lower than the more generally accepted norm values. However, Thomas et al were not able to fully explain the reasons for this difference. They drew attention to the fact that on silage diets the end products of silage fermentation may represent a significant proportion of the total "available" rumen energy, but are unlikely to be major contributors to the total production of ATP in the rumen, essential for microbial synthesis. They ruled out the possibility of likely limitations in total N supply, but drew attention to the work of Maeng and Baldwin (1976) which indicated that many bacterial species have an obligatory requirement for some preformed amino acids. It may be that in those situations where the rate of silage N degradation is rapid, and where non protein nitrogen may be a major constituent of total silage N (up to 65%), then specific amino acid limitations may occur, but unequivocal evidence on this aspect is not available.

However, Cottrill et al. (1982) in examining the digestion of N supplemented maize silage by growing cattle obtained some evidence in support of the importance of the composition of the ruminally degraded N as well as total supply. Four diets comprising at least 82% of the dry matter as maize silage were designed to be isocaloric (10.5 MJ ME/kg DM) and isonitrogenous (24 g/kg DM) with the supplemental N (equivalent to 0.55 g/g total dietary N) being supplied as either urea or fishmeal in the proportions 3:1, 1.4:1, 0.6:1 and 0.3:1. The results of this experiment are presented in Figure 2.

From this it can be seen that across the four diets, total ruminally degraded N declined in response to extra increments of fishmeal. In contrast, the proportion of the ruminally degraded N derived from degraded protein increased from 0.33 g/g to almost 0.49 g/g. Thus, in the light of these findings, Cottrill et al. (1982) concluded that on the high urea diet where only 57% of the ruminally degraded N was captured by the microbes, the overall synthesis of microbial N was limited by the composition of the ruminally degraded N. As the proportion of protein N in the ruminally degraded N increased, so the efficiency of N capture (83% of ruminally degraded N) and net microbial yields increased. Thereafter, the microbial N yields recorded on the two high fishmeal diets indicated an apparent capture of ruminally degraded N of almost 90%, and as such on these diets microbial N synthesis was restricted by total ruminally degraded N supply more so than by its composition.

2b. UTILIZATION OF SILAGES

Considerable research effort has been deployed to the gross evaluation of silage diets, using both beef cattle and sheep. It is generally recognized that wilting of forage prior to ensiling will enhance total DM intake by as much as 40% in sheep, 30% in growing cattle and 25% in dairy cows (Marsh, 1979). However, the data to show that this increased forage intake will sustain enhanced animal production is conflicting. In an early experiment, Durand et al. (1968) reported that N retention in sheep was markedly reduced on direct cut lucerne silage compared with wilted lucerne silage, with a pronounced increase in urine N output. This led Wilkinson et al. (1976) to speculate a reduced synthesis of microbial protein on the direct cut silage and hence a reduced protein supply to the animal. However, the data presented earlier in this study do not support this view. In contrast, work by Gordon (1979) with dairy cows fed wilted or direct cut silage provides the first indication that protein supply from wilted silage diets may be critical. From his study, significantly lower milk yields from cows fed wilted silage were recorded, whilst in a subsequent study (Gordon, 1980), protein supplementation of both wilted and direct cut grass silage showed the greatest response in milk yield on the wilted silage. More recently, other data on animal performance from wilted and direct cut silages has confirmed an increased consumption of wilted silage DM, whilst it would appear that the levels of animal performance which can be achieved from both types of silage are not markedly different. This would clearly indicate an improved efficiency of utilization of the direct cut material, possibly associated with its higher protein supply. In a recent study, Charmley and Thomas (1983) studied the effect of wilting on both conservation losses and energy and protein retention in growing steers. They concluded that whilst the two silages had markedly different chemical compositions at the time of feeding, the efficiencies of energy and protein utilization were similar on the 2 diets. However, when conservation losses were taken into account, the overall effect was an improved efficiency of conversion of the crop to animal products when conserved as direct cut silage compared with wilting.

The cattle growth experiments of Waldo (1975) with direct cut or formic acid-formaldehyde treated orchard grass provide an excellent complement to the digestion data discussed earlier. On the additive silage, Waldo reported a marked increase in live weight gain (0.51 and 0.29 kg/d) and after deduction of maintenance energy requirements, he calculated that the requirement of digestible energy/kg gain declined from 88 to 59 MJ as a result of using formaldehyde. Urea supplementation of the two diets had no effect on either voluntary intake or live weight gain, but a formalin treated soyabean meal supplement led to both intake and performance responses, with the overall calculated DE requirement/kg gain declining further to 54 MJ.

Parallel studies in the UK were undertaken by Lonsdale (1976) who fed the same silages as those used by Thomson et al. (1981) in the digestion experiment discussed earlier. The use of formalin as a silage additive enhanced metabolizable protein supply from 7.5 to 10.5 g/MJ metabolizable energy and whilst total body energy retention in growing cattle per unit of ME intake was not altered, fat deposition declined from 3.3 to 2.8 g/MJ ME, whilst net protein deposition increased from 1.9 to 2.8 g/MJ MJ.

Similar responses to the use of formaldehyde in terms of enhanced live weight gain and clean wool production in sheep have been recorded (Barry et al., 1973; Hemsley et al., 1970), but data on milk output responses are much more confusing. In an early lactation study, Thomas et al. (1978) showed the use of formaldehyde-containing silage additives to enhance milk yield by 11% between weeks 4 and 14 of lactation. However, post 14 weeks, the cows on the HCHO silage exhibited an increased rate of decline in milk output and by week 22, the overall (weeks 4-22) milk yields were not significantly different. These results are even more surprising in relation to the work of Siddons et al. (1979) who fed the same silages to mature sheep and showed a 70% increase in protein absorption on the treated diet.

In recent years, several experiments have been undertaken to examine the use of protein supplements with direct-cut or wilted silages. With supplements of fish meal, Garstang et al. (1979) reported a positive curvilinear response in forage intake and a positive linear response in live weight gain of growing cattle. Further work by Gill & England (1983) clearly demonstrated that the provision of supplemental protein to the diet of growing cattle could markedly stimulate silage intake but in a detailed examination of the processes of digestion and metabolism occurring in cattle fed such diets, Gill & Beever (1982) were unable to identify the causal mechanism of such a response.

There are still surprisingly few estimates of the efficiency of energy utilization of silage diets (Thomas et al., 1980). Earlier calorimetric studies indicated lower efficiencies of utilization, whilst Kelly & Thomas (unpubl. obs.) found higher values for a diet of silage and soyabean compared with a diet of silage and barley. This led Thomas et al. (1980) to conclude that the provision of extra protein may be having a stimulatory effect on the efficiency of energy utilization. On the other hand, Thomas et al. (1984) using comparative slaughter balance, reported that low digestibility grass silage supplemented with barley had a higher apparent efficiency of energy utilization in growing cattle than silage alone diets, whilst Beever et al. (1984b) who examined the same diets using respiration calorimetry, indicated no difference in k_f between the high and low digestibility grass silages (0.49), with barley addition to the low quality silage increasing k_f by approximately 10% (0.54).

CONCLUSIONS

To provide a succinct summary of a subject as diverse as the evaluation of both grazed and conserved forages is an impossible task. The data presented in this paper represent an overview of current progress, but it is clear that research interest in this area has not been exhausted. The information currently available confirms that ultimate nutrient supply to animals receiving forage-based diets can be highly variable. Both seasonal and varietal effects have been shown to affect nutrient supply of grazed forages, whilst the processes adopted during ensiling can equally influence nutrient supply. Through a further concerted effort, by employing a combination of both detailed techniques coupled with well-conducted production assay experiments, it should be possible in the future to obtain a better understanding of the factors limiting the voluntary consumption of forages, those factors affecting the efficiency of transfer of both ingested energy and protein into absorbed nutrients and how these nutrients are then utilized by the animal. In this context, it is insufficient to simply relate nutrient supply to animal output. Both the balance of the nutrients and the physiological state of the animal can have a major bearing on the disposal of absorbed nutrients by the animal, and hence a need for combined biochemical and endochrinological studies is established. Once the deficiencies in the overall process of converting forage nutrients to animal products are fully established, then manipulation of these events can be envisaged. Such attempts may involve manipulation of the processes of rumen fermentation as outlined by Beever et al. (1984a) or the supplement. To this end, work at this Institute on the use of energy supplements to dairy cows receiving a fresh ryegrass, white clover diet, is in progress, along with a detailed evaluation of the role of energy and protein supplements for grass silage diets fed to beef cattle.

ACKNOWLEDGEMENTS

The author wishes to acknowledge the helpful discussions which took place with Dr. M. Chalmers (Rowett Research Institute) during the preparation of this manuscript, and the unfailing support of the staff of the Animal Nutrition and Production Department of the Grassland Research Institute without whose help none of this work would have been possible.

REFERENCES

A.R.C. 1980. Nutr. Reqs. of Farm Livestock, C.A.B., Farnham Royal.

Barry, T.N., Fennessy, P.F. and Duncan, S.J. 1975. N.Z. J. Agric. Res. 16:64.

Barry, T.N., Davis, S.R., Manley, T.R. and Redekopp, C. 1982. BSAP Occ. Publ. 6:146.

Beever, D.E., Thomson, D.J., Pfeffer, E. and Armstrong, D.G. 1971. Brit. J. Nutr. 26:123.

Beever, D.E., Cammell, S.B. and Wallace, A.S. 1974. Proc. Nutr. Soc. 33:73A.

Beever, D.E., Thomson, D.J. and Cammell, S.B. 1976. J. Agric. Sci. (Camb.) 86:443.

Beever, D.E., Thomson, D.J., Cammell, S.B. and Harrison, D.G. 1977. J. Agric. Sci. (Camb.) 88:61.

Beever, D.E., 'Forage Conservation in the 80's'. Proc. Brit. Grassl. Soc., 131.

Beever, D.E., Losada, H.R., Gale, D.L. and Spooner, M.C. 1984a. Anim. Prod. (in press).

Beever, D.E., Cammell, S.B., Haines, M.J., Gale, D.L. and Thomas, C. 1984b. Animl Prod. (in press).

Black, J.L., Davies, S.T., Colebrook, W.F. and James, K.J. 1979. Proc. Nutr. Soc. Austr. 4:126.

Brett, P.A., Almond, M., Harrison, D.G., Rowlinson, P., Rooke, J. and Armstrong, D.G. 1979. Proc. Nutr. Soc. 38:148A.

Cammell, S.B., Beever, D.E., Thomson, D.J., Austin, A.R., Losada, H.R., Evans, R.T., Spooner, M.C. and Terry, R.A. 1982. Anim. Prod. 36:1A.

Charmley, E. and Thomas, C. 1983. Anim. Prod. 36:50A.

Corbett, J.L., Furnival, E.P., Inskip, M.W., Perez, C.J. and Pickering, F.S. 1976. Proc. Aust. Soc. Anim. Prod. 11:329.

Corbett, J.L., Furnival, E.P., Inskip, M.W. and Pickering, F.S. 1982. BSAP Occ. Publ. 10:141.

Cottrill, B.R., Beever, D.E., Austin, A.R. and Osbourn, D.F. 1982. Brit. J. Nutr. 48:527.

Curll, M. 1981. Ph.D. Thesis, Reading University.

Dinius, D.A., Simpson, M.E. and Marsh, P.B. 1976. J. Anim. Sci. 42:229.

Down, K.M. and Lazenby, A. 1981. 'Grassland in the British Economy', CAS Paper 10, p. 564.

Durand, M., Zetter, S.Z. and Isserand, J.L. 1968. Annals de Biologie Animale, Biochimie, Biophysique, 8:45.

Evans, R.T., Hayes, D.G. and Beever, D.E. 1981a. Lab. Prac. 30(6):591.

Evans, R.T., Skelton, K.V. and Beever, D.E. 1981b. Lab. Prac. 30(10):997.

Garstang, J.R., Thomas, C. and Gill, E.M. 1979. Anim. Prod. 28:423.

Gill, E.M. and Beever, D.E. 1982. Brit. J. Nutr. 48:37.

Gill, E.M. and England, P. 1982. Anim. Prod. 36:47A.

Gordon, F. 1974. 47th Ann. Rep. Agric. Res. Inst., N. Ireland, p. 13.

Gordon, F. 1979. Anim. Prod. 28:183.

Gordon, F. 1980. B.G.S. Winter Meeting, p. 1.1.

Hemsley, J.A., Hogan, J.P. and Weston, R.H. 1970. Proc. 11th Int. Grassl. Congr. 703.

H.F.R.O. 1979. Science in Hill Farming, HFRO, p. 81.

Hopkin A. and Down, K.M. 1981. 'Grassland in the British Economy', CAS Paper 10, p. 559.

Hume, I.D. and Purser, D.B. 1974. Aust. J. Agric. Res. 26:199.

Hvelpund, T. and Møller, P.D. 1976. Zeitschrift fur Tierphysiologie Tierernahrung and Futtermittelkunde, 37:183.

Jones, W.T., Anderson, L.B. and Ross, M.D. 1973. N.Z. J. Agric. Res. 16:441.

Kelly, N.C., Thomas, P.C. and Chamberlain, D.G. 1978. Proc. Nutr. Soc. 37:34A.

Le Du, Y.L.P., Baker, R.D. and Newberry, R.D. 1981. Grass and Forage Sci. 36:307.

Lonsdale, C.R. 1976. Ph.D. Thesis, Reading University.

Losada, H.R. 1983. Ph.D. Thesis, Reading University (submitted).

Losada, H.R., Cammell, S.B., Beever, D.E. and Austin, A.R. 1982. BSAP Occ. Publ. 6:44.

MacRae, J.C. and Ulyatt, M.J. 1974. J. Agric. Sci. (Camb.) 82:309.

Maeng, W.J. and Baldwin, R.L. 1976. J. Dairy Sci. 59:648.

Marsh, J.S. 1981. 'Grassland in the British Economy'. CAS Paper 10:64.

Marsh, R. 1979. Grass and Forage Sci. 34:1.

Mayes, R.W. and Lamb, C.S. 1982. BSAP Occ. Publ. 6:149.

McDonald, P. 1981. The Biochemistry of Silage, Wiley, New York and London.

Møller, P.D. and Thomson, K.V. 1977. Institut for Husdjurens Utfordring schward, Rapport 54:27.

Orr, R.J., Penning, P.D., Treacher, T.T. and Newton, J.E. 1982. GRI Ann. Rep. 1981.

Overend, M.A., Armstrong, D.G. 1982. BSAP Occ. Publ. 6:162.

Penning, P.D. and Treacher, T.T. 1982. Anim. Prod. 32:374.

Proud, C.J. 1972. Ph.D. Thesis. Newcastle-upon-Tyne University.

Reid, C.S.W., Ulyatt, M.J. and Wilson, J.M. 1974. Proc. N.Z. Soc. Anim. Prod. 34:82.

Rogers, G.L., Porter, R.H.D. and Robinson, I. 1979. Res. Rpt. Dairy Res. Inst., Ellinbank, Victoria, p. 59.

Rogers, G.L., Porter, R.H.D., Clarke, T. and Stewart, J.A. 1980. Aust. J. Agric. Res. 31:1147.

Rogers, G.L., Robinson, I. and Porter, R.H.D. 1980a. Res. Rpt. Dairy Res. Inst., Ellinbank Victoria, p. 54.

Siddons, R.C., Evans, R.T. and Beever, D.E. 1979. Brit. J. Nutr. 42:535.

Symmonds, H.L., Mather, D.L. and Collis, K.A. 1981. Brit. J. Nutr. 46:481.

Thomas, C., Aston, K., Tayler, J.C. and Daley, S.R. 1978. 5th Int. Sil. Symp. p. 42.

Thomas, C., Gibb, B.R., Thurnham, B. and Beever, D.E. 1984. Anim. Prod. (in press).

Thomas, P.C., Kelly, N.C. and Chamberlain, D.G. 1980a. Proc. Nutr. Soc. 39:257.

Thomas, P.C., Chamberlain, D.G., Kelly, N.C. and Wait, M.K. 1980b. Brit. J. Nutr. 43:469.

Thomson, D.J., Beever, D.E., Harrison, D.G., Hill, I.W. and Osbourn, D.F. 1971. Proc. Nutr. Soc. 30:14A.

Thomson, D.J. and Beever, D.E. 1980. In 'Digestive Physiology and Metabolism in the Ruminant', p. 291. MTP Press, Lancaster.

Thomson, D.J., Beever, D.E., Lonsdale, C.R., Cammell, S.B., Austin, A.R. and Haines, M.J. 1982. Brit. J. Nutr.

Thomson, D.J., Beever, D.E., Austin, A.R., Siddons, R.C., Cammell, S.B., Haines, M.J., Evans, R.T. and Dhanoa, M.S. 1982. Anim. Prod. 36:5A

Waldo, D.R. 1975. J. Anim. Sci. 41:42A.

Wilkinson, J.M., Wilson, R.F. and Barry, T.N. 1976. Outlook in Agriculture. 9:3.

Ulyatt, M.J. 1971. N.Z. J. Agric. Res. 14:352.

Ulyatt, M.J. and MacRae, J.C. 1974. J. Agric. Sci. (Camb.) 82:295.

Ulyatt, M.J., MacRae, J.C., Clarke, R.T.J. and Pearce, P.D. 1975. J. Agric. Sci. (Camb.) 84:453.

Ulyatt, M.J. and Egan, A.R. 1979. J. Agric. Sci. (Camb.) 92:605.

Ulyatt, M.J., Beever, D.E., Thomson, D.J., Evans, R.T. and Haines, M.J. 1980. Proc. Nutr. Soc. 39:67A.

Table 1 Aspects of organic matter and nitrogen digestion in mature sheep fed frozen (to represent fresh) and fresh perennial ryegrass

Expt. No.	Diet	INTAKE (g/d) OF:		APPARENT DIGESTIBILITY OF :		DUODENAL N :		ABSORBED N :		Ref.
		OM	N	OM	N	g/d	g/g N intake	g/d	g/g N intake	
1	S24 PRG† (frozen)	820	25.6	0.70	0.75	25.0	0.97	15.5	0.61	Beever et al. 1971 Proud 1972
2	S24 PRG (frozen)	820	25.5	0.78	0.77	21.6	0.85	13.5	0.53	Beever et al. 1976
3	S23 PRG (fresh)	675	20.7	ND	ND	18.7	0.90	12.7	0.61	Beever et al. 1974

† Perennial ryegrass

ND = Not Determined

Table 2 The *in vitro* and *in vivo* digestion characteristics of sainfoin (S), red clover (R) and two mixtures fed fresh to mature sheep

Diet	S	SR	RS	R
Forage content (% DM)				
Sainfoin	100	40	20	
Red clover		60	80	100
Dietary characteristics (g/100 g DM)				
Total nitrogen	3.4	3.7	3.8	3.8
Rumen liquor TCA soluble N	1.2	1.8	2.1	2.2
Buffer soluble N	0.8	1.1	1.4	1.5
In vitro observations				
Proteolytic activity*	7.8	10.0	9.5	10.4
Deaminative activity**	4.1	5.3	5.0	4.7
In vivo observations				
Duodenal amino acid (AA) flow (g/g AA intake)	0.83	0.65	0.75	0.67
Microbial AA synthesis :				
g/g degraded AA	0.61	0.44	0.51	0.44
g/kg OMADR	27	22	26	21

* mg casein N solubilized/ml rumen liquor

** mg NH_3-N produced/ml rumen liquor

Table 3 Flow of organic matter and non ammonia nitrogen to the small intestine of cattle grazing ryegrass or white clover, and NAN flow per unit of Metabolizable Energy intake

Diet	Month	Nutrient flow to small intestine		
		Organic matter (g/kg lwt)	Non ammonia nitrogen (g/kg lwt)	NAN*/ME† (g/MJ)
Ryegrass				
Primary growth	May	13.0	0.93	2.25
Early regrowth	Early June	10.2	0.69	2.19
Mid season regrowth	Late June	9.9	0.65	2.52
White Clover				
Late primary growth	July	13.3	0.75	3.18
Mid season regrowth	August	13.1	0.80	3.24

† Calculated assuming 15.4 MJ.ME/kg DOMI

* NAN = Non ammonia nitrogen

Table 4 Estimated organic matter intakes (kg/100 kg body weight) of grass and white clover offered at 3 and 6 kg DM/100 kg body weight/d to growing cattle

	Perennial ryegrass			White clover	
DM allowance (kg/100 kg body wt)	3	6		3	6
Date			Date		
May 13	1.33	1.59	June 3	2.56	2.58
May 21	1.81	1.99	June 17*	2.19	2.97
May 29	2.07	2.31	July 14*	2.61	2.62
June 10*	2.12	2.32	July 27*	2.79	3.23
June 25*	2.13	2.34	Aug. 10*	2.66	2.48
July 7*	2.28	2.28	Aug. 16*	2.14	2.42

* Indicates 4 week regrowth - all other crops primary growths.

Table 5 The ruminal digestion of perennial ryegrass and white clover fed to growing cattle at a rate of 2.2 kg DM/100 kg body weight

	Perennial ryegrass			White clover		
Stage of harvest	Early	Mid	Late	Early	Mid	Late
Mean ruminal NH_3 concentration mg NH_3-N/100 ml	4.4	7.0	21.7	27.8	33.6	60.4
Ruminal acids (molar %s)						
Acetate	68	69	68	69	70	68
Propionate	21	21	20	18	17	18
Butyrate	11	10	12	13	13	14
Fractional outflow rate of water (h^{-1})	2.8	3.2	4.1	2.3	3.3	2.1
Rumen volume (litres/100 kg body wt)	12.5	7.1	13.4	15.8	16.2	11.4

Table 6 The digestion of organic matter and nitrogen of perennial ryegrass and white clover by growing cattle fed at a rate of 2.2 kg DM/100 kg body weight

	Perennial ryegrass			White clover		
Stage of harvest	Early	Mid	Late	Early	Mid	Late
OM digestibility	0.82	0.81	0.81	0.83	0.76	0.80
Ruminal digestion of OM (g digested/g digestible OM intake)	0.65	0.67	0.65	0.48	0.43	0.46
NAN flow/N intake (g/g)	1.36	1.28	0.95	0.94	0.83	0.88
Microbial N synthesis						
a) g/kg OMADR	49.0	43.7	43.8	82.1	89.2	77.5
b) g/kg OMTDR*	32.9	30.4	30.4	45.1	47.1	43.7
Feed N degradability (g/g N intake)	0.88	0.85	0.87	0.81	0.85	0.81

* OMTDR = OM truly digested in the rumen assuming 1 g microbial N = 10 g microbial OM (Siddons, pers. comm.).

Table 7 The effect of monensin addition to or formaldehyde application on three fresh forages fed to growing cattle

	Perennial Ryegrass			White Clover					
	Primary growth			Primary growth			Regrowth		
Total N content (mg/g DM)	24.2			41.2			40.1		
Mean N intake (g/d)	119			237			257		
	C	M	F	C	M	F	C	M	F
Mean rumen NH_3 conc'n. (mg NH_3-N/100 ml)	18.6	14.8	14.1	41.6	36.6	29.1	44.9	41.8	22.9
OM digestion / OM intake (g/g)	0.54	0.54	0.51	0.51	0.49	0.45	0.48	0.46	0.37
NAN flow / N intake (g/g)	0.84	0.91	1.0	0.71	0.74	0.84	0.67	0.70	0.89
Total NAN flow (g/d)	100	108	119	169	172	199	174	181	228
Microbial N synthesis									
a) total (g/d)	ND	ND	ND	119	126	142	113	110	148
b) efficiency (g/kg OMTDR)	ND	ND	ND	31.2	33.8	38.4	29.6	29.6	41.5
Feed N degradability (g/g N intake)	ND	ND	ND	0.87	0.88	0.86	0.84	0.80	0.79

ND = Not Determined; C = Control; M = Monensin; F = Formaldehyde

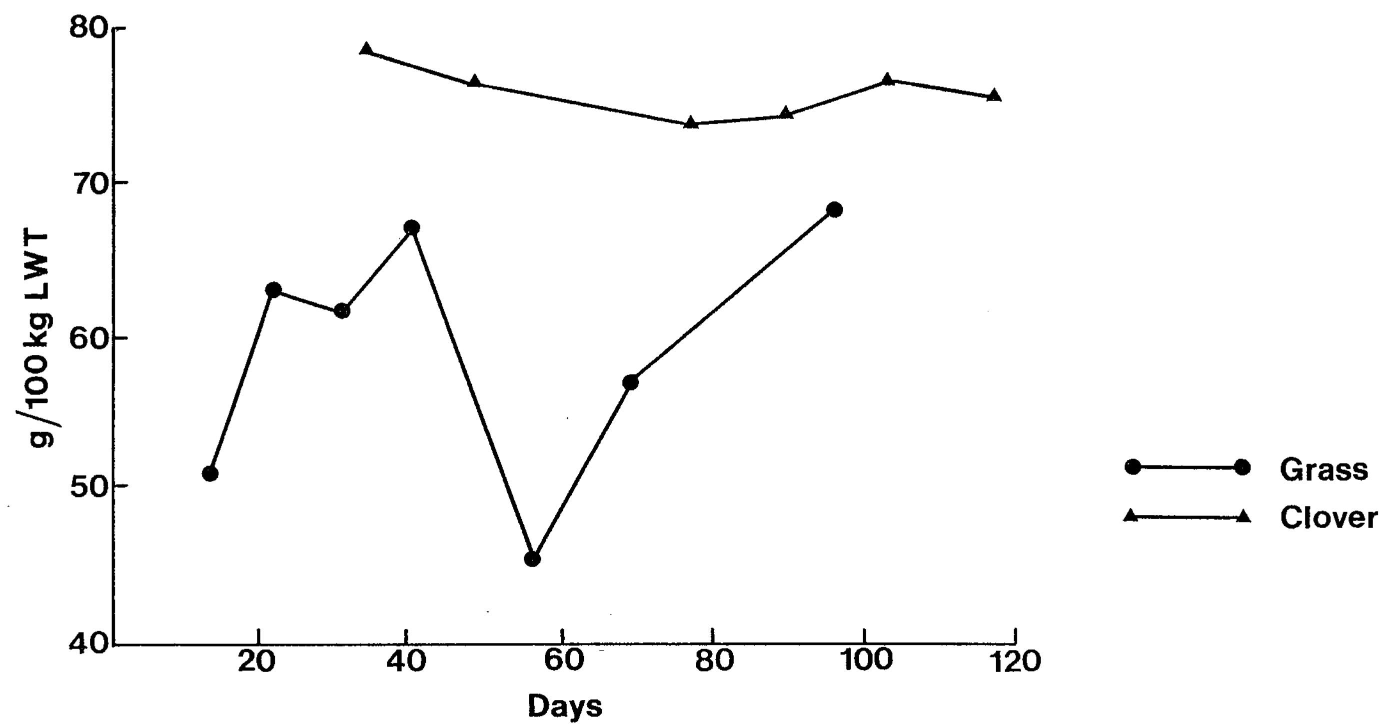
Table 8 Relationship between observed live-weight gains of lambs grazing perennial ryegrass (R), short rotational ryegrass (M) and white clover (C) and quantitative estimates of the end products of carbohydrate and protein digestion (after MacRae & Ulyatt, 1974).

	Experiment 1			Experiment 2			Correlation with live-weight gain
	R	M	C	R	M	C	
Live-weight gain (kg/d)	0.23	0.27	0.33	0.16	0.24	0.25	
Estimated VFA absorbed from rumen and large intestine (MJ/d)	10.2	8.6	9.9	9.4	10.3	9.1	0.02
Protein absorbed (NAN x 6.25) from small intestine (g/d)	119	175	188	113	188	163	0.79
Absorbed protein energy / Absorbed total energy	0.22	0.32	0.31	0.22	0.30	0.30	

Table 9 Duodenal amino acid-N flow and small intestinal amino acid-N absorption in sheep fed perennial ryegrass in three contrasting forms (all units of AA-N/g total N intake)

	Fresh Grass	Wilted Silage	Unwilted Silage
Duodenal AA-N flow	0.63	0.47	0.54
Small intestinal AA-N absorption	0.41	0.31	0.41

Fig. 1. Non-ammonia-nitrogen flow (per 100 kg LW) for the animals grazing ryegrass or white clover.



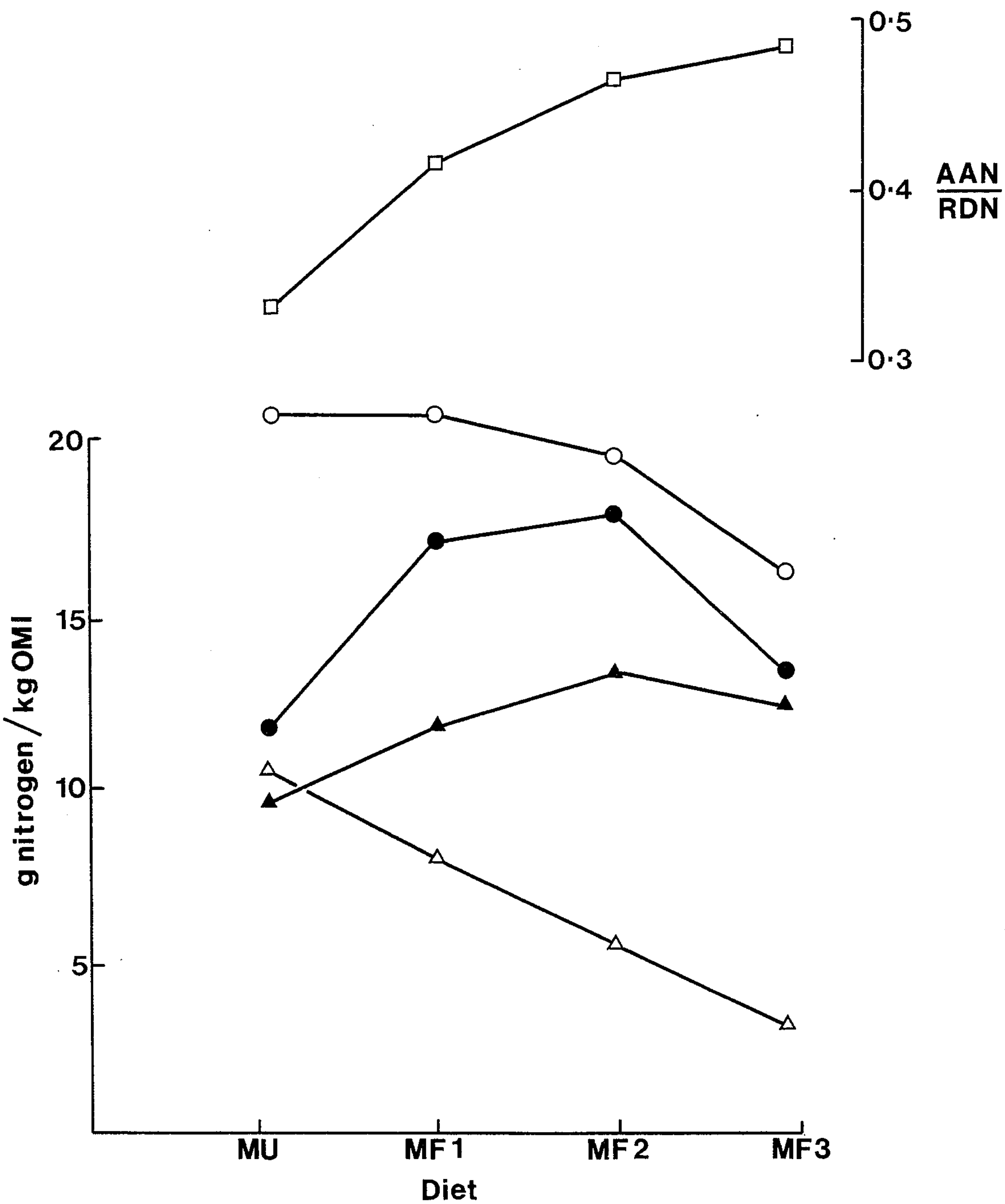


Fig. 2. The quantities of rumen-degradable nitrogen (RDN) (○—○) derived from urea (△—△) and degraded dietary protein (▲—▲) the proportion of RDN present in the form of α-amino acid-nitrogen (AAN) (□—□) and the effect of these on microbial-N synthesis (●—●) for the four low-energy diets (MU, MF1, MF2, and MF3.

Mineral composition of wheat forage as related to metabolic disorders of ruminants.[1]

D.L. Grunes, D.P. Hutcheson, F.P. Horn, B.A. Stewart, and D.J. Undersander[2]

SUMMARY

The literature is reviewed concerning the causes of some metabolic disorders of cattle grazing small grain forages. Some additional original data is also presented concerning the chemical composition of wheat pasture forage, and of the blood of animals grazing these pastures.

For older lactating or pregnant cattle, the problem forages generally occur in years when moisture levels are adequate for good plant growth. The problem forages are generally high in N, K, and organic acids, low or medium in Mg or Ca, and high in the ratio of K/(Ca + Mg). The percent dry matter is often low. The cattle are often severely hypocalcemic, and may also be hypomagnesemic. Death can occur quite rapidly.

The same forages frequently cause deaths of younger grazing stocker cattle due to frothy or gaseous bloat. These cattle often have low values of Ca in the blood, but Mg is usually normal. Nitrate toxicity does not appear to be a frequent problem.

INTRODUCTION

There have been a number of metabolic disorders of cattle grazing wheat forage. These include grass tetany and wheat pasture tetany of older lactating or pregnant beef cattle, frothy or gaseous bloat of younger animals (stocker steers), and nitrate toxicity of both mature and younger cattle (Bohman et al., 1983a,b; Clay, 1973; Clay et al., 1972; Horn, 1983.).

There have been several reviews of the grass tetany problem (Grunes et al., 1970; Grunes, 1973; Mayland and Grunes, 1979; Rendig, and Grunes (ed.) 1979; Whitaker, 1983). Grass tetany is a Mg deficiency disease which affects cattle and, less often, sheep. Older, lactating cattle are especially susceptible, in which case there is a high demand for Mg in the milk. Sometimes the disease occurs in pregnant cattle. Losses of grazing beef cattle have been appreciable in many parts of the U.S. The disease occurs most frequently in cool, wet springs, and can be related to plant composition. There may also be effects of climate on

1 Cooperative investigation, USDA-ARS, and Texas A&M University.
2 Soil scientist USDA-ARS, U.S. Plant, Soil and Nutrition Laboratory, Ithaca, NY; professor of ruminant nutrition, Texas A&M University, Amarillo, TX; Animal scientist, Southwestern Livestock and Forage Res. Stn., El Reno, OK; Soil scientist, Conservation and Production Research Laboratory, Bushland, TX; and Assistant professor of forage crops, Texas A&M University, Amarillo, TX.

the cattle.

Grass tetany occurs most frequently shortly after cattle graze rapidly growing grass or small grain pastures. It is accentuated by high N and high K in the forage. If forage concentrations of both Mg and Ca are low, the animals are more likely to get grass tetany. (Grunes et al., 1970).

When the Mg concentration in plants is 0.05-0.10% Mg, growth is generally decreased. To prevent grass tetany, about 0.20% Mg in the forage is considered safe unless the K and N in the plants are very high, in which case 0.25% Mg is better. Forages containing more than 3% K or 4% N are especially likely to cause grass tetany.

The National Research Council (1976) and Perry (1980) recommended 0.28% Ca and 0.28% P (on a dry weight basis) in the diet of 450 kg beef cows, nursing calves, when the cow is average in milking ability. For the same weight cow, of superior milking ability, they recommended 0.40% Ca and 0.37% P. Grunes (1983) quoted research by Kemp (1971) in the Netherlands as recommending a level of 0.10-0.15% Na in the forage for grazing cattle. Salt supplements can also supply appreciable Na.

Recommendations by the National Research Council (1976) and Perry (1980) for growing finishing calves and yearlings were as follows, on a dry weight basis, in the diet: for 150 kg animals, gaining 0.7 kg/day, 0.46% Ca and 0.36% P; for 200 kg animals, gaining 0.7 kg/day, 0.32% Ca and 0.28% P; for 200 kg animals, gaining 0.9 kg/day, 0.47% Ca and 0.37% P.

REVIEW OF LITERATURE AND DISCUSSION OF DATA

Mayland et al. (1976) indicated that wheat forage is low in Mg and Ca, often high in N and K, and would therefore be expected to be a tetany hazard for grazing lactating or pregnant cattle. Cummins et al., (1975) studied the composition of small grain forages sampled in Georgia. They indicated that wheat forage was low in Mg and Ca, and high in K and in the K/(Ca + Mg) ratio. Grunes (1983) reviewed the composition of a number of small grain and grass forages and also concluded that grazing wheat forage could be hazardous for cattle because of the low Mg and Ca, and the high N and K.

Concentrations of K, Ca, and Mg in wheat forages from Kansas where grass tetany occurred are listed in Table 1. These forages were low in Mg, medium in Ca, high in K, and have high K/(Ca + Mg) ratios. When this ratio is 2.2 or higher, the incidence of grass tetany has generally increased (Grunes et al., 1970). Other research from Kansas (Karlen et al., 1978; Karlen et al., 1980b) has indicated that high levels of soil moisture decreased Ca and Mg in wheat forage, while increasing the K/(Ca + Mg) ratios.

---

[1] Mention of a trade name does not constitute a recommendation for use by the USDA or Texas A&M University.

In a greenhouse study with wheat forage in Texas (Mathers et al., 1982), it was shown that the addition of the nitrification inhibitor nitrapyrin (N-serve[1]) inhibited nitrification of added NH_4-N. The plants also had lower concentrations of K, Ca, and Mg. However, the depressing effect was greater for the divalent cations, Ca and Mg, than for the monovalent cation, K, so the K/(Ca + Mg) ratio was increased. Therefore, when nitrapyrin is added, the forage may become more likely to cause grass tetany.

Stewart et al. (1981) sampled wheat forages in Bushland, Texas and El Reno, OK, for a 3 year period. Data are shown in Fig. 1 and Fig. 2. At Bushland, Texas, the forage was sampled almost weekly from 18 October to 11 May so that changes in forage quality could be related to climatic and other environmental conditions (Fig. 1). The N and K contents of the forage were very high in October, decreased until about early December, and remained fairy constant through mid-February. The sudden and sharp decline about the middle of November seemed to be related to a sudden drop in temperature. The N and K contents increased rapidly around the middle of February, corresponding to an increase in temperature. They increased until late February or early March and then decreased gradually as growth accelerated. The Mg content of the forage gradually decreased throughout the season and showed little, if any, change that could be attributed to temperature. The Ca data was somewhat variable, and no consistent trends were evident. There was a pronounced increase in the K/(Ca + Mg) ratios in February as a result of the increased K content. The ash alkalinity and aconitate values also increased rapidly during this period.

Cattle did not graze the field during the sampling period, so the yield data shown represent total accumulated forage. There was very little fall growth and only small amounts of precipitation occurred during the winter. Significant growth did not begin until March, but the big increase in N and K concentrations occurred 2 to 3 weeks earlier.

As seen in Fig. 2, at El Reno, OK, the N and K concentrations in the forage were high (in the 3.5 to 4.0 percentage range). Nitrogen, K, and Ca concentrations decreased with decreasing average temperature. The winter was exceptionally wet and cold so no forage was sampled from 12 January to 14 March. With the rapid rise in average temperature in the spring, both the quality and quantity of the forage increased dramatically. A topdressing of 50 kg of N/ha as NH_4NO_3 was added to a part of the field on 13 March so that the effect of N on forage composition could be determined.

The growing conditions during late March and April were almost ideal, since soil water and air temperatures were favorable. Between 13 March and 4 April, the N and K content of the forage increased suddenly. The K content increased from 2 to more than 4.5 within 2 weeks. Because the Mg and Ca concentrations changed very little, the K/(Ca + Mg) ratio increased markedly. The average temperature was also increasing sharply during this time. Yield, however, did not increase until after the 27 March sampling. This gain showed that growth lagged several days behind the plants' rapid uptake of nutrients and water in the spring. The dry matter percentages shown in Fig. 2 show a sharp decrease as the nutrient concentrations increased. This shows that the plants took up water and nutrients simultaneously. As the yield increases became very significant, the concentration of all nutrients measured decreased due to dilution effect. The yields shown in figure 2 are for grazed areas. Cages were moved to a grazed area immediately after each sampling, so that samples would represent material available to livestock.

Phosphorus concentrations tended to parallel Ca concentrations at both locations (Fig. 1 and Fig. 2). Calcium was generally higher at Bushland, and P generally higher at El Reno. When one compares the Ca and P concentrations in the wheat forage in this study with the previously mentioned recommendations of the National Research Council (1976) and of Perry (1980), the concentrations were low or minimal, at least for rapidly growing young stocker cattle and for lactating cows.

Nonstructural carbohydrates are sources of readily available energy that enhance rumen microbial activity and forage utilization. Changes in total nonstructural carbohydrates (TNC) concentrations with time in several plant species have been discussed by Jung et al. (1974, 1976). Those authors indicated that carbohydrate concentrations were considerably lower in N-fertilized herbage than in unfertilized controls during flower-stem elongation, but N had little effect on TNC concentrations at full bloom.

Mayland and Grunes (1979) discussed the value of carbohydrates in decreasing grass tetany and in increasing Mg availability to ruminants. They also discussed the detrimental effect of high N/carbohydrate ratios. Mayland et al. (1974) found that when the ratio of N to total water soluble carbohydrates (TWSC) increased rapidly, and was 0.4 and higher, the incidence of grass tetany increased markedly. The plant samples from Bushland and El Reno were analyzed for TNC instead of TWSC. The values for TNC are probably about 10% higher than those for TWSC, so that a N/TNC ratio of 0.36 would be equivalent to an N/NWSC ratio of 0.40.

At Bushland, the TNC values were highest in the fall, and decreased later on (Fig. 1). The N/TNC ratio was 0.37 on 4 March, when N was high and TNC was low. At El Reno, the TNC also increased in April, but the highest value for N/TNC also increased in April, but the highest value for N/TNC (0.63) was obtained on 14 March (Fig. 2). Fertilization with N decreased TNC concentrations.

The dry matter percentages were obtained only for El Reno samples (Fig. 2). The data suggest that dry matter could serve as an indicator for predicting the occurrence of grass tetany where the K and Mg status of the soil would lead to high values for K and low values for Mg in the forage. The K/(Ca + Mg) ratios were always highest when the dry matter percentages were lowest. The dry matter percentages also changed simultaneously with the changes noted in K and N concentrations. These findings are not surprising because conditions that lead to lush forage are the same as those that lead to high concentations of these soluble nutrients when nutrient supply is adequate. The amounts and ratios of various nutrients in plants depend on the inherent fertility of the soil and on the fertilizer applied, as well as on the temperature and soil moisture levels (Mayland and Grunes, 1979).

Bohman, et al. (1983b) conducted a grazing study with mature beef cows on a wheat-rye forage in Oklahoma. On the 105th day (March 19) after grazing was started, 5 of the 32 head of cattle developed grass tetany. At tetany, the forage K, N, digestibility, ash alkalinity, aconitic acid and total lipids increased suddenly and markedly. Forage dry matter and total non-structural carbohydrates (TNC) decreased. Forage Ca and Mg contents were slightly below or equal to the animals' requirements, and remained relatively constant during the period of tetany. The level of forage Na did not appear to be related to the incidence of tetany. The N:TNC ratio was high, as well as the K/(Ca + Mg) ratio.

The paper by Bohman, et al., (1983a) contains animal tissue analyses for the cattle grazing the mixed wheat-rye forage mentioned in the paper by Bohman, et al. (1983b). Cows with tetany had low levels of plasma Ca, and some had low levels of Mg.

Pearson et al. (1949) indicated that the most consistent biochemical lesions of cattle, with grass tetany and grazing winter wheat, were hypocalcemia and hypomagnesemia. The serum Ca often dropped from a normal of 11.0 mg/dl to 7.0 mg/dl. The decrease in blood Mg values was less consistent and pronounced than the decrease in Ca values.

Horn (1983) reviewed earlier research on wheat pasture poisoning, which normally affects only mature cows nursing newborn calves, or in the late stages of pregnancy. He presented the unpublished work of the late G.P. Mayer who studied cows with wheat pasture poisoning in Oklahoma. Mayer had indicated that only 25% of the "downer" cows were severely hypomagnesemic, and 40% had serum Mg concentrations in the normal range. All of the "downer" cows were hypocalcemic, and 74% were severely hypocalcemic (less than 5 mg Ca/dl).

Littledike et al. (1983) compared blood plasma components of lactating beef cows with grass tetany syndrome (GTS) and wheat pasture poisoning (WPP). Cows with GTS had much lower levels of Mg. Severe hypocalcemia was seen in cows affected with either of these diseases, but the most severe hypocalcemia was evident in cows with WPP. Plasma P was similar in both groups, and was in the normal range.

The same wheat forages which cause death of older cows can cause frothy or gaseous bloat and death of stocker cattle, averaging 135-230 kg. Horn et al. (1977) found in the forage of bloat-producing pastures that dry matter and soluble carbohydrate values were low; and that crude protein, soluble protein N, and soluble nonprotein N values were high. Low dry matter and soluble carbohydrates, and high crude protein and nonprotein N have also been related to grass tetany. Horn et al. (1977) also found that bloat-producing pastures were lower in total fiber, but this constituent has not been related to grass tetany.

As indicated in the review by Clarke and Reid (1974), the relationship of minerals to the incidence of bloat is confusing and contradictory. However, mineral supplements high in Mg, and sometimes those high in Ca, are commonly sold as a means of reducing bloat of stocker cattle on wheat pasture. The effectiveness of these supplements has not been proven. A discussion of the relationship between grass tetany and bloat is presented by Stewart et al. (1981). Antifoaming agents have been used to control bloat (Bartley, 1967; Bartley et al., 1975).

In a study of causes of deaths of stocker cattle, Clay (1973) indicated that Ca in small grain forage was generally deficient, and P and Mg were also often deficient. The Ca levels in the blood serum dropped as grazing progressed in the spring. Clay (1973) also indicated that high water content of forage may help cause foam formation and bloat by inhibiting the flow of animal saliva. Horn et al. (1974) and Horn (1983) indicated that calves grazing wheat pasture, with only a plain salt supplement, had dangerously low serum Ca (4.9 to 6.7 mg/dl) but normal serum Mg levels (2.2 to 2.6 mg/dl).

Clay (1973) reported that there were only occasional cases where toxic levels of NO_3-N were found in the forage. He also found that blood methemoglobin values did not indicate that nitrate toxicity of stocker cattle was very likely. Horn (1983) indicated that deaths of stocker cattle sometimes occurred following spring topdressing of N fertilizer. However, he stated that methemoglobin levels in the blood of calves grazing wheat indicated that nitrate toxicity is usually not a serious problem. Clay (1973) mentioned that blood ammonia values reflect the high N content of the forage and may contribute to sudden deaths of animals. However Horn et al. (1977) did not find high plasma ammonia levels in steers grazing wheat pastures.

Problems with grazing stocker cattle can generally be expected to occur during periods of rapid growth of wheat forage, such as in the fall or in early spring. There is little information in the literature on measurements of minerals in both forage and blood, and therefore such data is presented in Tables 2 and 3. A description of the Pullman clay loam at Bushland, Texas is contained in Table 1 of Stewart et al. (1981). Tam 101 wheat was planted in rows on 1 meter centers on August 24, 1979 at the rate of 101 kg/ha. It was irrigated the first week in September, and again the second week in October. Prior to planting, anhydrous ammonia was applied to the pastures at the rate of 250 kg N/ha. The cattle were English crossbred stocker steers, averaging 9 months of age and 184 kg in weight. There were 7 animals per pasture on each of 2 pastures. Grazing started on November 7, 1979. All cattle were given a free choice commercial mineral mix[1]. The mineral mix contained 12.10% Mg, 0.58% K, 3.00% Ca, 2.18% P, and 10.71% crude protein. The mineral mix was formulated from the following ingredients: magnesium oxide, cottonseed meal, dehydrated alfalfa,

---

1 HS Wheat Pasture Mineral. Farr Better Feeds, Hereford, Texas. Mention of a trade name does not constitute a recommendation for use by the USDA or Texas A&M University.

rice bran, salt, dicalcium phosphate, bentonite, tallow, trace minerals, iron oxide and calcium carbonate.

The percent dry matter in the forage was low on 6 November, increased in January and February, and decreased again in March (Table 2). Had the pastures been irrigated during January or February, growth would almost certainly have been more rapid, and the percent dry matter would probably have decreased. The N and K concentrations were not overly high, and probably would have been higher had the pastures been irrigated in January or February. The present authors believe that wheat forage levels of 0.2% P and 0.1% Mg should generally be adequate for stocker cattle. These are much lower than the earlier mentioned recommended values for mature grazing cattle which are either pregnant or lactating. The P values were a little low in January and February. The Mg values were believed to be adequate. The Ca values were not very high. The K/(Ca + Mg) ratio was high from 15 January to 18 March. As indicated earlier, for mature grazing cattle, K/(Ca + Mg) ratios of 2.2 or higher would indicate a danger of grass tetany, but information is not available concerning the importance of this ratio for stocker cattle.

Clay (1973) indicated that, for stocker cattle, normal values in the blood serum were 15-23 mg K/dl. It is not known why the K values in the blood serum shown in Table 3 are lower. It is true that the K concentrations in small grain forages reported by Clay (1973) are a little higher than those shown in Table 2. There was very little total forage available for grazing during January and February and this may be part of the reason why the serum K values shown in Table 3 are low. The K in the whole blood did increase after the calves began grazing wheat pasture in 1980. As indicated in Table 3, the red blood cell K was calculated, using the whole blood K and the packed cell volumes. The red blood cell K was higher in February and March than it had been earlier.

The Mg levels shown in Table 3 are higher than the values of 1.8-2.3 mg Mg/dl listed as normal by Clay (1973). The 12.10% Mg in the mineral mix may have been partly responsible for the higher Mg values in the present studies.

The Ca values shown in Table 3 are much lower than the 9.7 to 12.4 mg Ca/dl listed as normal by Clay (1973). However, Horn et al. (1974) and Horn (1983) indicated that in a study in Oklahoma, with calves grazing wheat pasture wth a plain salt supplement, the blood serum Ca was dangerously low (4.9 to 6.7 mg Ca/dl). The values in Table 3 showed minimums of 4.3 and 4.4 mg Ca/dl. The Na values in Table 3 agree with those that one of the authors (D.P. Hutcheson) has previously observed for normal grazing stocker steers.

CONCLUSIONS

Wheat pasture poisoning can occur with older lactating or pregnant beef cows grazing wheat pastures. When the plants start to grow rapidly early in the year, the forage concentrations are often high in N, K, and organic acids, and low or medium in Mg and Ca. Forage ratios of K/(Ca + Mg) are often high at the times problems occur with the animals. The forage is often quite lush, and the percent dry matter decreases to a low value. Animal problems are more likely to occur in a year with adequate rainfall than when moisture severely limits growth. High moisture tends to decrease Mg and Ca concentrations in the forage, relative to the concentration of K. It is possible that high soil levels of NH_4-N decrease the absorption of Mg and Ca. The animals with wheat pasture poisoning are often severely hypocalcemic, and may also be hypomagnesemic. Death can occur rapidly.

The same forages which cause death of older cattle can also cause frothy or gaseous bloat and death of younger stocker cattle. The bloat-provocative forages were found to be high in total N, soluble protein N, and soluble nonprotein N. Dry matter, soluble carbohydrates, and total fiber were low. Grazing stocker cattle often have low levels of Ca in the blood, but blood Mg is often normal. Nitrate toxicity does not appear to be a frequent problem.

AREAS OF NEEDED RESEARCH

Research is needed on the effect of levels of soil moisture, soil and air temperature, source and rate of N fertilization, and rate of K fertilization on the chemical composition of wheat and other small grain forages. Most ideally, grazing studies with pregnant or nursing beef cattle, as well as with younger stocker cattle should be carried out under the same conditions.

Fundamental studies on the causes of frothy and gaseous bloat of stocker steers are needed, including the effects of plant constituents, N and K fertilization, soil moisture, soil and air temperature, Ca and Mg levels in forage and feed supplements, and plant species.

LITERATURE CITED

Bartley, E.E. 1967. Progress in bloat prevention. Agric. Sci. Rev. 5(1):5-12, 36.

Bartley, E.E., G.W. Barr, and R. Mickelsen. 1975. Bloat in cattle. XVII. Wheat pasture bloat and its prevention with poloxalene. J. Anim. Sci. 41:752-759.

Bohman, V.R., F.P. Horn, E.T. Littledike, J.F. Hurst and D. Griffin. 1983a. Wheat pasture poisoning. II. Tissue composition of cattle grazing cereal forages and related to tetany. J. Anim. Sci. 57:1364-1373.

Bohman, V.R., F.P. Horn, B.A. Stewart, A.C. Mathers, and D.L. Grunes. 1983b. Wheat pasture poisoning. I. An evaluation of cereal pastures as related to tetany in beef cows. J. Anim. Sci. 57:1352-1363.

Clarke, R.T.J., and C.S.W. Reid. 1974. Foamy bloat of cattle. A review. J. Dairy Sci. 57:753-785.

Clay, B.R. 1973. Stocker cattle losses on small grain pastures. J. Oklahoma Vet. Med. Assoc. 25(4):15-20.

Clay, B.R., G. Hoehne, and A.D. Tillman. 1972. Animal problems in grazing wheat and other small grains pasture. Oklahoma State Univ. Extension Facts 3007:3007-3007.3

Cummins, D.G., M.J. Bitzer, and L.R. Nelson. 1975. Macronutrient variation in small grain forage as related to specie and variety. Commun. in Soil Sci. and Plant Analysis 6:599-607.

Grunes, D.L. 1973. Grass tetany of cattle and sheep. p. 113-140. In A.G. Matches (ed.) Anti-quality components of forages. Crop Sci. Soc. Am., Madison, WI.

Grunes, D.L. 1983. Uptake of magnesium by different plant species. p. 23-38. In J.P. Fontenot, G.E. Bunce, K.E. Webb, Jr., and V.G. Allen. Role of magnesium in animal nutrition. Proc. John Lee Pratt Int. Symp. on the Role of Magnesium in Anim. Nutrition. Virginia Polytechnic Inst. Press, Blacksburg, VA.

Grunes, D.L., P.R. Stout, and J.R. Brownell. 1970. Grass tetany of ruminants. Adv. Agron. 22:331-374.

Horn, F.P. 1983. Metabolic disorders of cattle grazing wheat pasture. p. 211-219. In J.P. Fontenot, G.E. Bunce, K.E. Webb, Jr., and V.G. Allen. Role of magnesium in animal nutrition. Proc. John Lee Pratt Int. Symp. on the Role of Magnesium in Anim. Nutrition. Virginia Polytechnic Institute Press, Blacksburg, VA.

Horn, F.P., G.W. Horn, and H.R. Crookshank. 1977. Effect of short-term fasting and refeeding on weight and blood components of steers grazing wheat pasture. J. Anim. Sci. 44:288-294.

Horn, F.P., D.G. Wagner, R.R. Oltjen, T. Rumsey, and A.D. Tillman. 1974. Observations on the preconditioning effect of wheat pasture, its nutritive value and the health of grazing steers. Okl. Agric. Exp. Stn Rep. MP-92:7-18.

Horn, G.W., B.R. Clay, and L.I. Croy. 1977. Wheat pasture bloat of stockers. 1977. Oklahoma Agric. Exp. Stn. MP-101:26-31.

Jung, G.A., R.E. Kocher, C.F. Gross, C.C. Berg, and O.L. Bennett. 1974. Seasonal fluctuations of nonstructural carbohydrate concentration in the forage of cool-season grassses. Grassland Utilization Sec. Proc. 12th Int. Grassl. Congr. Moscow, USSR. p. 285-293.

Jung, G.A., R.E. Kocher, C.F. Gross, C.C. Berg, and O.L. Bennett. 1976. Nonstructural carbohydrate in the spring herbage of temperate grasses. Crop Sci. 16:353-359.

Karlen, D.L., R. Ellis, Jr., D.A. Whitney, and D.L. Grunes. 1978. Influence of soil moisture and plant cultivar on cation uptake by wheat with respect to grass tetany. Agron. J. 70:918-921.

Karlen, D.L., R. Ellis, Jr., D.A. Whitney, and D.L. Grunes. 1980a. Soil and plant parameters associated with grass tetany of cattle in Kansas. Agron. J. 72:61-65.

Karlen, D.L., R. Ellis, Jr., D.A. Whitney, and D.L. Grunes. 1980b. Influence of soil moisture on soil solution cation concentrations and the tetany potential of wheat forage. Agron. J. 72:73-78.

Kemp, A. 1971. The effects of K and N dressings on the mineral supply of grazing animals. In Potassium and systems of grassland farming. Potassium Inst., 1st Colloq., Proc. (Henley-on Thames, England). p. 1-14.

Littledike, E.T., J.A. Stuedemann, S.R. Wilkinson, and R.L. Horst. 1983. Grass tetany syndrome. p. 173-195. In J.P. Fontenot, G.E. Bunce, K.E. Webb, Jr., and V.G. Allen. Role of magnesium in animal nutrition. Proc. John Lee Pratt Int. Symp. on the Role of Magnesium in Anim. Nutrition. Virginia Polytechnic Institute Press, Blacksburg, VA.

Mathers, A.C., B.A. Stewart, and D.L. Grunes. 1982. Effect of a nitrification inhibitor on the K, Ca, and Mg composition of winter wheat forage. Agron. J. 74:569-573.

Mayland, H.F., and D.L. Grunes. 1979. Soil-climate-plant relationship in the etiology of grass tetany. p. 123-175. In V.V. Rendig and D.L. Grunes (ed.) Grass tetany. Spec. Pub. No. 35, ASA, Madison, WI.

Mayland, H.F., D.L. Grunes, and V.A. Lazar. 1976. Grass tetany hazard of cereal forages based upon chemical composition. Agron. J. 68:665-667.

Mayland, H.F., D.L. Grunes, and D.M. Stuart. 1974. Chemical composition of *Agropyron desertorum* as related to grass tetany. Agron. J. 66:441-446.

National Research Council. 1976. Nutrient requirements of domestic animals. No. 4. Nutrient requirements of beef cattle. 5th Revised edition. Natl. Acad. Sci., Washington, D.C.

Pearson, P.B., J.A. Gray, and R. Reiser. 1949. The calcium, magnesium, and potassium contents of the serum of ewes fed high levels of potassium. J. Anim. Sci. 8:52-56.

Perry, T.W. 1980. Dietary nutrient allowances for growing and finishing beef cattle. Feedstuffs Reference Issue 52:41-47.

Rendig, V.V., and D.L. Grunes (ed.) 1979. Grass tetany. Spec. Pub. 35, Am. Soc. Agron., Madison, WI. 175p.

Stewart, B.A., D.L. Grunes, A.C. Mathers, and F.P. Horn. 1981. Chemical composition of winter wheat forage grown where grass tetany and bloat occur. Agron. J. 73:337-347.

Whitaker, D.A. 1983. Hypomagnesaemia in dairy cattle. Outlook on Agr. 12:77-82.

Table 1. Mineral concentrations in wheat forages from Kansas fields where grass tetany of beef cattle occurred.+

Location	Number of sites	K %	Ca %	Mg %	K/(Ca + Mg) meq. basis
Central	6	3.36	0.33	0.098	3.8
Northeast	3	3.79	0.42	0.102	3.3
North central	6	3.44	0.35	0.150	3.0

+ Adapted from Karlen et al. (1980a).

Table 2. Data for wheat forage grazed to steer stocker cattle on Pullman clay loam at Bushland, Texas.+

DATE	Dry matter %	N %	P %	K %	Ca %	Mg %	K/(Ca + Mg) meq. basis
11/6/79	22	3.81	0.20	2.00	0.16	0.17	1.4
1/3/80	40	3.04	0.15	1.40	0.23	0.18	1.2
1/15/80	37	3.23	0.14	2.03	0.17	0.15	2.5
2/19/80	44	3.38	0.12	1.91	0.20	0.12	2.5
3/18/80	31	4.05	0.22	1.98	0.20	0.12	2.6

+ Unpublished data of D.J. Undersander and D.P. Hutcheson.

Table 3. Average blood data for 14 steer stocker cattle grazed on Pullman clay loam at Bushland, Texas.[+]

	Concentrations in blood serum				Whole blood	Packed cell volume	Red blood cell
Date	K	Ca	Mg	Na	K	(PCV)	K[‡]
	mg/dl	mg/dl	mg/dl	mg/dl	mg/dl	%	mg/dl
11/7/79	14.90	6.2	3.78	336	18.4	33.1	25.5
1/4/80	14.90	4.3	3.40	297	23.5	40.9	35.9
2/6/80	8.80	6.4	2.98	294	26.1	41.1	50.9
2/21/80	8.99	4.4	4.12	304	25.0	39.5	49.5
3/20/80	10.80	5.0	4.99	329	23.5	39.2	43.2

[+] Unpublished data of D.J. Undersander and D.P. Hutcheson.

[‡] (mg K/dl of serum) x (1-%PCV/100) + UNK (PCV/100) = Whole blood K. UNK = mg/dl of RBC.

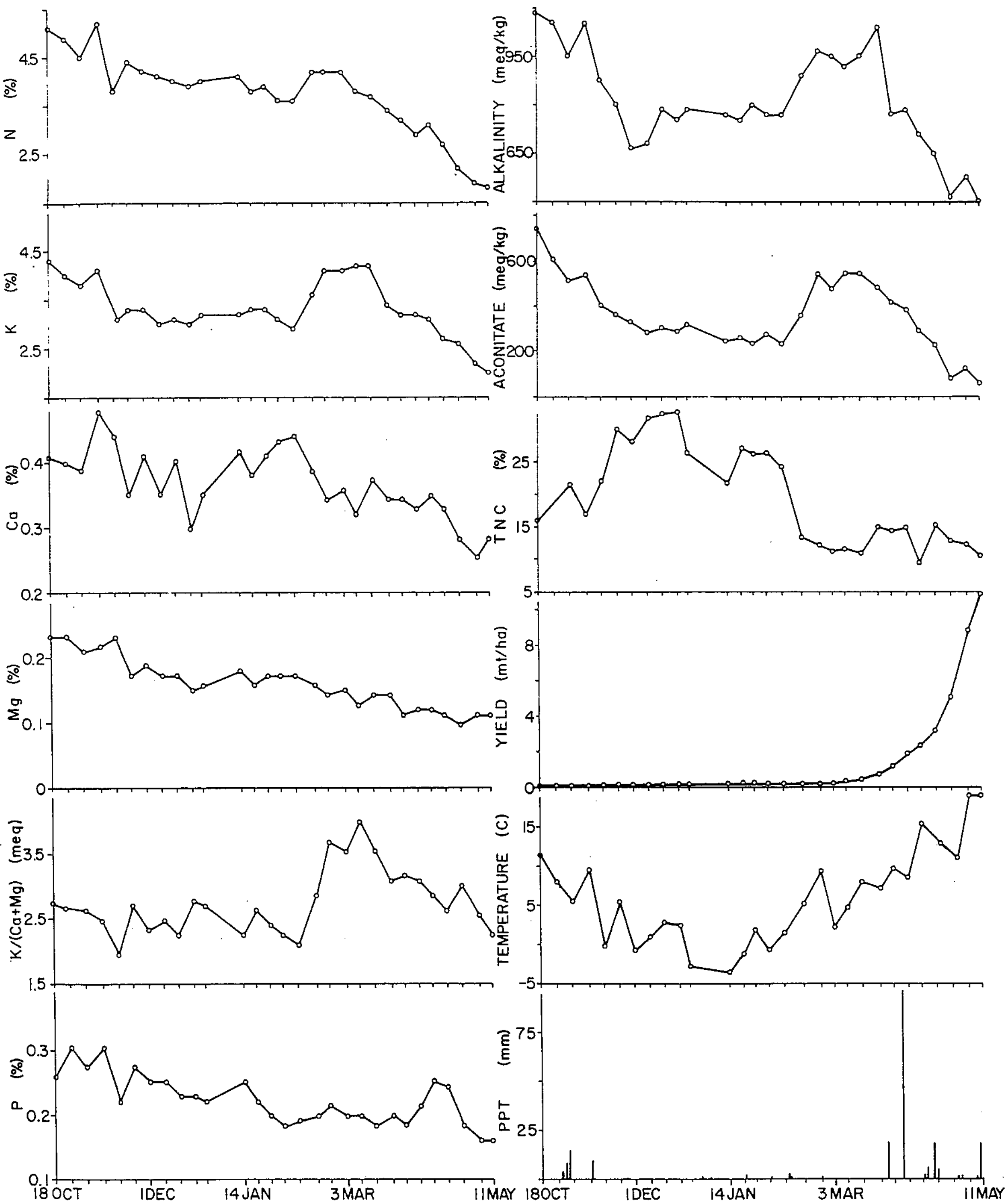


Fig. 1. Seasonal trends in the chemical composition of winter wheat forage at Bushland, TX, in 1976 to 1977. Precipitation and irrigation water and weekly mean air temperature values are also shown. Yields are cumulative. (TNC is total nonstructural carbohydrates.)

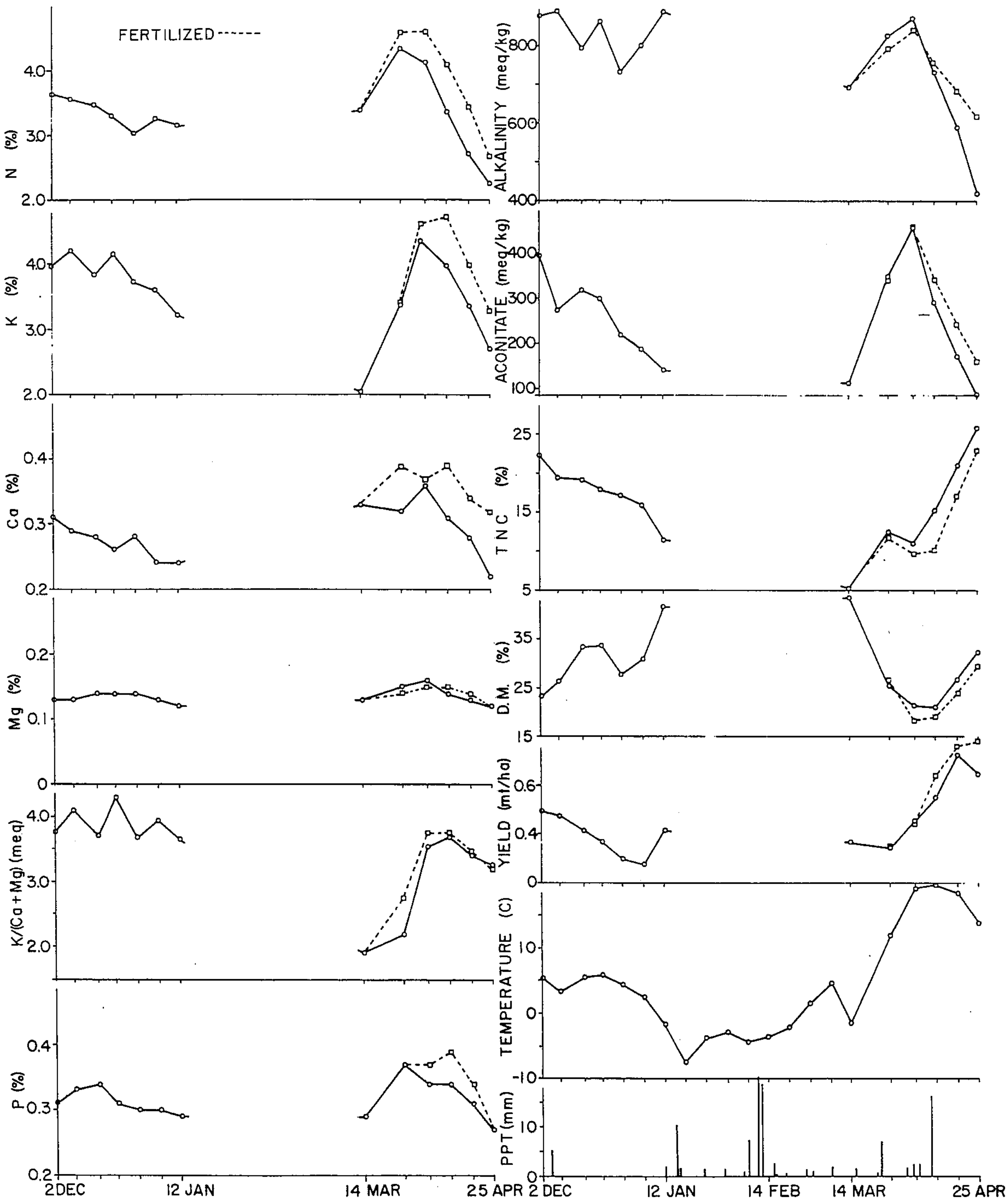


Fig. 2. Seasonal trends in the chemical composition of winter wheat forage at El Reno, OK, in 1977 to 1978 when fertilized at time of seeding (O——O), and additionally topdressed with 50 kg/ha NH_4NO_3 early in 1978 (□---□). Precipitation and weekly mean air temperature values are also shown. Yields are not cumulative. (TNC is total nonstructural carbohydrates.)

Role of Magnesium, Potassium and Calcium in Normal Neuromuscular Function in Ruminants

by

Dr. James E. Breazile[1]

Summary

The role of calcium, magnesium and potassium in normal neuromuscular function involves the regulation of membrane proteins (known as ionic channels, the electrical conduction of action potentials) the transmission of neural activity to skeletal muscle and finally the contraction and relaxation of skeletal muscle. The necessity for a concurrent control of energy metabolism to provide the energy needed for work performed is provided through the availability of magnesium for the activity of kinase enzymes, and the regulation of calcium through phosphorylation of enzyme systems to control energy availability for muscle contraction. These mechanisms are discussed, with an eye toward their involvement in neuromuscular abnormalities in disease.

Introduction

Nerve and skeletal muscle cells are excitable cells, in that they produce on their surface membranes, all-or-none changes in electrical potentials which are conducted throughout the length of their electrically excitable membranes. Skeletal muscle cells also demonstrate the property of contractility, through which the work of postural support and locomotion is carried out. The activity of skeletal muscle is totally dependent upon activity in the nerves which innervate them, and therefore represents the neural output of the central nervous system for postural and locomotor control mechanisms. The neuromuscular junction, which transmits neural information to muscular activity is critical in this transfer of activity from nerve to muscle. Calcium, magnesium and potassium, as well as other ions (such as chloride, and sodium) play critical roles in the production and propagation of electrical activity in neurons and muscle cells, the transfer of neural activity to muscle activity, and the contractile activity of skeletal muscle. In the following discussion, the interrelationships of these mechanisms will be discussed.

Muscle and Nerve Excitability[6,9,10,13,14,18,19,21]

The excitability of nerve and skeletal muscle primarily reflects the physiologic capacities of the surface membranes of these cells. This organelle represents both a physical and a metabolic barrier to the diffusion of a large number of ionic substances and through this property, functionally separates two fluid environments of differing ionic composition. The extracellular fluid compartment characteristically contains a relatively high concentration of sodium and chloride ions

[1]Department of Physiological Sciences, College of Veterinary Medicine, OSU.

and a low concentration of potassium and magnesium ions while the intracellular fluid compartment contains a relatively high concentration of potassium and magnesium ions and low concentrations of sodium and chloride ions. A major component of the intracellular magnesium ions are protein bound, and are thus not free to diffuse, while the sodium, chloride and potassium ions are relatively free to diffuse across the cell membrane. Calcium ions are high in concentration in the extracellular fluid and low in the intracellular fluid, but do not diffuse across the cell membrane because of membrane impermeability. Also present within the cytoplasm of the cells is a large concentration of organic anions (represented by proteins, purines and pyrimidines) which are virtually absent from the extracellular fluid. These ions, like calcium, cannot diffuse across the cell membrane. The ability of sodium, potassium and chloride to diffuse across the cell membrane, and their relationship to the intracellular fluid organic anions provide the basis for the property of excitability of nerves and skeletal muscle.

Sodium, potassium and chloride ions diffuse across the cell membrane through lipoprotein "channels," which provide a pathway for the water soluble ions to pass between intracellular and extracellular fluid compartments as dictated by their concentration gradients, and electrical potentials across the cell membrane. In resting nerve and muscle cells, potassium ions diffuse out of the cell more rapidly than either chloride or sodium ions diffuse in, due to differential permeabilities of their individual channels. Chloride ions can diffuse at a rate intermediate between that of sodium and potassium, and sodium ions diffuse very slowly into the cell.

As potassium diffuses out of the intracellular fluid compartment, leaving behind the organic anions, a membrane potential of as much as 100 mV can be produced, negative inside (due to the organic anions) and positive outside (due to the potassium ion diffusion). Because this is the major mechanism producing membrane potentials in resting cells, the resting membrane potential (Em) is considered to be a <u>potassium ion diffusion potential</u> (Note! It is diffusion, not the concentration gradient that produces the membrane potential). Factors which influence the rate of potassium ion diffusion, have a considerable influence on the resting excitability of nerve and muscle cells. These factors include, increased extracellular potassium ion concentration, decreased extracellular or intracellular potassium ion concentration (the latter is likely to occur with prolonged loss of potassium in the urine), or alterations in cell membrane permeability. The inward diffusion of sodium ions, even though slight, tends to reduce the membrane potential below that which would be produced if potassium ions were diffusion alone, so that the resting membrane potentials of nerve and skeletal muscle results in the summation of sodium and potassium ion diffusion. Chloride ions can diffuse through the cell membrane, but in the resting cell, the force driving chloride ions into the cell is exactly balanced by the membrane potential produced by sodium and potassium diffusion, which prevents inward diffusion. Chloride is therefore in equilibrium with the membrane potential, and does not contribute to the resting membrane potential.

The continual diffusion of sodium and potassium through the cell membranes of nerves and skeletal muscle is maintained through active transport mechanisms (the sodium-potassium pump) which transport sodium out of the cell and potassium into the cell. The inward transport of potassium requires only a small amount of metabolic energy, because inward movement of potassium is aided by the membrane potential. The outward transport of sodium, however, requires considerable metabolic energy as these ions must be transported against both their concentration gradients and against the extracellular positivity of the membrane potentials. The active transport mechanism for sodium and potassium derives its energy from the breakdown of adenosine triphosphate (ATP). The release of ATP energy is catalyzed by a membrane bound protein, closely related to the sodium-potassium pump, which is a sodium-potassium ion sensitive, magnesium dependent ATPase. A major proportion of the total metabolic energy consumed by nerve and muscle cells (estimates range from 25-35%) is utilized to maintain the concentration gradients of sodium and potassium ions.

Because the transport of sodium and potassium by these cells utilize such a high proportion of total metabolic energy, in deficiencies in energy metabolism, or in intracellular magnesium ion availability (a situation which often occurs in the pasturing of wheat), the primary clinical signs reflect deficiencies in the transport of these ions.

The ability to produce action potentials represents the property of excitability in nerve and skeletal muscle. Action potentials are non-decremental, propagated, all-or-none changes in the resting membrane potential, which is dependent upon a self-regenerating alteration in membrane permeability to sodium ions (known as sodium channel activation). In nerves, action potentials are produced by central nervous system mechanisms. In skeletal muscle, action potentials are normally generated by the action of acetylcholine upon specialized areas of the cell membrane comprising a portion of the neuromuscular junction. Acetylcholine is released from the nerve terminals of neuromuscular junctions when these terminals are depolarized by the arrival of an action potential in the nerve fiber. This depolarization induced release of acetylcholine is a calcium dependent mechanism. Depolarization of the nerve terminals causes calcium channels of the nerve surface membrane to be activated, resulting in an inward diffusion of calcium into the cytoplasm of the nerve terminal. An increase in cytoplasmic calcium ion concentration, causes nerve terminal vesicles (containing acetylcholine) to fuse with the nerve terminal membrane, and release their contents into the extracellular space between the nerve terminal and the endplate region of the muscle cell membrane.

The activation of calcium channels is inhibited by an extracellular fluid increase in magnesium ion concentration, but such concentrations do not occur without the intentional administration of magnesium salts.

The acetylcholine released from the nerve terminals attaches to the muscle endplate membrane and activates the sodium and potassium channels of this area, increasing the rate of diffusion of both sodium and potassium. As in the resting state, potassium diffusion is nearly maximal, and sodium diffusion is relatively slow, the increase in diffusion rate of both ions, results in sodium ions exerting a greater effect. The membrane potential of the endplate, therefore, decreases (depolarizes) and causes a depolarization to spread over the surface of the muscle cell. When depolarization reaches a critical level (threshold membrane potential, usually 10 to 15 mV less than the resting potential), a spontaneous, complete (all-or-none) activation of sodium channels occurs, so that sodium diffusion further increases and results in a rapid depolarization of the membrane. This depolarization persists for only a short period of time (usually less than 1 msec.) because the activation of sodium channels is short lived, and followed immediately by inactivation to resting levels of permeability to sodium ions. During the time that sodium permeability is high, potassium permeability is also increased, and the increased rate of diffusion of potassium ions tends to limit the influence of sodium ion diffusion, but during a major part of the action potential, the membrane potential is dominated by sodium diffusion. As sodium diffusion rate diminishes, during inactivation of sodium ion channels, the high rate of potassium ion diffusion quickly restores the membrane potential back toward its resting values. Potassium permeability is regulated by the membrane potential, so that as the membrane potential is restored toward its normal value, the permeability of potassium channels and the membrane potential are restored to resting values. The action potential is conducted over the entire surface of the muscle cell membrane as action potentials in the vicinity of the neuromuscular junction results in depolarization of adjacent membranes to threshold.

Excitation-Contraction Coupling in Skeletal Muscle[4,7,15,22]

Associated with the depolarization and repolarization of the muscle cell membrane by action potentials, membranes directly associated with the muscle cell membrane, but which lie within the cell are similarly affected. The surface membrane invaginates into the intracellular compartment of the muscle cell to form an extensive transverse tubular membrane system (referred to as the T-tube system). In mammalian skeletal muscle, these invaginations occur in a segmental manner along the length of muscle cells, in register with the transverse striations of the cells known as the A-I junctions. Within the cell, the T-tube system makes contact with the endoplasmic reticulum (sarcoplasmic reticulum), which represents a second extensive intracellular membrane system. As the action potentials depolarize the transverse tubule system, calcium ions, which are bound to the lipoprotein membrane components of the tubule system, are released into the cytoplasm, increasing the intracellular free calcium ion concentration. The cytoplasmic calcium, released in this fashion reacts with surface lipoproteins of the sarcoplasmic reticulum, triggering a second release of large amounts of calcium, which in the resting state are stored within the cisternae of the sarcoplasmic reticulum, bound to a protein known as calsequestrin. The net effect of these activities is to increase the quantity of calcium within the cytosol of muscle cells.

Calcium within the cytosol of most cells, is rarely in the form of free calcium, but is predominantly bound to a cytosolic protein known as calmodulin. It is apparent that the calcium-calmodulin complex interacts with the sarcoplasmic reticulum membrane to trigger the release of calcium from calsequestrin. As this additional calcium enters the cytosol, it too is bound to calmodulin, which regulates its distribution within the cytosol, and the reaction of calcium with other muscle cell proteins which are involved in muscle contraction.

Muscle Contraction[1,2,4,7,11,12,16,17,22,23]

The most characteristic feature of skeletal muscle is the regular pattern of banding which occurs throughout the length of the muscle cells. The presence of such banding is responsible for classifying skeletal muscle as a type of striated muscle. With light microscopic examination, the banding is observed to represent regular alternating light and dark transverse bands known as I bands and A bands respectively. The I bands are interrupted in their midportions by a dense transverse line, the Z bands and the A bands are interrupted in their midportion by a lighter portion, the H bands. The segment of the muscle fiber which lies between adjacent Z bands represents the functional unit of skeletal muscle, the sarcomere. Each sarcomere is of similar intrinsic organization and chemical composition.

There are at least four proteins which form the banding in skeletal muscle, and form the basis for completing excitation-contraction coupling and the resulting muscle contraction. These proteins are myosin, actin, tropomyosin and troponin. Within the limits of the A band there are thick myofilaments, comprised predominantly of myosin. Myosin is a fibrous protein with a globular terminal, demonstrating a molecular weight of about 450,000. The fibrous portion is represented as an alpha helix, which cross-polymerizes with other fibrous segments of adjacent myosin molecules, thus forming the thick myofilament of skeletal muscle. The globular portion of the myosin molecules and the adjacent portion of the alpha helix does not cross-polymerize with other myosin molecules and thus protrudes from the surface of the thick myofilament. These globular protrusions contain an ATPase activity (which is functional in releasing energy for muscle contraction) and are capable or interacting with the adjacent actin molecules when the intracellular environment and physicochemical properties of actin molecules are altered.

Actin is a globular protein (G-actin) with a molecular weight of 47,000, which is polymerized in the cytoplasm of skeletal muscle to form a double stranded helix. The binding of globular actin to a nucleotide (ATP) and calcium is necessary for the maintenance of polymerization. Actin molecular strands are continuous through the Z lines into adjacent sarcomeres and thus link sarcomeres together. Actin is the major protein of thin myofilaments of skeletal muscle and represents the principal protein of the I bands, but interdigitates between the thick myosin filaments of the A bands. The interdigitated ends of actin myofilaments do not extend to the center of the A bands and thus provide a central, lighter portion of the A band known as the H band.

Tropomyosin is a fibrous protein with a molecular weight of about 70,000, forming a double coiled helix, represented by two alpha helices wound around each other. This complex structure forms a stratum upon which the actin filaments are coiled. The close relationship between tropomyosin and actin in muscle at rest prevents interaction between actin and myosin. It appears that this inhibitory action is produced by a mechanism of stearic hindrance.

Troponin is a globular protein with a molecular weight of about 80,000. It is comprised of three subunits known as troponin C, which has a high affinity for calcium; troponin T, which has an affinity for tropomyosin and attaches troponin to this molecule and troponin I which is inhibitory to the ATPase activity of the adjacent globular portion of the myosin molecules. Troponin is attached to the tropomyosin strands at intervals of about 410 Angstroms through its troponin T component. Thin filaments of striated muscle are therefore comprised of three proteins, tropomyosin, actin and troponin complexes, while thick filaments are comprised of myosin.

The sequence of events which begins with an increased intracellular concentration of calcium-calmodulin complexes and ends with muscle contraction is referred to as the sliding filament mechanism of muscle contraction. This mechanism results from an interaction between actin and myosin which results in the shortening of each sarcomere, with thin filaments sliding along the thick filaments, encroaching upon the H lines and pulling the Z bands toward each other.

Increased intracytoplasmic calcium calmodulin complexes result in the activation of protein kinase enzymes which phosphorylate troponin C, and results in the transfer of calcium from calmodulin to troponin C molecules to form calcium-troponin C complexes. The formation of calcium-troponin C complexes results in the alteration of the troponin I and troponin T components of troponin (and likely other phosphorylations), so that the troponin I inhibition of myosin ATPase and tropomyosin stearic hindrance of actin and myosin interaction is removed. Thus energy is available for muscle contraction from the degradation of ATP, and actin and myosin complex formation results in muscle contraction.

The degree of contraction is related to the quantity of calcium available to form calcium-troponin complexes. The number of calcium-troponin complexes formed is directly proportional to the number and rate of actin and myosin interactions and the force of muscle contraction.

Muscle Relaxation[1,2,7,20,23]

Muscle relaxation results from the reversal of the process of contraction and is the consequence of intracytoplasmic regulation of calcium ions. The calcium released in excitation-contraction coupling is rapidly rebound to the sarcoplasmic reticulum, and transported into the cisternae by calcium-sensitive ATPase dependent active transport mechanisms (Calcium pumps). Within the cisternae calcium is again rebound to calsequestrin. Calcium is also rebound to the transverse tubule systems and the surface membrane (probably through a mechanism which involves calmodulin), and is actively transported into the cisternae of the transverse tubules by calcium pumps. As the cytoplasmic store of calcium-calmodulin is reduced, calcium is released from calcium-troponin C complexes, restoring troponin C, troponin I and troponin T to their original state (most likely involving dephosphorylation reactions). These alterations in troponin result in the reestablishment of troponin I inhibition of myosin ATPase, and tropomyosin inhibition of interaction between actin and myosin, so that muscle relaxation occurs.

Energy Metabolism in Skeletal Muscle[3,5]

The amount of ATP present in skeletal muscle to maintain the transmembrane distribution of diffusible ions and to be hydrolyzed by myosin ATPase to provide energy for muscular contraction determines both the state of excitability and contractility of muscle. The amount of ATP available is dependent upon the ability of muscle cells to form ATP directly from energy metabolism and from a storage form of energy as creatine phosphate. Creatine phosphate is formed through energy-producing metabolism in muscle from the transformation of ATP to ADP, releasing phosphate which is in turn bound to creatine without the loss of energy stored in the terminal phosphate bond of ATP. This reaction requires the presence of magnesium ions and a cytoplasmic enzyme, creatine phosphokinase (CPK).

The energy requirements of skeletal muscle cells differ in accordance with the conditions under which they are typically called upon to function. Three types of skeletal muscle cells have been identified on this basis: Type I (slow twitch-oxidative type, red muscle fibers or type B slow twitch fibers) depend primarily upon oxidative phosphorylation for energy. These muscle fibers contain numerous mitochondria and a lower concentration of myosin ATPase activity than other types of muscle cells. These muscle cells are found in muscles which are not called upon for strong muscular contraction and are therefore most numerous in muscles which function with the development of only slight strength. Type II cells (fast twitch-glycolytic, type A fast twitch or white muscle fibers) primarily depend upon substrate phosphorylation for their energy source. They contain higher concentrations of glycogen than type I cells and a greater concentration of myosin ATPase activity. A third type of skeletal muscle fiber known as type III is intermediate between types I and II. Type III fibers are classified as fast twitch-oxidative-glycolytic muscle cells.

It is evident from the above classifications that a single view of energy metabolism will not be adequate for all muscle cells, as white muscle cells depend primarily upon glycolysis for energy and operate at maximal contraction for only short periods of time before depleting this energy store, while red muscle fibers derive their energy primarily from the oxidation of fatty acids and glucose (as well as lactate, pyruvate, ketone bodies and amino acids) and are capable of maintaining sustained contractions without depletion of their energy source. In the latter type of muscle, glycolysis becomes an important source of energy only when oxygen is restricted or sustained muscle contraction restricts the blood flow through muscular tissue.

In red muscle, glucose metabolism comprises a major source of energy, as long as oxygen supply to the muscle is plentiful. Plasma glucose is transported into muscle cells through a carrier-mediated (facilitated transport) passive mechanism, which requires insulin for its activity. Insulin attaches to surface receptors of the muscle membrane and, through interaction with such receptors, alters the carrier for glucose to maximize its efficiency. As long as adequate insulin is present, transport of glucose across the sarcolemma does not limit the rate of glucose utilization in animals with normal blood glucose levels. Once glucose is inside the cell, it must be phosphorylated for further metabolism. This is accomplished through the action of hexokinase, which requires magnesium and ATP to produce glucose-6-phosphate (G-6-P). The activity of hexokinase is regulated by intracytoplasmic levels of G-6-P, thereby providing a control mechanism for the further transport of glucose into the cell. If adequate G-6-P is present within the cell to meet the metabolic needs, hexokinase inhibition prevents the phosphorylation of glucose and allows intracellular glucose concentrations to increase. This in turn decreases the rate at which facilitated transport can allow the passage of glucose into the cell.

Glucose-6-phosphate represents an important nodal point in the metabolism of glucose within muscle cells, as it may be converted by specific enzymes into glucose-1-phosphate (G-1-P) and fructose-6-phosphate (F-6-P). Conversion to G-1-P occurs through a reversible reaction catalyzed by phosphohexose isomerase and leads to glycogen formation. Conversion of G-6-P to F-6-P is catalyzed by the enzyme phosphohexose isomerase and leads to glycolysis to produce pyruvate. In some tissues G-6-P can be converted to 6-phosphogluconic acid to enter the pentose shunt. This metabolic pathway is absent in skeletal muscle due to the lack of the initiating enzyme, glucose-6-phosphate dehydrogenase.

Glycogen Metabolism

G-1-P is polymerized to glycogen through an intermediate reaction involving uridine triphosphate and catalyzed by the cytoplasmic enzyme, glycogen transferase. This enzyme represents an avenue for control of glycogen synthesis, as it is transformed from a relatively inactive form (transferase I) to a more active form (transferase D) through the action of epinephrine (utilizing a cyclic AMP-dependent protein kinase mechanism) on the cell membrane surface. Transferase D is dependent upon the presence of G-6-P for its activity and is inhibited by ATP, so that variations of these substances in the cytoplasm regulate glycogen deposition.

A second enzyme system (which is dependent upon pyridoxal phosphate for its action) breaks down glycogen (glycogenolysis) so that it can be converted back to G-1-P. This system is represented by phosphorylase a and phosphorylase b. Phosphorylase b is considered to be inactive in resting muscle because it is inhibited by G-6-P and ATP. In circumstances in which the concentrations of these substances are low, as during periods of intense muscular activity or anoxia, phosphorylase b is quite effective as an enzyme. Phosphorylase b is converted to phosphorylase a by a specific kinase enzyme which is activated by the presence of calcium calmodulin complexes in the cytoplasm.

Phosphorylase a is not dependent upon G-6-P or ATP levels for its activity and thus can be activated prior to an energy deficit. Such activation is produced through the influence of epinephrine on a cyclic AMP mechanism and through an increase in cytoplasmic calcium, which results from action potentials on the sarcolemma of the cell. It is through the latter mechanism that glycogenolysis is regulated to produce adequate energy for muscle contraction. This mechanism for balancing energy metabolism from glycogen stores with the intensity of muscle contraction (as both are controlled by intracytoplasmic calcium concentration) is most significant in type II muscle fibers (fast twitch-glycolytic). There is some indication that phosphorylase activity is associated with intracytoplasmic magnesium levels. As a good deal of the magnesium of the cytoplasm is bound to ATP, the breakdown of ATP for muscle contraction results primarily in an increase in these ions in the cytoplasm, and secondarily in an enhancement of phosphorylase activity.

It should be noted that epinephrine affects both synthesis and breakdown of glycogen through a cyclic AMP mechanism. The net effect of epinephrine, however, is dependent upon the G-6-P levels of the cell. In circumstances of enhanced muscular activity, in which G-6-P levels are low, the influence of epinephrine is to turn off glycogen synthesis while promoting glycogen breakdown.

Glycolysis

In the utilization of G-6-P for energy, its conversion to F-6-P by phosphohexose isomerase is critical to cellular metabolism of either glucose or glycogen for energy. This metabolic pathway produces pyruvate or lactate as its end-products, depending upon the state of oxygenation of the tissues. A number of enzymes are used in this metabolism but the second reaction in the series, the conversion of F-6-P to fructose 1-6-diphosphate (F-1-6-DP) through the action of the enzyme phosphofructokinase, represents the major control point for the metabolic pathway. This enzyme is inhibited by increased cytoplasmic levels of ATP and of citric acid (both of which are products of aerobic metabolism of pyruvate) and is stimulated by ADP and AMP, thus providing a feedback control which regulates the production of pyruvate to be in accord with the utilization of energy and oxygen. As ATP levels and citric acid levels drop in response to enhanced energy utilization through muscular contraction or in response to tissue anoxia, an increasing amount of G-6-P is utilized by the glycolytic pathway to produce pyruvate for oxidative phosphorylation. Phosphofructokinase is an inducible enzyme, which means that the cytoplasmic concentration increases with continued use of the metabolic pathway. This may be an important mechanism in the conditioning of muscle for enhanced energy metabolism during training.

Glycolysis can proceed during periods of anoxia and provide three moles of ATP for each mole of glucose utilized. In anaerobic conditions, in which either the circulation to muscle is interrupted due to prolonged muscle contraction or in which the oxygen supply does not meet the energy requirements, pyruvate is converted to lactic acid. This reaction is produced through the mediation of the enzyme, lactic acid dehydrogenase. There are five forms (isozymes) of lactic acid dehydrogenase (LDH), the relative concentrations of which vary with different tissues, depending on the conditions under which they ordinarily function. Heart muscle, for example, contains an isozyme which is known as LDH-H_4 (the H indicating its dominance in heart). This isozyme is comprised of four sub-units of H (thus the subscript 4). This form of LDH operates only in tissues in which anaerobic conditions are not present during the normal circumstances of cell function. LDH-H4 produces little lactic acid, as pyruvate which inhibits the enzyme is utilized through oxidative pathways to provide further energy for muscular activity. Because of the presence of this enzyme in heart muscle, lactic acid is not ordinarily formed, but is used as a substrate for energy metabolism in heart muscle. The isozyme of skeletal muscle is predominantly LDH-M_4 (the M indicating muscle and the subscript 4 indicating 4 units of the molecule), which is only weakly inhibited by pyruvate and converts large amounts of pyruvate to lactate at a rapid rate. This conversion is of importance in tissues such as skeletal muscle, which are at times required to function in periods of relative anaerobic states, as the conversion of pyruvate to lactic acid results in the oxidation of nicotinamide adenine dinucleotide (NAD) from its reduced form (NADH). NAD is necessary in the glycolytic pathway to serve as an electron receptor co-factor in the conversion of F-6-P to pyruvate. Thus, through the formation of lactic acid, the glycolytic pathway continues to function during anaerobic states.

The lactic acid formed during muscle contraction may diffuse into the extracellular fluid, enter the blood and be converted back to glucose by the liver. This process cannot occur in muscle, even at rest, because muscle cells lack the enzyme, glucose-6-phosphatase, which is required to convert G-6-P to glucose. The glucose provided by the liver is available to serve as a source of muscle glucose. The mechanism whereby lactate, produced in muscle, is transported to the liver, where it is converted to glucose and transported back to muscle for utilization, is referred to as the Cori cycle.

Under aerobic conditions, lactic acid can be transformed back into pyruvate, which then undergoes oxidative degradation in the tricarboxylic acid cycle (TCA cycle). The conversion of lactic acid to pyruvate is catalyzed by LDH. As cytoplasmic concentrations of pyruvate are reduced by oxidative metabolism, the equilibrium is shifted from the production of lactic acid to the production of pyruvate. Under these conditions, lactate in the blood can be utilized for energy by skeletal muscle.

The enzymes which metabolize pyruvate in the TCA cycle are located within mitochondria. For pyruvate to be metabolized to CO_2 and water in the TCA cycle, it must enter the mitochondria. Pyruvate apparently accomplishes this through passive diffusion. Because there is a constant equilibrium between the pyruvate concentrations of the cytoplasm of the mitochondrial matrix, there is a dynamic relationship between intramitochondrial metabolism of pyruvate and its cytoplasmic concentration. Thus, mitochrondrial metabolism of pyruvate determines whether or not lactic acid is allowed to accumulate or is converted to pyruvate for energy.

The first enzyme complex in the metabolism of pyruvate plays a key role in the regulation of glucose metabolism for oxidative energy. This enzyme complex, known as pyruvate decarboxylase, in the presence of Coenzyme A, thiamine pyrophosphate, lipoic acid and magnesium, converts pyruvate into acetyl-CoA, which is the entry substance for the TCA cycle. The conversion reduces NAD, which becomes available to the cytoplasmic compartment of the cell to allow continuation of glycolysis (thus replacing the function of pyruvate to lactate conversion). The enzyme complex, pyruvate decarboxylase, is inhibited by reduced NAD, acetyl-CoA (both of which are produced by the reaction) and by ATP (which is the end product of oxidation of pyruvate by the TCA cycle. There is, therefore, a fine-grained control of the entry of pyruvate into the TCA cycle for complete oxidation to CO_2 and water. Since acetyl-CoA is also produced as the end-product of beta oxidation of fatty acids within the mitochondria, fatty acid catabolism can effectively block the oxidative metabolism of pyruvate.

In situations in which dietary sources of glucose do not satisfy the metabolic demands of the animal, gluconeogenic substances are used to supply glucose for energy. A source of gluconeogenic substances is the amino acids derived from muscle protein. The release of amino acids from muscle is controlled by endocrine mechanisms which alter synthesis and degradation of protein. Insulin not only enhances uptake of glucose by muscle cells, but also stimulates the uptake of amino acids. Glucocorticoids inhibit muscle membrane uptake of amino acids and incorporation into muscle protein, thus providing amino acids for hepatic gluconeogenesis (which is also stimulated by these hormones). The effect of glucocorticoids on muscle, however, overrides that on the liver and results in increased plasma levels of amino acid nitrogen. Growth hormone increases amino acid uptake and incorporation into muscle protein while decreasing plasma amino acid nitrogen.

The amino acid, alanine, appears to be more important than other amino acids taken up by muscle, as it serves as the basis for the so-called alanine cycle. The alanine cycle, like the Cori cycle, is functional in maintaining plasma glucose levels for adequate muscular energy formation through hepatic conversion (gluconeogenesis) of a substance produced in muscle. In this case, transaminase reactions result in the formation of alanine in muscle cells from pyruvate. Alanine diffuses out of the cell and is carried to the liver, where it is deaminated to pyruvate for conversion to glucose, which in turn becomes available to the muscle.

Besides contributing to energy metabolism, the alanine cycle also provides a protective mechanism for muscle. Muscle does not possess the enzymatic apparatus to synthesize urea; therefore, by releasing nitrogen as alanine, muscle is able to utilize amino acids as fuel without the risk of releasing large amounts of NH_3 into the circulation.

Ketone bodies represent a significant source of energy for muscle cells, particularly in ruminants, colonic fermenters and cecal fermenters, in which volatile fatty acid metabolism often results in borderline ketotic states. The ketone bodies, acetoacetate, beta-hydroxy butyrate and acetone, are metabolized by way of acetyl-CoA and the TCA cycle. Because they generate acetyl-CoA, their metabolism results in depression of pyruvate metabolism and thus conservation of glucose as an energy source.

Magnesium ions, which are second in concentration of intracellular cations, being exceeded only by potassium, are indispensable for normal muscular function. Magnesium is required in all reactions involving ATP and other high-energy phosphate reactions. In these reactions, magnesium is bound to ATP and the complex serves as a substrate for energy metabolism. In the absence of adequate magnesium, the primary deficit can be related to this function in energy metabolism.

The role of selenium in muscle metabolism and its interrelationship with vitamin E metabolism has long been of concern to those who recognize the involvement of these agents in the production of muscle disorders when deficiencies occur. It has been clearly demonstrated that selenium is an essential element in the chemical structure of glutathione peroxidase, which prevents the accumulation of peroxides in the cytoplasm and organelles of muscle and other cell types. Peroxides are formed as a normal course of metabolism through the action of amino acid oxidases, xanthine oxidase and other similar systems of enzymes. Peroxides not only result in damage to the sarcolemma resulting in alterations in membrane permeability and disturbing electrophysiologic mechanisms, but also disrupt the membranes of organelles within the cell (particularly mitochondria), which leads to disturbances of energy metabolism. Glutathione peroxidase is one of several peroxidase systems which prevent such as accumulation.

The interaction of vitamin E and selenium is believed to prevent lipid hydroperoxide formation, which is also destructive to cell membranes. Vitamin E is viewed to function in this regard primarily as a cellular "antioxidant." Lipid peroxides form most readily from unsaturated lipids and accumulate when these substances are being utilized as an energy source. The enhancement of lipid peroxidation has been demonstrated in skeletal muscle of aging animals; thus the requirement for peroxidase and antioxidant functions of selenium and vitamin E could be expected to increase with age.

Besides the production of peroxides as toxic byproducts of oxidative metabolism, the superoxide radical (O_2^-) is an important agent of oxygen toxicity. All oxygen-metabolizing cells so far examined have been found to contain enzymes which catalyze the reaction $2O_2 + 2H^+ \longrightarrow H_2O_2 + O_2$. These copper, zinc metalloprotein enzymes are known as superoxide dismutases. The regulation of copper and zinc metabolism plays a critical role in the normal maintenance of this critical protective mechanism of muscle cells.

Conclusions

It is apparent from the preceding discussion that magnesium, calcium and potassium are involved in all stages of muscle activity, including the neural activity which activates skeletal muscle, the activation of skeletal muscle itself, the contractile and relation mechanisms of skeletal muscle, and muscle metabolism to provide the energy that is requisite for muscle contraction. The role of magnesium is primarily, but not limited to, its necessity for the activity of kinase enzymes which regulate the transfer of energy between metabolic molecules and finally to the mechanisms of muscle contraction and relaxation. Potassium plays a key role in the maintenance and regulation of nerve and muscle excitation, and may play important metabolic roles within the cytoplasm of muscle cells. Calcium, which regulates muscle contraction and relaxation, also regulates the activation of important enzymatic reactions, which regulate the energy available for muscle contraction, and also controls the intensity of muscle contraction. These calcium regulatory mechanisms operate through calcium carrier molecules within the cytoplasm of muscle cells, known as calmodulin. It is apparent that there are several calmodulins present in cells, the importance of different forms of calmodulin remains to be elucidated.

Areas of Needed Research

Virtually every aspect of neuromuscular function is in need of further investigation. The nature of surface membrane ionic channels, and factors which regulate them is very limited, and today reside as models which are used to explain cause and effect interactions, without a clear insight to the molecular interactions involved. The means by which magnesium and calcium interaction occurs in the activation of surface membrane channels and in the control of energy releasing mechanisms within the cells contains many similar model systems of which details are lacking. These mechanisms are particularly important in understanding the close control which appears to be present between availability of energy and the energy needs of muscle contraction.

Literature Cited

1 Adelstein, R. S. Phosphorylation of muscle contractile proteins. Federation Proc. (1980) 39:1544-1573.

2 Adelstein, T. S. and Eisenberg, E. Regulation and kinetics of the actin-myosin-ATP interaction. Ann. Rev. Biochem. (1980) 49: 921-956.

3 Cantor, A. H., Scott, M. L. and Noguchi, T. Biological availability of selenium in feedstuffs and selenium compounds for prevention of exudative diathesis in chicks. J. Nutr. (1975) 105:96-101.

4 Cheung, W. Y. (editor). Calcium and Cell Function. New York: Academic Press, 1980, Vol. I.

5 Combs, G. F., Jr., Noguchi, T. and Scott, M. L. Mechanisms of action of selenium and vitamin E in protection of biological membranes. Fed. Proc. (1975) 34:2090-2095.

6 Eldefrawi, M. E. and Eldefrawi, A. T. Coupling between the nicotinic receptor site and the ionic channel site. Ann. NY Acad. Sci. (1980) 358:239-252.

7 Gergely, J. Excitation-contraction coupling-cardiac muscle events in the myofilament. Fed. Proc. (1976) 35:1283-1285.

8 Hers, H. G. and Hue, L. Gluconeogenesis and related aspects of glycolysis. Ann. Rev. Biochem. (1983) 52:617-653.

9 Jackson, M. B., Lecar, H., Askansas, V., Engel, W. K. Single cholinergic receptor channel currents in cultured human muscle. J. Neurosci. (1982) 2:1465-1473.

10 Kistler, J., Stroud, R. M., Klymkowsky, M. W., Lalancette, R. A., Fairclough, R. H. Structure and function of an acetylcholine receptor. Biophys. J. (1982) 37:371-383.

11 Knowles, J. R. Enzyme-catalyzed phosphoryl transfer reactions. Ann. Rev. Biochem. (1980) 49:877-919.

12 Kretsinger, R. H. The informational role of calcium modulated proteins. Crit. Rev. Biochem. (1980) 8:119-174.

13 Labarca, P., Linstrom, J. and Montal, M. Studies on the properties of the purified acetylcholine receptor reconstituted in planar lipid bilayers. Biophys. J. (1982) 27:170a.

14 Lambert, J. J., Durant, N. N. and Henderson, E. G. Drug induced modification of ionic conductance at the neuromuscular junction. Ann. Rev. Pharmacol. Toxicol. (1983) 23:505-539.

15 Means, A. R., Tash, J. S. and Chalfouleas, J. G. Physiological implications of the presence, distribution and regulation of calmodulin in eukaryotic cells. Physiol. Revs. (1982) 62:1-39.

16 Norimoto, K. and Harrington, W. F. Substructure of the thick filament of vertebrate striated muscle. J. Mol. Biol. (1974) 83: 83-92.

17 Nairen, A. C. and Perry, S. V. Calmodulin and myosin light chain kinase of rabbit fast skeletal muscle. J. Biochem. Tokyo, (1979) 179:89-97.

18 Peper, K., Bradley, R. J. and Dreyer, F. The acetylcholine receptor at the neuromuscular junction. Physiol. Revs. (1982) 62:1271-1340.

19 Raftery, M. A. and Changeux, J.-P. The nicotinic acetylcholine receptor (AChR). Neurosci. Res. Prog. Bull. (1982) 20:277-301.

20 Schwartz, A. Cell Membrane Na^+, K^+ -ATPase and sarcoplasmic reticulum: Possible regulators of intracellular ion activity. Fed. Proc. (1976) 35:1279-1283.

21 Standaert, F. G. Release of transmitter at the neuromuscular junction. Br. J. Anaesth. (1982) 54:131-145.

22 Watterson, D. M. and Vincenzi, F. F. (editors). Calmodulin and cell functions. Ann. NY Acad. Sci. (1980) 356:1-446.

23 Weber, A. and Murray, J. M. Molecular control mechanisms in muscle contraction. Physiol. Rev. (1974) 53:612-757.

MECHANISMS OF TETANY IN COWS GRAZED ON WHEAT PASTURE

V.R. Bohman, F.P. Horn, W. Travis Littledike,
J.G. Hurst and D. Girffin

University of Nevada
Reno, Nevada 89557
United States Department of Agriculture
El Reno, Oklahoma 73036 and
Ames, Iowa 50010
and
Oklahoma State University
Stillwater, Oklahoma 74078

Summary

Wheat pasture poisoning (WPP) is the clinical manifestation of a variety of interacting events of both plant and animal origin that may quickly result in the death of an apparently normal grazing animal. It metabolically resembles milk fever more closely than the usual pattern of grass tetany.

The proposed etiology of WPP is as follows: Plant factors associated with this syndrome are present in cereal forages in the fall or early winter and again in the spring as the forage rapidly accelerates its growth rate in response to a rise in temperature and adequate soil moisture. At these times the plant moisture, potassium (K), nitrogen (N), aconitic acid and lipids especially linolenic acid (C18:3), are unusually high while the total nonstructural carbohydrates (TNC) levels are low. Calcium (Ca) and magnesium (Mg) levels are adequate to borderline in the cereal forage. Although the forage is tetany prone at both times, the cow is more susceptible at calving in the spring. As the cow approaches parturition, plasma Mg decreases and plasma Ca increases and consequently the rate of mobilization of bone Ca as measured by the levels of hydroxyproline in the blood decreases. Apparently the absorption of Ca from the digestive tract is adequeate to meet the animal's needs at this time. When the composition of the forage rapidly changes and the tetany-related plant components markedly increase, less Ca and Mg are absorbed from the digestive tract and additional amounts are chelated by organic acids post absorption.

In addition, the requirements of the animal for Ca and Mg are increasing by approaching parturition and lactation or by lactation itself. The animal tends to compensate for these changes by secreting larger amounts of parathyroid hormone (PTH) and increasing the synthesis of 1, 25 dihydroxycholecalciferol (1,25$(OH)_2D_3$). Hypomagnesemia limits the effectiveness of this action. Prior to or as these changes occur, inappetence occurs and the adverse metabolic effects are accelerated. Plasma Ca then drops precipitously and the animal goes into tetany. The rapid muscular contraction of the animal and concurrent stress elevates both plasma glucose and lactic acid. If no therapeutic action is taken, the animal ususlly dies within 4 to 8 hours after the initial symptoms are seen.

The sequence of these events is based upon several independent studies and seem reasonable. At least it suggests areas of needed research to either confirm this hypothesis or suggest more exacting mechanisms.

Introduction

Winter wheat is used extensively as a forage for grazing beef cattle particularly in the Southern Great Plains of the U.S. This forage is nutritious and provides a timely feed source for grazing animals without diminishing grain yields if the forage is not grazed too late in the spring. When mature cows graze on winter wheat, they frequently develop a condition known as wheat pasture poisoning (WPP). Death losses from this malady are frequently as high as 2-3 percent but may be as high as 20 percent (Stewart et al., 1981) and unpredictable. The symptoms begin with undue excitement, incoordination and loss of appetite. As the condition progresses, viciousness, staggering and falling develops. Nervousness becomes more apparent with muscular twitching, particularly of the extremities. The animal has an anxious expression and may grind its teeth and salivate profusely. This is usually accompanied by frequent urination and defecation. General tetanic contractions of the muscles then occur. Labored breathing and a pounding heart, followed by a comatose condition subsequently develop. If left untreated, convulsions with periods of relaxation will be seen which terminate in death (Crookshank and Sims, 1955).

Wheat pasture poisoning is similar to grass tetany in many aspects and is considered synonymous to by some writers (Sell and Fontenot, 1980).

The purpose of this paper is to review the literature on the animal aspects of WPP, to explore some of the similarities, differences and relationships between grass tetany and WPP and to define some of the metabolic changes that occur with this malady.

Review of Literature

Sjollema (1932) described the occurrence of both milk fever and grass tetany with grazing animals. Milk fever occurred in one to seven days postpartum with low levels of plasma calcium (Ca) while grass tetany usually occurred shortly after cows were placed on pasture, but sometimes later, with low levels of plasma magnesium (Mg). Hypomagnesemic animals tended to be more nervous and excited while hypocalcemic animals were more lethargic. The primary treatment, 50 years ago, was an intravenous injection (iv) of a solution of Ca and Mg salts, in fact, the same solution for both maladies.

In 1942 McMillen and Langham reported the serum composition of cows grazing wheat pastures with WPP. All animals (6) were hypocalcemic (3.5 mg/dl). The average serum Mg was 2.9 mg/dl except for one animal that was hypomagnesemic. He defined the hypocalcemic animals as afflicted with milk fever and the hypomagnesemic animal as grass tetany. The animals were treated with calcium gluconate and responded positively. Crookshank and Sims (1955) have given us the classical description of WPP as mentioned in the introduction. They sampled the blood of sixty cows affected with WPP from the Texas Panhandle and found that these animals were hypocalcemic (6.7 mg/dl) and moderately hypomagnesemic (1.35 mg/dl). Obviously some were both hypocalcemic and hypomagnesemic with low values of 3.3 mg Ca/dl and .4 mg Mg/dl. Serum samples were collected in the winters of 1973-74 and 1974-75 in Oklahoma (Horn, 1980 quoting Mayer) from cows with WPP. Twenty five percent of the samples indicated severe hypomagnesemia (< 1 mg/dl; tetany prone) while 74% were severely hypocalcemic (< 5 mg/dl) and all were hypocalcemic (<9 mg/dl). With this atypical blood composition, Horn questioned if WPP was typically grass tetany.

In a recent review Littledike et al. (1981) noted that grass tetany could be classified by clinical types, i.e. the tetanic syndrome type which was characterized by nervousness, muscle twitching, ataxia, convulsions, recombency with spasms and opisthotonus (grass tetany type) and the paretic type which was characterized by listlessness, staggering, paresis, recumbency and coma without spasms (milk fever type). In addition the grass tetany type is characterized by low levels of plasma Mg while animals with the milk fever are hypocalcemic. Obviously as one reviews the literature, both types can occur in the same animal at the same time on occasion and within a herd, both types may occur. The physical symptoms of the tetanic type are more obvious but the animal may be both hypocalcemic and hypomagnesemic.

In studies conducted at the Southwestern Livestock and Forage Research Center in Oklahoma, the tissue composition of cattle grazing mixed wheat and rye forage was followed (Bohman et al. 1983a). After 104 days on these pastures, 5 cows developed tetany. A detailed comparison was possible of cows managed similarly that did (tetany cows) or did not (non-tetany cows) develop tetany. Plasma Ca levels were similar in these groups until the day before tetany. At that time, the non-tetany cattle had plasma Ca levels of 6.7 mg/dl while the tetany cows were 5.7 mg/dl. At tetany, the plasma Ca levels were 4.1 mg/dl for the tetany cows. After treatment the levels of plasma Ca quickly returned to low normal levels (8 mg/dl). In contrast, plasma Mg levels were similar initially then decreased to 1.2 mg/dl 15 d before tetany, rose to 1.6 at tetany, dropped again to 1.2 mg/dl 6 d post tetany then gradually returned to normal (figure 1).

The parathyroid hormone (PTH) plasma levels were inversely related to plasma Ca. The levels peaked at tetany but the tetany cows had lower levels than the non-tetany animals. The level of PTH started to increase prior to the decrease in plasma Ca (figure 2). When EDTA was used to lower plasma Ca, Contreras et al. (1982) found that hypomagnesemia reduced the Ca mobilization rate in both steers and non-pregnant lactating cows with even relatively small reductions in plasma Mg (2.2 to 1.7 mg/dl). Sansom et al. (1983) in a related study stated that the greater the decrease in Mg concentration, the greater the reduction in Ca mobilization rate. The difference between the tetany and non-tetany cattle in plasma Mg levels in the Oklahoma study (Bohman et al. 1983a) was similar to the differences measured by Contreras et al. (1982) and was lower than their initial values (1.8 to 1.2 mg/dl; figure 1).

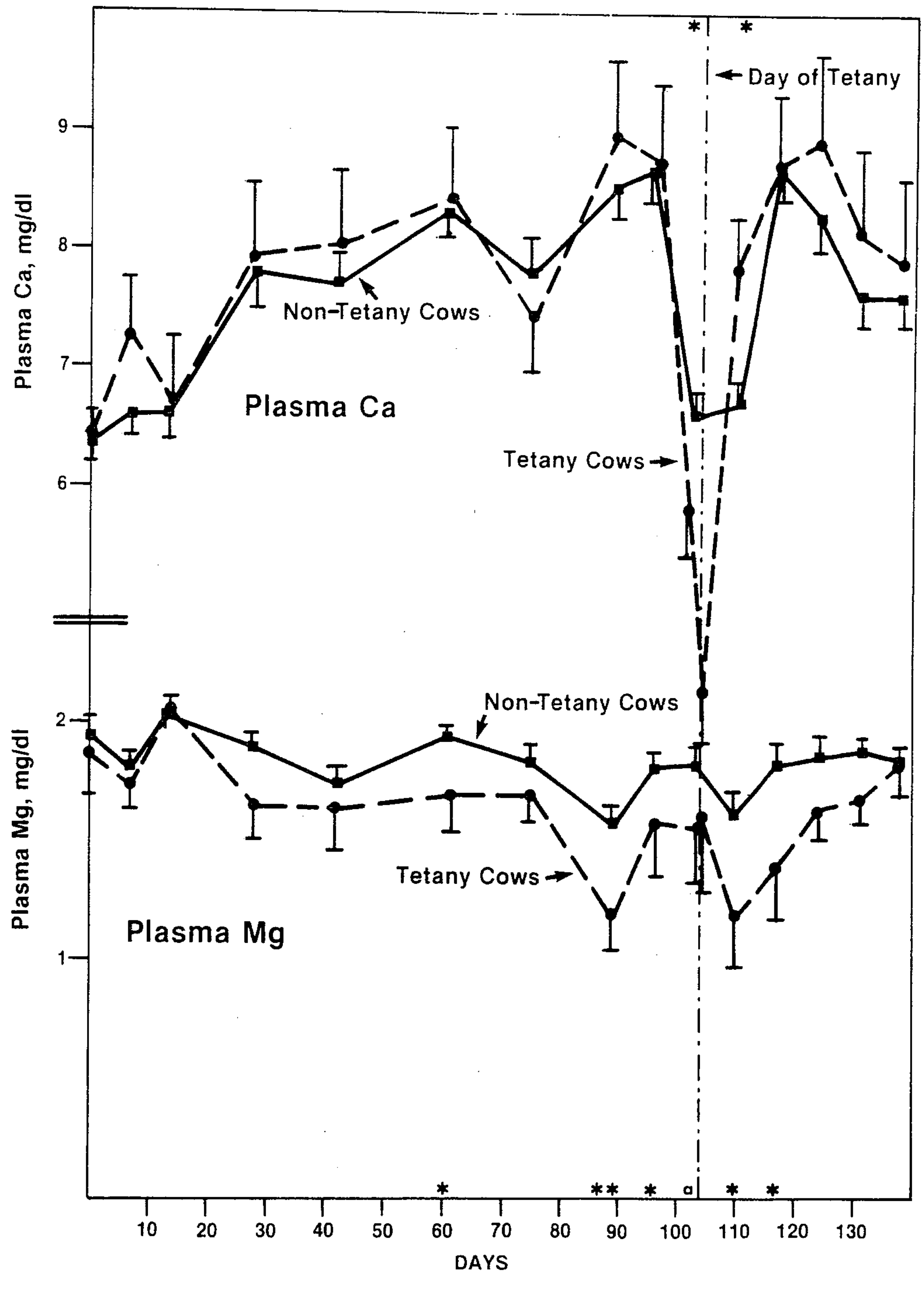


Figure 1. Plasma Ca and Mg concentrations in tetany (n=5) and non-tetany (n=27) cows. Statistical significance between plasma values of tetany and non-tetany cattle is indicated as follows: **, significant at P .01; *, significant at P .05; [a], significant at P .1. Each value is the mean ± SE (Bohman et al. 1938b).

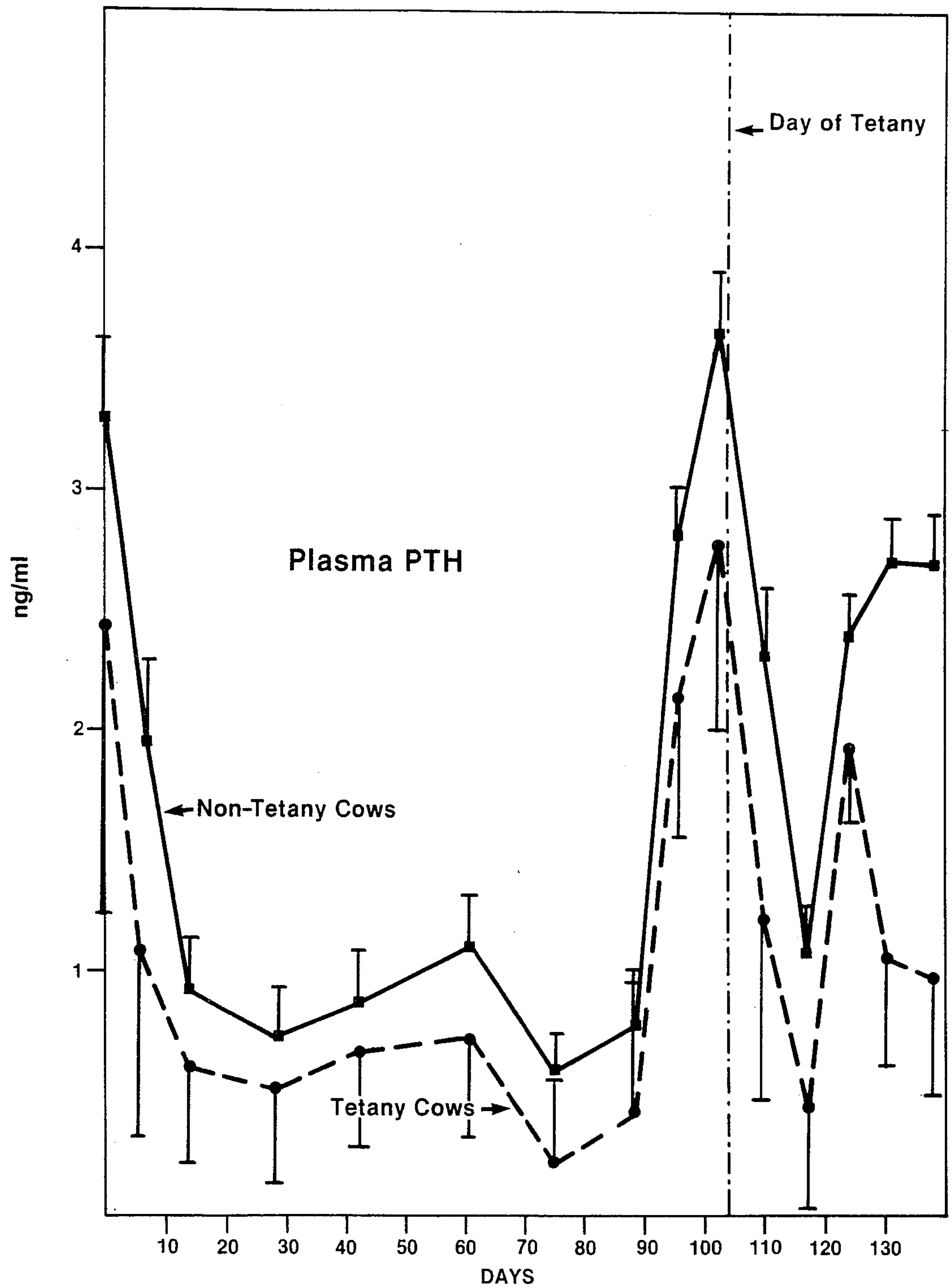


Figure 2. Plasma PTH concentration in tetany (n=5 and non-tetany (n=27) cows. Each value is the mean ± SE (Bohman et al. 1983b).

Sansom et al. (1983) indicated that the effect of hypomagnesemia might be caused by an interference with PTH secretion, with the action of this hormone on target organs or by interference with the metabolism of vit. D_3 (cholecalciferol).

The Oklahoma study provides data that can support this hypothesis. Although plasma PTH increased with both the tetany and non-tetany cattle, the plasma PTH was lower in the tetany cows indicating an interference with PTH secretion. Conversely, plasma Ca decreased in both groups of cattle but the effect was greater in those animals that developed tetany thus the action of PTH on mobilizing calcium may have been limited or the amount of PTH secreted was not adequate for this purpose. Although data is not available on the concentration of 1, 25 (OH) 2 D in the non-tetany animals and although the amount of this hormone increased markedly at tetany in the affected animals, it obviously was not adequate to prevent the extreme hypocalcemia and tetany. The British researchers (Contreras et al. 1982, Sansom et al. 1983) related their studies to the occurrence of milk fever, but they should have equal applicability to the occurrence of WPP. Plasma (K) does not appear to be related to WPP. Although high levels of K were ingested (Bohman et al. 1983b), the levels in the plasma were normal. Apparently the animal execreted the high levels of K readily. Other studies have shown similar effects (Scotto et al. 1971). This is not completely unexpected because high dietary K usually exerts its role in Mg and Ca metabolism in the gastro-intestinal tract rather than in the blood or other body tissues.

Tetany cows consistently had lower levels of plasma glucose and lactic acid prior to tetany which increased rapidly at tetany. The reasons for the differences between tetany and non-tetany cattle prior to the tetany symptoms is not apparent; it appears that some metabolic abnormality, yet unexplained, may be present. It is of interest that a similar hemopattern also occurs with epilepsy in man (Orringer et al. 1977). Plasma β-hydroxybutyric acid was lowest near the beginning of the study and steadily increased until the time of tetany (figure 3). This ketone body reflects the catabolism of body fat and an increase in β-hydroxybutyric acid may reflect a reduced consumption of forage. A large increase in plasma β-hydroxybutyric acid concentrations was associated with the period of severe hypocalcemic tetany. This increase in plasma β-hydroxybutyric acid persisted for about 1 week and then decreased to the end of the study. These differences in plasma β-hydroxybutyric acid between the tetany and non-tetany cows were statistically different ($P<.05$) on d 42, 61 and 110. Littledike and Cox (1979) summarized the effect of fasting on plasma Mg and Ca. Both elements decreased markedly in the plasma during fasting (1 to 6 days). Herd (1966) made similar observations with both cattle and sheep. This inappetence, even for a short period of time, could be an important precipitating factor in the development of tetany in susceptible animals. One week after high levels of β-hydroxybutyric acid occurred and probably low forage intake, the level of plasma Mg also dropped (1.2 mg/dl) (Bohman et al. 1983a). This could be fasting hypomagnesemia rather than some other metabolic malfunction.

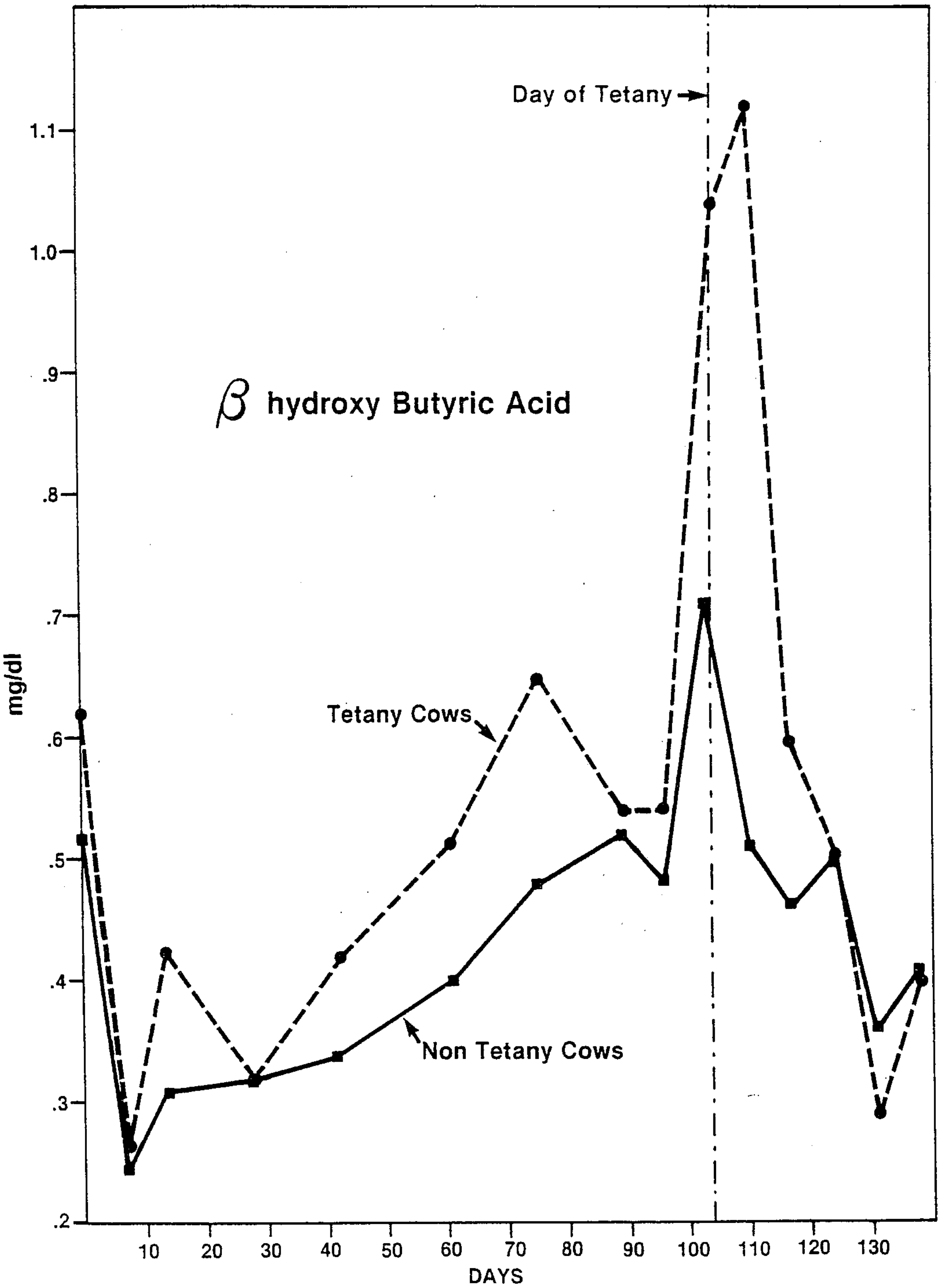


Figure 3. Beta hydroxybutyric acid in the plasma of tetany (5 cows) and non-tetany (27 cows) animals. (Bohman et al. 1983a).

Generally animals recovered faster from fasting hypocalcemia than from hypomagnesemia.

Blood urea nitrogen (BUN) is indicative of N intake (Bartley et al. 1976; Bohman et al. 1983a). During most of the grazing season, cattle that developed tetany had higher levels of BUN suggesting that their intake was higher in N and possibly other metabolities, perhaps to their detriment, especially near tetany. Apparently these animals (tetany cows) selected forage higher in nitrogen during the pretetany period and especially near tetany. High concentrations of dietary N have been associated with tetany in other studies (Belyea et al. 1978; Bohman et al. 1983b; Horn, et al. 1980; Kemp et al, 1961; Stewart et al. 1981). In fact, at times, the N levels have been high enough that ammonia toxicity has been postulated in grazing animals (Horn et al. 1977; Horn, 1980) but blood ammonia did not reach toxic levels in those studies.

Mean plasma hydroxyproline concentrations were 1.4 μg/ml or more in both groups of cows at the beginning of the experiment while the cows were still consuming hay and were hypocalcemic (Bohman et al. 1983a). However, plasma hydroxyproline decreased steadily in both groups of cows until d 89 as plasma Ca increased (figure 4). At tetany, the plasma hydroxyproline in the tetany cows rose sharply while plasma Ca precipitously dropped. Post tetany the plasma hydroxyproline continued to rise until the end of the study, except for d 110. On d 8 (December 13), plasma hydroxyproline concentrations were higher ($P<.05$) in tetany cows than the non-tetany animals during April (d 119 to 138). If plasma hydroxyproline is a true indicator of the level of bone resorption that existed, then bone Ca was more important in attempting to maintain Ca homeostasis at the beginning and the end of the experiment than during the several weeks before tetany. It also implies that dietary Ca was adequate to maintain plasma Ca during most of the pre tetany period. Thus, bone Ca may have been more important in the maintenance of plasma Ca when levels of N, lipids, K and aconitic acid were high in the forage compared to usual values which would tend to limit the uptake of both dietary Ca and Mg. After tetany, the levels of plasma hydroxyproline increased in all cows. Because tetany cows calved an average of 2 weeks before the non-tetany animals, the higher hydroxyproline levels of this group during the post tetany period may be a reflection of the increased demands for Ca due to lactation and mobilization of bone Ca that occurred to meet this demand. The tetany cows calved on the average 4.5 days post tetany.

In another study (Martin et al. 1983), the extended adminstration of KCl (300 g/day) caused both hypocalcemia (4.7 mg/dl) and hypomagnesemia (1.0 mg/dl) in growing heifers which would make the animals more tetany prone. High levels of citric acid or aconitic acid have been associated with induced tetany. Citric acid is rapidly absorbed from the rumen and it is postulated that aconitic acid is also. Hence, the effect of these acids of Mg and possibly Ca availability occurs post absorption (Bohman, 1969; Scotto et al. 1972). High K diets have consistently been associated with tetany (Bohman et al. 1983b, Horn, 1980; Bohman et al. 1969). Other investigators have also noted a positive relationship between K and N (Miller, 1939; Metson et al. 1966).

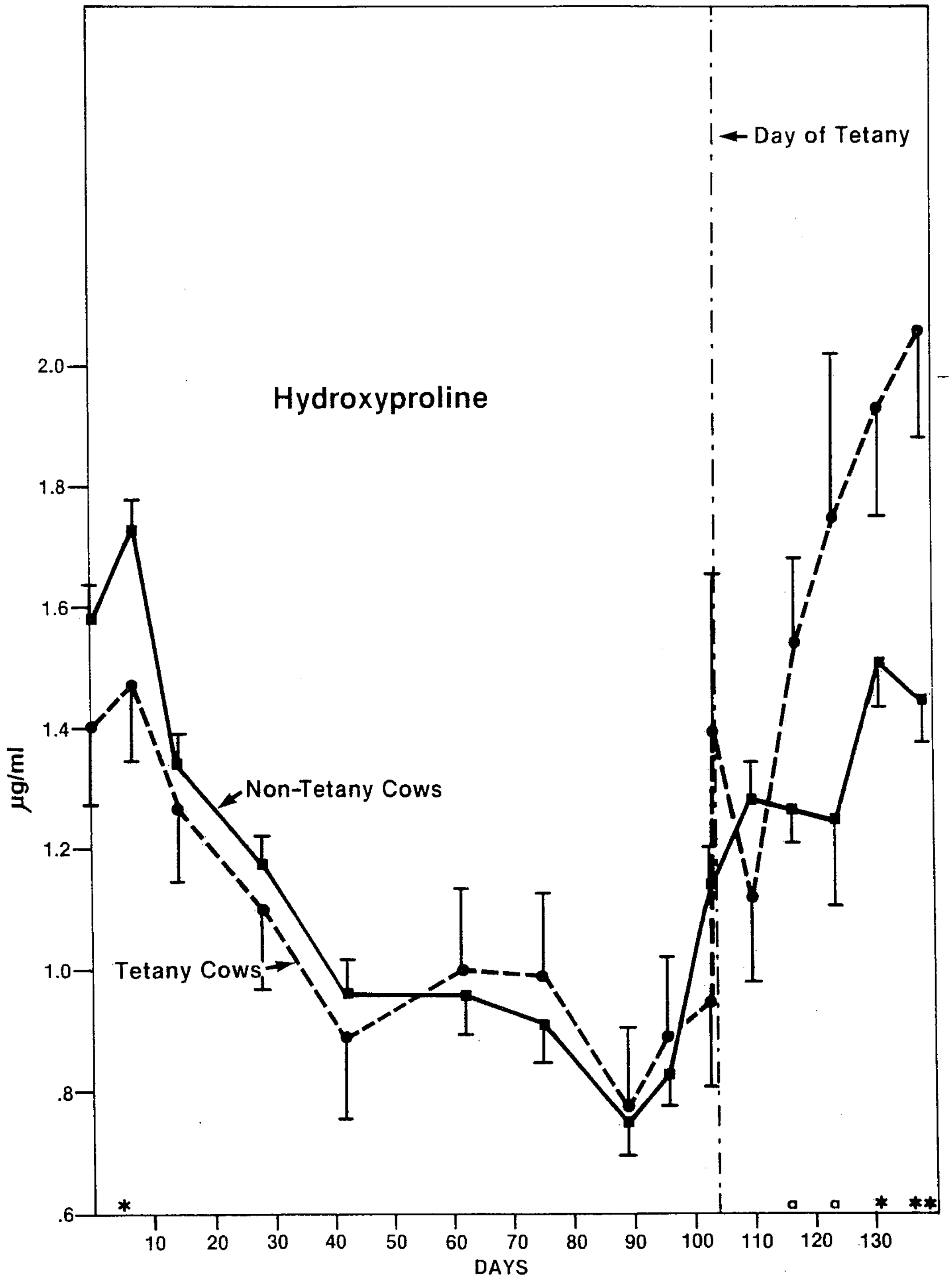


Figure 4. Plasma hydroxyproline in tetany (n=5) and non-tetany (n=27) cows. Statistical significance between plasma values of tetany and non-tetany cattle is indicated as follows: **, significant at P <.01; *, significant at P <.05; [a], significant at P <.0. Each value is the ± SE (Bohman et al. 1983a).

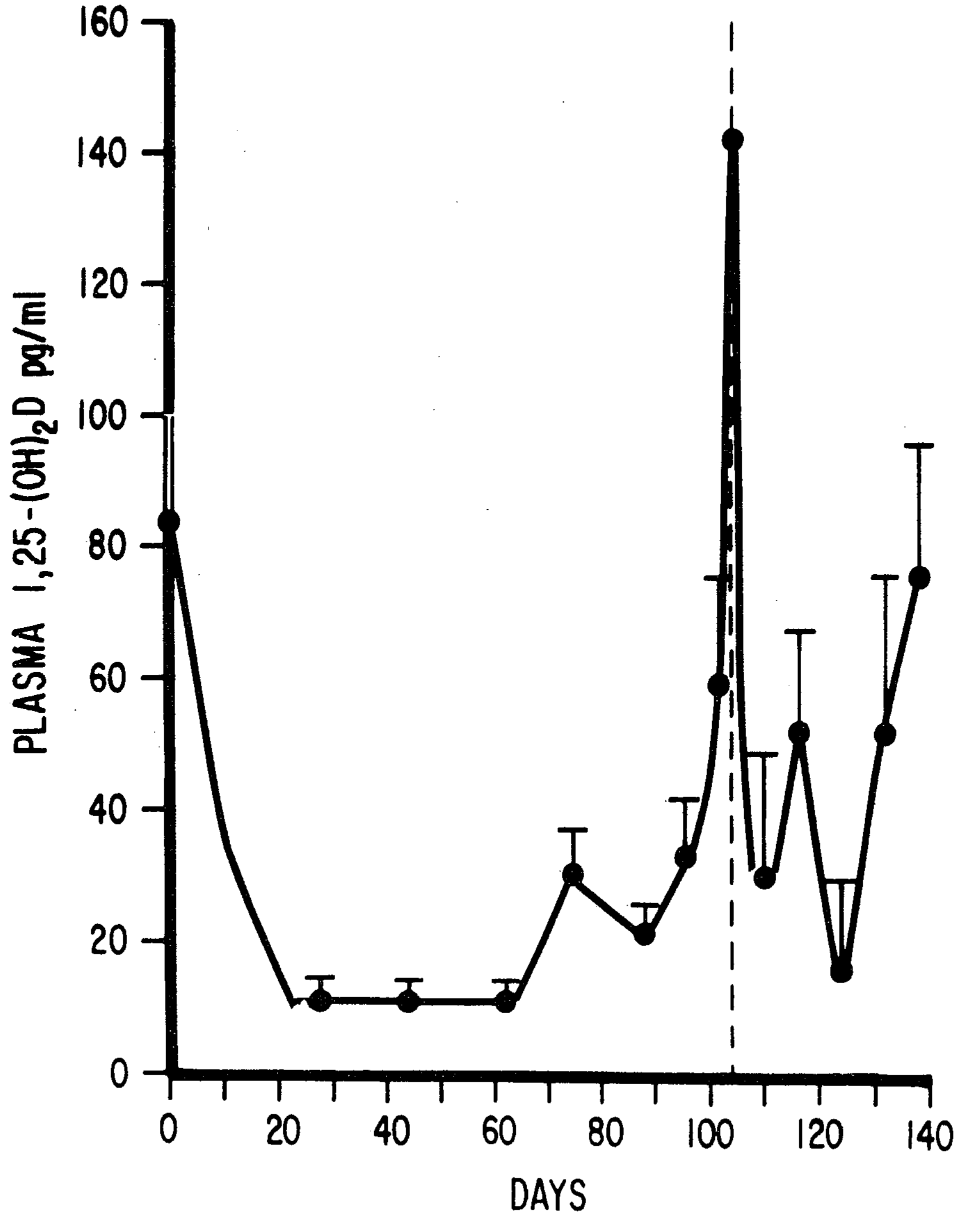


Figure 5. Plasma vitamin 1, 25-$(OH)_2D$ concentration in tetany cows (5). Each value is the mean $\pm$ SE (Bohman et al. 1983a).

Areas of Needed Research

Several questions are yet to be answered in regards to WPP, such as: What is the most effective way to maintain suitable levels of plasma Ca? (Suggested answers to this question may be in areas of PTH manipulation, Ca supplementation, Mg additions to water or feed, or use of 1, 25-$(OH)_2D$.) What is the role of natural chelating elements present in the diet i.e. citrate, aconitate, fatty acids etc? Are there better ways to predict the occurrence of tetany at a suitable time that are economically effective? Although the environment where tetany occurs is similar to the environment that produces bloat in young cattle, what is the relation, if any, between these metabolic conditions. Citrate, malate and/or aconitate are present in forage samples at high levels at times. Metabolically, does the animal differentiate between these acids? Can we apply knowledge learned from a study of milk fever to reduce the incidence of WPP? Can legumes be coseeded with cereal grains to meet the need for additional Ca? Answers to these questions will increase our knowledge of WPP poisoning and will also help us to prevent this problem in the future.

Literature Cited

Belyea, R.L., F.A. Martz, R.E. Rickets, R.R. Rachlow and R. C. Bennett, 1978. In vitro dry matter digestibility, detergent fiber, protein and mineral content of wheat forage as a dairy cattle feed. J. Anim. Sci. 46:873.

Bohman, V.R., F.P. Horn, E.T. Littledike, J.G. Hurst and D. Griffin. 1983a. Wheat pasture poisoning II. Tissue composition of cattle grazing cereal forages and related to tetany. J. Anim. Sci. 59: 1364.

Bohman, V.R., F.P. Horn, B.A. Stewart, A.C. Mather and D.L. Grunes. 1983b. Wheat pasture poisoning I. An evaluation of cereal pastures as related to tetany in beef cows. J. Anim. Sci. 59: 1352.

Bohman, V.R., A.L. Lesperance, G.D. Harding and D.L. Graves. 1969. Induction of experimental tetany in cattle. J. Anim. Sci. 29:99.

Contreras, P.A., R. Manston and B.F. Sansom. 1982. Calcium mobilization in hypomagnesemic cattle. Res. Vet. Sci. 33:10.

Crookshank, H.R. and F.H. Sims. 1955. Serum values in wheat pasture poisoning cases. J. Anim. Sci. 14:964.

Herd, R.P. 1966. Fasting in relation to hypocalcemia and hypomagnesemia in lactating cows and ewes. Aust. Vet. Journal. 42:269.

Horn, F.H. 1983. Metabolic disorders of cattle grazing wheat pasture. In Proc. John Lee Pratt Inst. Symp. Role of magnesium in animal nutrition. Blacksburg, VA. 211.

Horn, F.P., G.W. Horn and H.R. Crookshank. 1977. Effect of short-term fasting and refeeding on weight and blood components of steers grazing wheat pasture. J. Anim. Sci. 44:288.

Kemp, A., W.B. Deija, O.J. Hemkes and A.J.H. VanEs. 1961. Hypomagnesemia in milking cows: Intake and utilization of magnesium from herbage by lactating cows. Netherlands J. Agr. Sci. 9:134.

Littledike, E.T. and P.S. Cox. 1979. Clinical, mineral and endocrine interrelationships in V.F. Rendig and D.L. Grunes (Ed.) Grass Tetany, Am. Soc. Agron. Pub. #35, Madison, WI.

Littledike, E.T., J.W. Young and D.C. Beitz. 1981. Common metabolic diseases of cattle: Ketosis, milk fever, grass tetany and downer cow complex. J. Dairy Sci. 64:1465.

Martin, D.G., V.R. Bohman, C.R. Blincoe and D.R. Hanks. 1983. Prolonged administration of citric acid and potassium chloride to growing beef heifers. Proc. West. Sec. Amer. Soc. Anim. Sci. 34:320.

Plasma 1, 25-$(OH)_2D$ concentrations in cows with tetany (figure 5) were initially quite high, but decreased to low concentrations when the cows were put on pasture. At the time of tetany and severe hypocalcemia, 1, 25-$(OH)_2D$ concentrations markedly increased and then later returned to the normal range. The plasma levels of 1, 25-$(OH)_2D$ and PTH paralleled each other at this time, further substantiating the role of hypocalcemia in inducing tetany.

With the high levels of plasma PTH and 1, 25-$(OH)_2D$ and the extremely low level of plasma Ca at tetany, the tetany was caused by hypocalcemia and not hypomagnesemia. Although hypomagnesemia did occur prior to and after tetany, the levels were higher than those usually associated with tetany. Undoubtably Ca and Mg metabolism are interrelated in this malady.

Conclusions

1. Mature cattle frequently develop tetany when grazing wheat forage.

2. This tetany, wheat pasture poisoning, is predominently of the milk fever type i.e.: low levels of plasma Ca and lethargic behavior. However, if the cattle are both hypocalcemic and hypomagnesemic, the animal will be excitable.

3. Conditions for the initiation of (WPP) are similar to those described for hypomagnesemia.

4. On occasion, afflicted cattle may be both hypomagnesemic as well as hypocalcemic and on these occasions will be excitable.

5. At tetany, cattle will have high levels of plasma glucose and lactic acid with normal levels of K. They will also have elevated levels of PTH and 1, 25-$(OH)_2D$.

6. High levels of plasma β-hydroxybutyric acid suggests that inappetence occurs near tetany which may be a contributing factor to the initiation of tetany symptoms.

7. Hypomagnesemia may also be a contributing factor to the initiation of WPP tetany symptoms by decreasing the rate of mobilization of Ca from the bones.

8. As tetany approaches, little mobilization of bone Ca occurs as indicated by the low levels of hydroxyproline in the blood. Bone Ca plays an important role at tetany in an attempt to create Ca homeostasis in the blood.

9. High levels of dietary K for extended periods will lower plasma levels of both Mg and Ca.

10. Management procedures to maintain normal plasma levels of Ca and Mg appear necessary to prevent this malady.

McMillen, W.N. and W. Langham. 1942. Grazing winter wheat with special reference to the mineral blood picture. J. Anim. Sci. 1:14.

Metson, A.J., W.M.H. Saunders, T.W. Collie and V.W. Graham. 1966. Chemical composition of pastures in relation to grass tetany in beef breeding cows. N. Zealand J. Agr. Res. 9:410.

Miller, E.C. 1939. A physiological study of the winter wheat plant at different stages of its development. Kansas Agr. Exp. Sta. Tech. Bull. 47.

Orringer, E.E., J.C. Eustace, C.D. Wunsch and L.B. Gardner. 1977. Natural history of lactic acidosis after grand-mal seizures. New England J. Med. 297:796.

Sansom, B.F., R. Manston, and M.J. Vagg. 1983. Magnesium and milk fever. Vet. Record. 112:447.

Scotto, K.C., V.R. Bohman and A.L. Lesperance. 1971. Effect of oral potassium and sodium chloride on plasma composition of cattle: a grass tetany related study. J. Anim. Sci. 32:354.

Sell, J.L. and J.P. Fontenot. 1980. Magnesium in animal nutrition. National Feed Ingredients Ass'n. One Corporate Place, Suite 375, West Des Moines, Iowa.

Sjollema, B. 1932. Nutritional and metabolic disorders in cattle. Nutr. Abst. Rev. 1:621.

Stewart, B.A., D.L. Grunes, A.C. Mathers and F.P. Horn. 1981. Chemical composition of winter wheat (Triticum aestivam L.) forage grown where tetany occurs. Agron. J. 59:21.

WHEAT PASTURE BLOAT OF STOCKER CATTLE: A COMPARISON WITH LEGUME PASTURE BLOAT

R. E. Howarth[1] and G. W. Horn[2]

SUMMARY

Research on wheat pasture bloat of cattle has been conducted primarily in four areas: (1) the grazing behavior of cattle during passage of a weather front, (2) the chemical composition of forage samples from wheat pastures where bloat was and was not observed, (3) relationships between chemical components of wheat forage and characteristics of rumen fluid foam, and (4) the role of rumen motility and function of the cardia in the bloating of wheat pasture stocker cattle. The first three of these areas are discussed in this paper and the fourth is discussed in the paper by Colvin and Horn, in these proceedings.

Recent studies on the causes and occurrence of alfalfa pasture bloat have involved comparisons of bloat-safe and bloat-causing legumes and examination of forage and rumen fluid composition in relation to the occurrence of bloat or frothy rumen contents. The theories that fraction 1 (or 18 S) protein and/or saponins cause bloat on alfalfa pasture have been replaced by a theory involving both soluble and insoluble protein fractions, as well as their release during grazing and microbial digestion.

INTRODUCTION

Frothy bloat is a major cause of death of stocker cattle grazed on winter wheat pastures of the Southern Great Plains (4). Death losses are believed to be about 2.5% of total stockers and have been as high as 20% on some pastures. Less research has been conducted relative to bloat on wheat pasture as compared with legume pasture bloat. Therefore, this paper reviews the present knowledge on wheat pasture bloat and compares it with legume pasture bloat. Emphasis is given to understanding the basic

[1]Senior Research Scientist, Agriculture Canada, 107 Science Crescent, Saskatoon, Saskatchewan, S7N 0X2, Canada.

[2]Animal Science Department, Oklahoma State University, Stillwater 74078.

causes of pasture bloat and to assessing the risk of bloat by field observations or laboratory analyses. The ultimate goal is to suggest and evaluate management practices for the control of wheat pasture bloat.

REVIEW OF LITERATURE

Occurrence of bloat on wheat pasture

Bloat of stocker cattle on wheat pastures of the Southern Great Plains may occur throughout the grazing season but two peak periods occur in November and March when the wheat is succulent and growing rapidly. The number of deaths due to bloat also increases during periods of rapidly fluctuating weather conditions (4).

Horn et al. (9) conducted grazing behavior studies during the 1973-74 wheat pasture grazing season. Thirty stocker calves on wheat pasture were observed continuously for a 72-hour period while a severe weather front was moving through the area. Observations were made every 15 min as to how many calves were grazing, not grazing, seeking shelter, lying down, or drinking water. The normal grazing period was from 7 am to 12 midnight, but they grazed most intensively from 9-10 am and 8-10 pm. All the calves sought shelter immediately before the storm front hit the pasture (5 pm, 2-20-74), and did not graze again until the weather had cleared (9 am, 2-21-74). Once they began to graze again, they grazed very intensively for 6 to 8 hours. About 25% of the calves exhibited marked abdominal distension at 9 hours after the weather had cleared and were believed to be bloated. These studies indicated that self-imposed periods of non-grazing for various periods of time could occur quite frequently in stocker cattle on the Southern Great Plains, and may be an important etiological factor in bloat. Periods of little or no grazing followed by periods of very active grazing could be conducive to bloat. The implication of these studies is that cattle on wheat pasture be filled with hay, silage or some other roughage immediately before or after passage of weather fronts. One cannot, however, get too excited about the practicality of such a recommendation.

Heavy frosts frequently accompany early winter weather fronts, and many producers feel that bloat in cattle is increased by grazing frosted forage. However, the grazing study suggests that altered grazing behavior may also contribute.

Occurrence of bloat on alfalfa

On the Northern Great Plains, bloat may occur on grass-alfalfa pastures with one peak period occurring during the spring flush of growth when the forage is immature and succulent. A second smaller peak occurs around the time of the first fall frost. The fall frost periods are not usually accompanied by storms, suggesting that frost contributes to the occurrence of bloat by rupture of the plant cells, rather than by disruption of grazing behavior. However, grazing behavior may be altered by flies and mosquitoes and farmers have associated these disruptions with the occurrence of bloat. Thus field observations in the Northern Plains suggest that both frosted forage and disruptions in feeding patterns may contribute to the occurrence of legume bloat.

The Canadian experimental studies on alfalfa bloat have been conducted at the Summerland (27) and Kamloops (17,23,24) Research Stations in the province of British Columbia. The cattle are held in a feedlot and each morning they are fed freshly chopped alfalfa herbage. They eat to voluntary intake and excess feed is removed in mid-afternoon. Cattle are scored for the occurrence and severity of bloat, usually 2 hours after feeding. In recent years, all the cattle have been rumen cannulated. The cannulae are opened each day to relieve bloat and to examine the rumen contents for frothiness. The alfalfa is grown with irrigaton and is cut at the vegetative to early bloom stages of growth. The two locations are interior mountain valleys with warm, arid climates. Average day/night temperatures are 29/13°C in July and 22/7°C in May and September.

In these studies, bloat has been closely associated with maturity of the alfalfa. The occurrence of bloat is high during the prebud and early bud stages of growth and decreases rapidly thereafter. Except for fall frosts, there has been no seasonal variation in bloat incidence, probably because the alfalfa is irrigated. A high incidence of bloat has been observed on frosted alfalfa, without alteration in the feeding pattern.

Chemical composition of bloat-causing wheat pasture

Bartley et al. (1) reported the dry matter, crude protein, insoluble and soluble protein, and non-protein nitrogen concentrations in forage samples from wheat pastures where bloated or dead cattle were observed and compared them to where there was no evidence of bloat. They suggested a possible relationship between the incidence of bloat in wheat pasture stocker cattle and the nitrogen-containing fractions of wheat.

Table 1 shows the composition of wheat forage samples collected from Oklahoma wheat pastures where bloat was not observed and where bloat was frequently observed and/or stockers had very recently died of bloat (10). Forage samples from bloat-provocative pastures contained less dry matter and neutral detergent fiber (NDF). The concentrations of crude protein and soluble nitrogen (N) fractions (total soluble N, soluble protein N, and soluble non-protein N) of forage samples from bloat provocative pastures were all significantly increased ($P<.05$).

Mader et al. (22) reported that wheat forage from one pasture (where 18 steer days of bloat occurred) had higher ($P<.05$) crude protein and in vitro dry matter disappearance values and lower ($P<.05$) NDF concentrations than wheat forage of another pasture in which only one steer day of bloat occurred.

Chemical composition of legumes in relation to bloat

After the general recognition that legume pasture bloat is a frothy bloat, research on legume pasture bloat was dominated by efforts to identify the forage constituent(s) responsible for the frothiness of rumen contents. Proteins, saponins, lipids, minerals, pectic substances, and other carbohydrates were implicated by various researchers (3). A summary of the reported relationships to the occurrence of bloat is shown in Table 2. Generally, percent dry matter and fiber content of the forage have a negative relationship to the occurrence of bloat, while the intracellular constituents (non-protein nitrogen, protein, starch, etc.) have a positive association with bloat.

The soluble proteins have received the most attention as the principal bloat-causing constituents of legumes, and one of the soluble proteins, fraction I (or 18 S) protein has received special attention as a foam stabilizing protein. It is enzymatically active as ribulose diphosphate carboxylase (28) in the important photosynthetic step of carbon dioxide fixation (29).

At one time fraction I protein was thought to be the exclusive foaming agent in alfalfa (26,27) but this theory has now been proven invalid (18). Howarth et al. (17) examined all the protein and nitrogen fractions in relation to the occurrence of bloat. Most of the fractions examined gave statistically significant, but relatively low correlations with the occurrence of bloat (Table 3). This relationship is very closely linked to the maturity of the forage. When a regular supply of immature alfalfa is available, the correlations between bloat and forage protein content are very low and are not always statistically significant.

Certain legume forages, eg. arrowleaf clover, sainfoin, birdsfoot trefoil, sericea lespedeza, crownvetch, and cicer milkvetch, are bloat-safe or nonbloating. Tannins, which precipitate soluble protein, were the traditional explanation for bloat-safe legume forages (19). Although tannins are not present in any bloat-causing legumes, they are also absent from some bloat-safe legumes, i.e. arrowleaf clover and cicer milkvetch. Howarth et al. (14) observed greater cell wall strength in some nonbloating legumes and formulated the cell rupture theory. This theory proposed that cell walls of bloat-safe forages are more resistant to rupture than the cell walls of bloat-causing forages. Thus intracellar constituents are released sufficiently slow into the rumen fluid that bloat does not occur. Leaf rupture could result from mechanical rupture during grazing or from digestion of the cell wall by rumen microorganisms.

Subsequent investigations demonstrated that bloat-safe legumes are digested more slowly than bloat-causing legumes (5,6,11,12, 13,15). All of the bloat-safe legumes examined to date have slower digestion (Table 4). This characteristic has been attributed to a variety of factors, i.e. slower leaching of nutrients (6), the presence of tannins (11), vein structure (20), and mesophyll cell wall characteristics (2,5,11,14,20,21), including thickness and mechanical strength.

The rates of digestion and cell rupture theories form the basis of the Canadian program to breed a bloat-safe alfalfa. Rates of digestion are determined by a modified nylon bag technique. Dry matter disappearance (DMD) is measured after a 4-6 hour period of digestion when typical DMD values for alfalfa are 40-70% (12).

It was of interest to know whether changes in rates of digestion might correlate with day-to-day changes in the occurrence of bloat from immature alfalfa. Like the nitrogen and protein fractions, significant correlations were observed but the differences were small compared to the effects of animal predisposition to bloat. Rates of digestion in alfalfa decrease with maturity of the stand.

The possible role of alfalfa saponins in pasture bloat was

Stocking rate may influence the occurrence of bloat by affecting the maturity of forage available to the cattle. The accumulated forage in an understocked pasture will become mature and fibrous and the incidence of bloat should decrease. Conversely, a heavily stocked pasture will have a smaller proportion of accummulated growth and a higher proportion of immature regrowth. Bloat is more likely in this situation. Figure 2 shows the relationship between some factors affecting wheat forage maturity and possibly the incidence of bloat.

Climatic and Soil Fertility Effects

Climatic and soil conditions may alter the normal pattern of plant growth and thus influence the occurrence of bloat. A high risk of bloat is associated with rapid growth during the vegetative stage of growth. Rapid growth requires optimum temperatures and adequate availability of soil moisture and minerals. Cool temperatures will delay maturity and prolong the high risk period. Cool night temperatures in particular, including light frosts, have a positive association with bloat. Conversely high temperatures and/or drought stress will accelerate the physiological maturation of the forage and reduce the risk of bloat.

Mineral composition is the one area where wheat and legume forages are quite different. Field observations on soil fertility and plant mineral composition in relation to legume bloat are often contradictory, suggesting that these relationships are not simple. At this time, recommendations for mineral supplmentation or soil fertility amendments to control bloat should be regarded as highly speculative and not supported by adequate research.

CONCLUSIONS

Alfalfa causes bloat because it has a high protein content and because it is susceptible to rapid digestion in the rumen. Both soluble and insoluble protein constituents of alfalfa are now implicated in causing bloat. Animal susceptibility to bloat is related to the concentration of chloroplast membrane fragments suspended in the rumen fluid. These fragments, with their adherent bacteria, contribute to frothiness of rumen contents and provide an active innoculum for the rapid fermentation of newly ingested forage. Frothiness occurs prior to feeding and the immediate onset of rumen distension is caused by the rapid fermentation of readily digestible nutrients released from the newly ingested forage.

Wheat pasture herbage is very similar to immature alfalfa in having a high percentage of protein and soluble nutrients that are susceptible to rapid digestion. Athough data are not available on rumen fluid chlorophyll for wheat pasture bloat, the grazing behavior studies suggest that predisposition of the rumen followed by a fill of readily digested herbage is also involved in the occurrence of wheat pasture bloat.

Both types of bloat are associated with immature forage, rapid growth, frost, and disruptions in feeding pattern. The climatic and soil fertility effects are complex and are not fully understood at this time.

AREAS OF NEEDED RESEARCH

1. The basic causes of bloat of cattle on wheat and alfalfa pastures appear similar. This needs to be confirmed so that research methods from alfalfa bloat (plant nitrogen, rates of digestion, and rumen chlorophyll) can be applied to wheat pasture bloat. Factors affecting predisposition of cattle to wheat pasture bloat (e.g., the dispersion of chloroplast particles in rumen fluid, pH, electrolytes etc.) and the clearance of particles from the rumen should be investigated.

2. Establish whether the association of bloat with high water content of forages is related to stage of maturity _per se_ and the presence of foam stabilizing components or to impaired eructation.

3. Clarify the etiological significance of altered grazing behavior (and rate of forage intake) of stocker cattle on wheat pasture due to movement of weather fronts _versus_ changes in chemical composition and/or fragility of forage affected by frost.

4. Clarify the etiological significance of the mineral status of stocker cattle on wheat pasture, and possible effects of mineral supplementation on the occurrence of bloat.

5. Establish whether bloat is related to:

    A. Type (anhydrous ammonia _versus_ ammonium nitrate and/or urea) and amount of nitrogen fertilization of soils.
    B. Soil type (ie., sandy _versus_ "tighter" soils).

Is soil type (including mineral content) *per se* important or rate of soil warming important?

6. Develop a wheat forage growth model that would include effects of key environmental factors on rate of wheat forage growth and chemical components associated with bloat.

7. Determine the effects of continuous feeding of bloat preventive compounds on weight gains of cattle on wheat pasture, and the economics of their long-term use.

8. Develop slow-release surfactant(s), which could be administered for prevention of bloat once or twice during the wheat pasture grazing period.

9. Selection of low-bloat or bloat-free wheat varieties.

LITERATURE CITED

1. Bartley, E. E., G. W. Barr, and R. Mickelsen. 1975. Bloat in cattle. XVII. Wheat pasture bloat and its prevention with poloxalene. J. Anim. Sci. 41:752.
2. Cheng, K.-J., J. P. Fay, R. E. Howarth, and J. W. Costerton. 1980. Sequence of events in the digestion of fresh legume leaves by rumen bacteria. Appl. Environ. Microbiol. 40: 613-625.
3. Clarke, R. T. J., and C. S. W. Reid. 1974. Foamy bloat of cattle. A review. J. Dairy Sci. 57: 753-785.
4. Clay, B. R. 1973. Stocker cattle losses on small grain pastures. J. Okla. Vet. Med. Assn. 25:15-20.
5. Fay, J. P., K.-J. Cheng, M. R. Hanna, R. E. Howarth, and J. W. Costerton. 1980. In vitro digestion of bloat-safe and bloat-causing legumes by rumen microorganisms: Gas and foam production. J. Dairy Sci. 63: 1273-1281.
6. Fay, J. P., K.-J. Cheng, M. R. Hanna, R. E. Howarth, and J. W. Costerton. 1981. A scanning electron microscopy study of the invasion of leaflets of a bloat-safe and a bloat-causing legume by rumen microorganisms. Can. J. Microbiol. 27: 390-399.
7. Frost, D. F. 1978. Ruminal motility and bloat potential of wheat pasture stockers. M.Sc. Thesis. Oklahoma State University, Stillwater.
8. Frost, D. F., G. W. Horn, L. I. Croy, and G. L. Burnett. 1978. Stocker bloat on wheat pasture. Okla. Agr. Exp. Sta. Res. Rep. MP-103:54-59.
9. Horn, F. P., G. W. Horn, H. R. Crookshank, W. Jackson, H. J. Muncrief, and R. Osborne. 1976. Influence of periods of starvation on blood ammonia and plasma urea concentrations of steers grazing wheat pasture.

Okla. Agr. Exp. Sta. Res. Rep. MP-96:48.

10. Horn, G. W., B. R. Clay, and L. I. Croy. 1977. Wheat pasture bloat of stockers. Okla. Agr. Exp. Sta. Res. Rep. MP-101:26.

11. Howarth, R. E., K.-J. Cheng, J. P. Fay, W. Majak, G. L. Lees, B. P. Goplen, and J. W. Costerton. 1983. Initial rate of digestion and legume pasture bloat. p. 719-722. In J. A. Smith and V. W. Hays (ed.) Proc. XIV Int. Grassl. Cong.

12. Howarth, R. E., B. P. Goplen, S. A. Brandt, and K.-J. Cheng. 1982. Disruption of leaf tissues by rumen microorganisms: an approach to breeding bloat-safe forage legumes. Crop Sci. 22:564-568.

13. Howarth, R. E., B. P. Goplen, J. P. Fay, and K.-J. Cheng. 1979. Digestion of bloat-causing and bloat-safe legumes. Ann. Rech. Vet. 10: 332-334.

14. Howarth, R. E., B. P. Goplen, A. C. Fesser, and S. A. Brandt. 1978. A possible role for leaf cell rupture in legume pasture bloat. Crop Sci. 18: 129-133.

15. Howarth, R. E., G. L. Lees, B. P. Goplen, W. Majak, and K.-J. Cheng. 1983. Arrowleaf clover (Trifolium vesiculosum Savi): A unique bloat-safe legume. Agron. Abst. p. 134.

16. Howarth, R. E., W. Majak, A. C. Fesser, and P. Narasimhalu. 1983. Rumen fluid chlorophyll and protein concentrations in relation to alfalfa pasture bloat. In preparation for Can. J. Anim. Sci.

17. Howarth, R. E., W. Majak, D. E. Waldern, S. A. Brandt, A. C. Fesser, B. P. Goplen, and D. T. Spurr. 1977. Relationships between ruminant bloat and the chemical composition of alfalfa herbage. I. Nitrogen and protein fractions. Can. J. Anim. Sci. 57: 345-357.

18. Howarth, R. E., J. M. McArthur, M. Hikichi, and S. K. Sarkar. 1973. Bloat investigations: denaturation of alfalfa fraction II proteins by foaming. Can. J. Anim. Sci. 53: 439-443.

19. Kendall, W. A. 1966. Factors affecting foams with forage legumes. Crop Sci. 6: 487-489.

20. Lees, G. L., R. E. Howarth, and B. P. Goplen. 1982. Morphological characteristics of leaves from some legumes forages: relation to digestion and mechanical strength. Can. J. Bot. 60: 2126-2132.

21. Lees, G. L., R. E. Howarth, B. P. Goplen, and A. C. Fesser. 1981. Mechanical disruption of leaf tissues and cells in some bloat-causing and bloat-safe and forage legumes. 1981. Crop Sci. 21: 444-448.

22. Mader, T. L., G. W. Horn, W. A. Phillips, and R. W. McNew. 1983. Low-quality roughages for steers grazing wheat pasture. I. Effect on weight gains and

bloat. J. Anim. Sci. 56:1021-1028.
23. Majak, W., R. E. Howarth, K.-J. Cheng, and J. W. Hall. 1983. Rumen conditions that predispose cattle to bloat. J. Dairy. Sci. 66: 1683-1688.
24. Majak, W., R. E. Howarth, A. C. Fesser, B. P. Goplen, and M. W. Pedersen. 1980. Relationships between ruminant bloat and the composition of alfalfa herbage. II. Saponins. Can. J. Anim. Sci. 60: 699-708.
25. Mangan, J. L. 1958. Bloat in cattle. VII. The measurement of foaming properties of surface-active compounds. N.Z.J. Agr. Res. 1:140-147.
26. McArthur, J. M., J. E. Miltimore, and M. J. Pratt. 1964. Bloat investigations. The foam stabilizing protein of alfalfa. Can. J. Anim. Sci. 44: 200-206.
27. Miltimore, J. E., J. M. McArthur, J. L. Mason, and D. L. Ashby. 1970. The threshold fraction 1 (18 S) protein concentration for bloat and relationships between bloat and lipid, tannin, Ca, Mg, Ni, and Zn concentrations in alfalfa. Can. J. Anim. Sci. 50: 61-68.
28. Trown, P. W. 1965. An improved method for the isolation of carboxy-dismutase. Biochem. 4:908.
29. Weissbach, A., B. L. Horecker, and Jerard Hurwitz. 1956. The enzymatic formation of phosphoglyceric acid from ribulose diphosphate and carbon dioxide. J. Biol. Chem. 218-795.

Table 1. Chemical composition of wheat forage from pastures where bloat was not observed and from bloat-provocative pastures. From Horn et al. (10).

Wheat pasture	Bloat not observed	Bloat provocative pastures
Number of samples	9	7
Dry matter (DM), %	28.48	22.31
Neutral detergent fiber, % of DM	44.59	35.02*
Crude protein, % of DM	25.40	31.75*
Soluble nitrogen		
% of DM	1.85	3.24**
% of total N	44.94	61.79*
Soluble protein nitrogen		
% of DM	0.79	1.30*
% of total N	19.07	24.53
Soluble non-protein nitrogen		
% of DM	1.06	1.94**
% of total N	25.84	37.18**
Soluble carbohydrate, % of DM	13.09	9.27

Significantly different from wheat forage samples taken from pastures where bloat was not observed: *P<.05; **P<.01.

Table 2. Summary of reported relationships between legume forage constituents and the occurrence of legume pasture bloat.

Plant constituent, %	Relationship to bloat: Positive	None	Negative
Dry matter			-
Fiber			-
Total nitrogen	+		
Insoluble nitrogen		0	
Soluble nitrogen	+		
Soluble proteins	+		
Non-protein nitrogen	+		
Sugars		0	
Starch	+		
Pectin	+		
Lipids	+	0	-
Saponins	+	0	
Tannins			-
Phenols		0	
Sulfur	+		
Calcium	+	0	
Magnesium	+	0	
Phosphorus		0	-
Ca/P ratio	+		
Potassium	+	0	
Sodium			-
K/Na ratio	+		
Nickel	+		
Zinc	+		

Table 3. Distribution of nitrogen (N) fractions in alfalfa and relationships to the occurrence of bloat. From Howarth et al. (16).

Nitrogen fraction	Concentration in alfalfa	Relationship to bloat
	(mg N/g D.W.)	(r^2)
Total N	37.2	.09**
Insoluble N	19.8	.06+
Soluble N	17.8	.12**
Soluble non-protein N	7.4	.08**
Soluble protein N	10.1	.11**
Fraction I (18 S) protein N	1.9	.05
Fraction II protein N	6.7	.07*

**P<.01; *P<.05; +P<.10.

Table 4. Summary of data demonstrating differences between bloat-causing and bloat-safe legumes. Results are expressed as a percentage of results with alfalfa. From Howarth et al. (11).

	Bloat	Dry-matter disappearance		Gas production In vitro+	Sheep rumen fluid	
		Nylon bag*	In vitro**		Soluble protein nitrogen++	Chlorophyll++
Alfalfa	Yes	100	100	100	100	100
Red clover	Yes	101	128	83	–	–
White clover	Yes	103	130	88	–	–
Birdsfoot trefoil	No	79	80	62	12	16
Cicer milkvetch	No	64	80	83	53	51
Sainfoin	No	26	47	58	23	28
Arrowleaf clover	Very little	74#	93#	71#	–	–

* Chopped leaves, 8 hours digestion in fistulated sheep, Howarth et al. (13).
** Whole leaves, 22 hours digestion, Fay et al. (6).
\+ Whole leaves, 10 hours digestion, Fay et al. (5).
++ Two hours after feeding, Howarth et al (13).
\# Howarth et al. (15).

Table 5. Wheat forage chemical components analyzed during the various wheat pasture grazing seasons. From Horn et al. (10), Frost et al. (8) and Frost (7).

Chemical component	Year 1975-76	Year 1976-77	Year 1977-78
Dry matter	x[a]	x[a]	x[b]
Neutral detergent fiber		x[b]	x[b]
Soluble carbohydrates	x[a]		
Fraction I protein	x[a]		
Crude protein	x[a]	x[a]	x[b]
Total soluble nitrogen		x[b]	x[b]
Soluble protein nitrogen		x[b]	x[b]
Soluble non-protein nitrogen		x[b]	x[b]

[a]Samples analyzed at one week intervals.
[b]Samples analyzed at two week intervals.

Table 6. Coefficients of determination (R-square values) between rumen fluid foam stability and chemical component of wheat forage. From Horn et al. (10), Frost et al. (8) and Frost (7).

Independent variables	Year 1975-76	1976-77	1977-78
Crude protein (CP)	.019 NS	.006 NS	.132 NS
Fraction I protein (FIP)	.025 NS	-	-
CP and FIP	.062 NS	-	-
Dry matter, CP, and FIP	.079 NS	-	-
Soluble protein nitrogen (SPN)	-	.318 ***	.089 NS
Neutral detergent fiber (NDF)	-	.360 ***	.123 NS
CP and NDF	-	.418 ***	.157 NS
SPN and NDF	-	.387 **	.197 NS

NS = not significant, P>.05; **P<.01; ***P<.005.

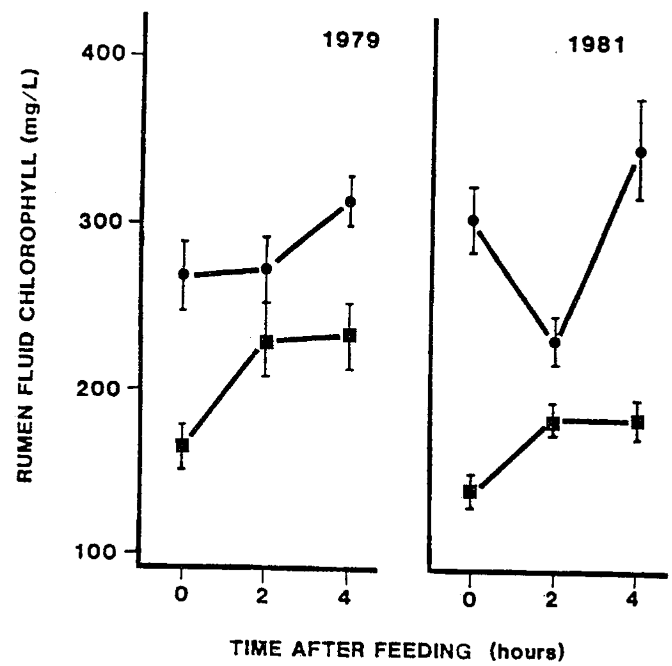


Figure 1. Mean rumen chlorophyll concentration (with standard errors) before (0 h) and after feeding (2 and 4 h) in cattle that bloated (•) and those that did not (■) during 1979 and 1981. From Majak et al. (23).

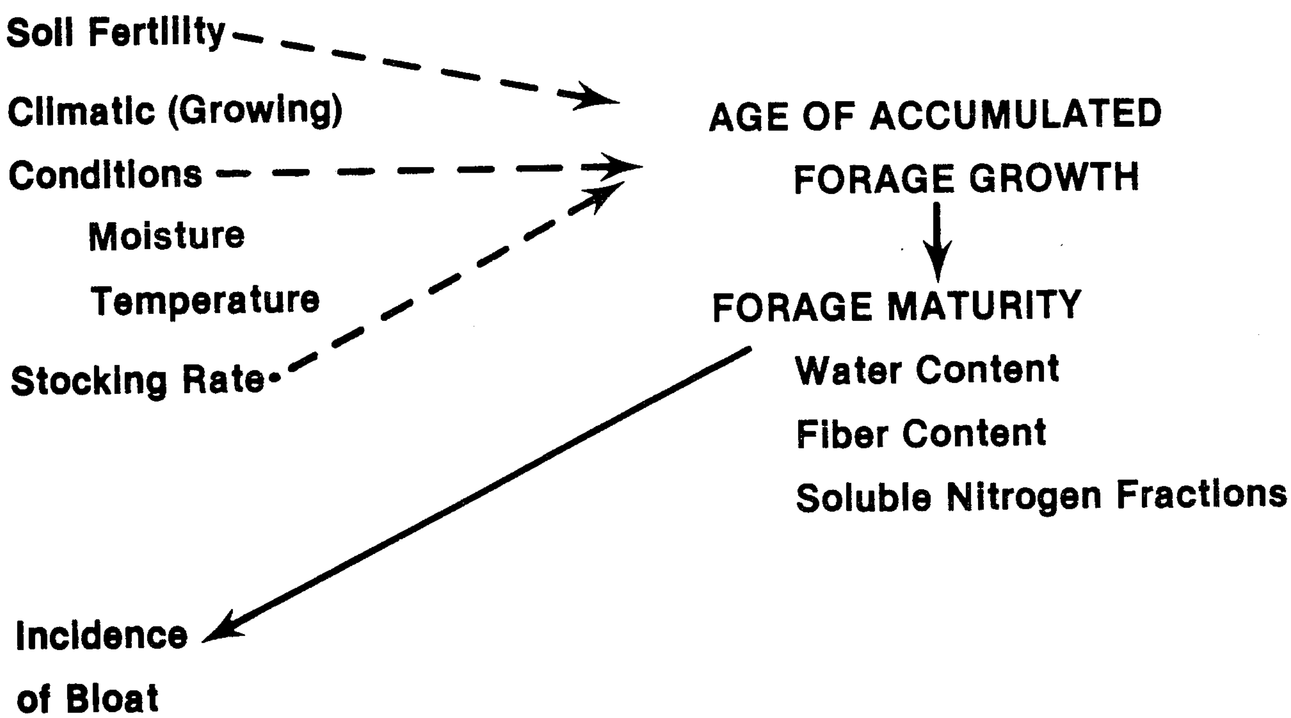


Figure 2. Some variables affecting forage maturity and the incidence of bloat in wheat pasture stockers.

THE SIGNIFICANCE OF RUMINAL MOTILITY IN THE ETIOLOGY OF BLOAT

H. W. Colvin, Jr.[1] and G. W. Horn[2]

University of California, Davis[1]

and

Oklahoma State University, Stillwater[2]

Bloat is a product of domestication and results from our unending attempts to feed high quality nutrients to ruminants as inexpensively as possible. By permitting ruminants to graze high quality pasture in the form of alfalfa, clover, and young cereal grains we by-pass expensive labor costs. But in so doing, we expose ourselves to another expense - death due to bloat (Clark and Reid, 1974).

The reticulorumen is the fermentation area of the ruminant stomach and is the site of the evolution of large volumes of gases, primarily CO_2 and CH_4 (Brodie, 1945). When these gases cannot be rapidly belched away, bloat ensues (Colvin et al., 1959).

Belching (eructation) is associated with one of the contractions of the rumen (Wester, 1926; Weiss, 1953). Recognizing the relationship between eructation and ruminal contractions, Cole et al. (1945) queried, "In bloat, is there a lack of ruminal contractions....?" Fragmentary evidence prompted these workers to conclude that ruminal motility was present during early phases of bloat. In fact, Wester (1926) found rumen contractions to increase in frequency during bloat onset. Convincing evidence to support this contention was presented by Colvin (1957) and Colvin et al. (1978) who worked with bloat-provoking and non-bloat provoking diets and reported a positive linear relationship between ruminal contraction frequency and intrarumen pressure.

This report will be concerned with evidence demonstrating the effect of intraruminal pressure on ruminal motility from naturally bloated cattle and cattle where intraruminal pressure was artificially increased by insufflation of gas into the reticulorumen. For the sake of clarity, a brief review of rumen anatomy and physiology will be presented.

RETICULORUMEN ANATOMY AND PHYSIOLOGY

A diagram of the isolated reticulorumen is shown in figure 1. The following structures should be noted: reticulum, cardiac orifice, anterior dorsal sac, dorsal sac, posterior dorsal blind sac, posterior ventral blind sac, and ventral sac. In the adult animal, the reticulorumen occupies the left side of the abdominal cavity.

The musculature of the reticulorumen is complex and contracts in two distinct sequences. One sequence is referred to as the primary or mixing contraction and the other as the secondary or eructation contraction.

The primary or mixing wave of contraction begins with a biphasic contraction of the reticulum and then passes sequentially to the anterior dorsal sac, dorsal sac, posterior dorsal blind sac, ventral sac, and posterior ventral blind sac. Ingesta and gases are pushed back, down, and then forward (Schalk and Amadon, 1928; Ruckebusch and Tomov, 1973).

The secondary or eructation contraction wave begins with a contraction of the posterior ventral blind sac and involves sequentially contractions of the posterior dorsal blind sac, dorsal sac, and a relaxation of the reticulum (Wester, 1926; Ruckebusch and Tomov, 1973). The purpose of this part of the eructation wave is to move fermentation gases forward to the cardiac orifice. When the intrarumen pressure is at its peak and the reticulum is relaxed, the cardiac orifice actively dilates (Wester, 1926) and the gases rush into the esophagus for indirect disposal into the atmosphere (Colvin et al., 1957). The final phase of the eructation contraction is a contraction of the ventral sac and posterior ventral blind sac (Ruckebusch and Tomov, 1973).

By inserting a cannula through the skin and into the dorsal sac of the rumen (Quin et al., 1938), and connecting the cannula to a pressure sensitive device (Louvier et al., 1979), it is possible to record the changes in intraruminal pressure associated with ruminal contractions.

A record of the pressure changes associated with ruminal contractions is shown in figure 2. These pressure waves, referred to as contractions, are divided into large and small. The large are called primary and are, in fact, the mixing contractions. Numbers 17, 18, and 20 refer to primaries. The small contraction, number 19, is an example of a secondary and is associated with eructation. The normal resting intraruminal pressure is negative.

METHODS

The study of natural and artificial bloat under laboratory conditions requires an evaluation of eructation and ruminal motility. As stated previously, motility can be recorded from a rumen cannula (Quin et al., 1938) connected to a pressure transducer and a suitable recording device (Louvier et al., 1979). The recorder must have at least two channels, one to record changes in intrarumen pressure and one to record atmospheric pressure.

Eructation measurement requires the transected tracheal technique of Colvin et al. (1957). In ruminants, belched gas is not expelled directly into the atmosphere from the esophagus. Rather, as the gas comes up the esophagus, it is aspirated into the trachea via an open glottis and an inspiratory effort. The gas remaining after trans-alveolar absorption is expelled into the atmosphere via the next expiration.

RESULTS AND DISCUSSION

Acute bloat

It is possible to cause bloat under laboratory conditions by feeding the tops (upper 4-5 inches) of pre-bloom alfalfa plants. The sequence of events in a case of laboratory bloat is shown in figures 3, 4, and 5.

The top record of figure 3 shows the fasting preprandial ruminal motility. When this cow was fed a coarse scabrous diet of oat hay, her resting intrarumen pressure would be in the range of -10 to -12 cm HOH. Notice here that her resting intrarumen pressure was only -2, an indication that she had a carry-over effect of the alfalfa tops trial of the previous day, the usual observation when succulent legumes are fed continuously.

In the middle record of figure 3, the cow had been eating for 20 minutes. She had already begun to bloat but she was still eating. The motility rate is now 3-4 times greater than preprandial.

The cow ceased eating 25-30 minutes after food was offered. The bottom record of figure 3 was made at time 40 or 10 minutes postprandial. Intrarumen pressure has continued to increase and the motility rate has declined because of the cessation of afferent impulses associated with receptors involved with chewing and swallowing (Borgatti and Matscher, 1958). However, the contraction rate is 1/3 greater than during the preprandial period. Eructation contractions are occurring regularly but no gas is leaving the rumen.

As shown in figure 4, intrarumen pressure continued to increase for an hour after the end of eating. At this time gas began to be eructated in conjunction with some of the secondary contractions, as shown on the bottom record, and the intrarumen pressure began to decline.

By 90 minutes postprandial eructations were associated with every secondary contraction and by 240 minutes postprandial, intraruminal pressure was slightly sub-atmospheric (figure 5). However, the motility rate is still more rapid than the preprandial rate, and even after 4 hours, eructations were not occurring on every secondary contraction (bottom record, figure 5).

The reason for the ineffectiveness of the eructation contractions was made clear when the experiment was terminated. The rumen was almost filled with frothing rumen ingesta. Other experiments on this same cow showed that when an antifrothing agent was administered after bloating had begun, normal resting intrarumen pressure was achieved within 40 minutes (Colvin et al., 1959). The administration of the antifrothing agent before alfalfa tops were fed prevented bloat completely (figure 6).

Along with the decrease in the primary contraction amplitude there is a change in the character or shape of the contractile wave as intraruminal pressure increases (figures 4 and 9). The relationship between the character of the primary contractions and the electrical activity occurring in the ruminal musculature during elevated intraruminal pressure can be studied by implanting microelectrodes in various areas of the reticuloruminal wall and connecting these electrodes to a sensitive recording device (Ruckebusch et al., 1968).

The electrical activity which accompanies ruminal motility is seen as a rapid series of deflections (spikes) of the writing lever of the electronic recorder which is connected to the myoelectrodes (figure 13). The following is the electrical sequence of events during a primary contraction: reticulum, dorsal sac, posterior dorsal blind sac, ventral sac, posterior ventral blind sac. For the secondary contraction the sequence begins with spiking in the posterior ventral blind sac and proceeds to the ventral sac, dorsal sac, anterior dorsal sac, and finally the ventral sac and posterior ventral blind sac again (Ruckebusch and Tomov, 1973; Colvin et al., 1982). Note the absence of electrical activity in the reticulum during the secondary contraction.

Figure 14 illustrates the influence of a sustained intraruminal pressure of 20 cm HOH on rumen events (Colvin et al., 1982). Contraction 4 is a pre-insufflation normal rumen contraction. Contractions 5, 6, and 7, all primaries, illustrate the immediate effect of pressure of this magnitude on the nature of the contractions. After 1.5 minutes, deciding whether these are contractions or not becomes difficult.

Normal myoelectric activity is shown for contraction 4 (figure 14). Within 30 seconds after insufflation, spiking activity had changed, coinciding with the physical changes in motility. By three minutes, spiking disappeared completely.

Figure 15 illustrates the early phases of the deflation process. Without the eructation measuring apparatus, there would have been great difficulty in determining which was a secondary contraction because the electrical activity was essentially indistinguishable and the motility record difficult to assess. For example, contractions 10E, 11E, and 14E are eructation contractions.

Contraction 30, as shown in figure 16, is 20 minutes after the end of insufflation. It is now possible to differentiate contractions from respiratory events but even the experienced eye could have difficulty in deciding which is a primary and which is a secondary. However, the myoelectrodes assist the decision making process. For example, contractions 26, 27, 29, 30, and 31 are primaries and 28 and 29-1 are definitely secondaries; the former are primaries because of the reticular activity and the latter secondaries because of the absence of reticular activity. Even though the intraruminal pressure is almost normal, electrical activity and motility remain depressed, especially electrical activity in the ventral and posterior ventral blind sacs.

The practice of feeding hay, especially grass hay, before turning cattle out to graze bloat provoking legume pastures, has been used successfully in preventing bloat completely or at least alleviating its severity (Cole and Kleiber, 1945; Colvin et al., 1958a). Low quality roughage in the form of wheat straw or sorghum-sudan hay, was used to control bloat in cattle grazing wheat pasture (Mader et al., 1983). Since the incidence of bloat during the study was low, it was not possible for the workers to make a general recommendation concerning the use of roughage of this type for controlling bloat. It is important, however, if grass hay is to be used to control bloat, for it to be sufficiently palatable so that adequate amounts can be consumed before grazing is permitted (Cole and Kleiber, 1945; Meyer et al., 1956; Colvin et al., 1958a).

In the following experiments, oat hay was fed to cows the night before they were allowed to eat alfalfa tops under laboratory conditions (Colvin et al., 1958b). Measurements included ruminal motility and eructation. The increase in motility rate during eating (figure 7, middle record) exceeded that of fasting (figure 7, upper record). When oat hay was not included in the diet (figure 3, middle record), the cow began to bloat while eating. However, when oat hay was fed before alfalfa tops were fed, intraruminal pressure exceeded atmospheric only slightly at 60 minutes postprandial (figure 8, upper record). By 90 minutes, the intraruminal pressure was sub-atmospheric (figure 8, middle record).

Acute frothy bloat is also a problem in cattle grazing winter wheat. Horn and Frost (1982) conducted ruminal motility studies with stocker cattle grazing such pasture. Measurements were made in two different years with periods for pre-grazing, grazing, and post-grazing.

The results for year one are shown in table 1. The amplitude of the contractions were significantly greater during the grazing period than during the pre- or post-grazing periods. There were no significant differences in contraction frequencies. Significant differences existed between the grazing and pre- and post-grazing periods for amplitude times frequency.

During the second year, the data for the pre- and post-grazing periods were not found to be statistically different; therefore, means were calculated from the pooled data for amplitude, frequency, and amplitude times frequency as shown on the first line of values on Table 2.

There were 14 different trials during the second year. In 10 of the 14 trials, there was no significant difference between grazing and pre- and post-grazing contraction amplitudes.

As far as contraction frequencies are concerned, in 8 of the 14 trials, the values were not significantly different. In 4 trials, the grazing values were significantly lower and in 2, they were significantly higher. In 2 of the 14 trials, amplitude times frequency for the grazing periods were significantly greater than the control periods. In neither of the two years did bloat occur.

The foregoing experiments with cattle either consuming bloat-provoking alfalfa tops under laboratory conditions or grazing immature wheat pasture substantiate two points,

1. During the onset of legume bloat and during the course of a case of bloat which would be classified generally as "moderate", ruminal motility is more active than fasting or pre-prandial motility.

2. Ruminal motility is normal in stocker cattle grazing wheat pasture.

Artificially induced bloat

Whereas, the ruminal motility of cattle during mild and moderate bloat is actually enhanced, what is the effect on motility of intraruminal pressure equivalent to severe bloat? To conduct such an experiment, the pressure within the rumen was artifically elevated to approximately 60 cm HOH by the insufflation of air. Ruminal motility and eructation were evaluated (Colvin, 1957).

Pre-insufflation motility is shown in the upper record of figure 9. The middle record shows the effect on motility of the rapid increase of intraruminal pressure. Note the rapid frequency of the greatly modified contractions. Unlike the naturally bloated cow, eructation was very efficient and intraruminal pressure decreased rapidly. Within 10 minutes intraruminal pressure was less than half the maximum insufflation pressure (figure 9, bottom record). Within 30 minutes post insufflation (figure 10), intraruminal pressure was normal and by 50 minutes, the ruminal contractions were the same as pre-insufflation although they were more frequent (figure 10, bottom record).

The effect of intrarumen pressure on the frequency of rumen contractions is summarized in figure 11 (Louvier et al., 1979). The top lines illustrate the positive linear relationship between intrarumen pressure and the total number of rumen contractions. The middle lines indicate that the frequency of secondary contractions also is positively correlated with intraruminal pressure. The relationship between primary contractions and intrarumen pressure is curvilinear as shown by the bottom lines.

Clearly, there is a maximum frequency of ruminal contractions as dictated by refractory periods in the motility center and rumen musculature itself. As pressure increases, primary contractions decrease to compensate for the increased frequency of secondary contractions.

As can be seen in figures 4 and 9, as intraruminal pressure increases, the amplitude of primary contractions decreases. The graphic relationship of pressure and contraction amplitude is summarized in figure 12 (Louvier and Colvin, 1978).

Contraction 76 on figure 17 is 47 minutes after the end of insufflation. Ruminal contraction amplitude is about normal for this sheep but intraruminal pressure is still atmospheric or slightly above. The electrical activity now has returned to all sacs and resembles very closely the pre-insufflation events.

Chemical compounds and motility

A deleterious effect on motility of various chemical compounds normally found in bloat-provoking plants is, for the most part, undocumented. Compounds such as saponins, which have been isolated and used to study their effect on bloat (Lindahl et al., 1954) and motility (Colvin et al., 1955), have been administered in doses far exceeding concentrations normally found in the rumens of grazing animals. The same is true for compounds in the rumen of metabolic origin, such as, gases (Dougherty, 1942; Clark and Quin, 1945), short-chain organic acids (LeBars et al., 1954; Shinozaki, 1958; Bide and Dorward, 1983), and nitrogenous compounds (Dougherty, 1942; Clark, 1950; LeBars et al., 1957; Shinozaki, 1957; Bueno et al., 1977; Juhasz and Szegedi, 1983).

It is true that extremes of pH (less than 4 and greater than 8) can alter motility (Clark and Lombard, 1951; Hungate et al., 1952; Shinozaki, 1958; Dougherty, 1975; Leek et al., 1976; Juhasz and Szegedi, 1983) but when fresh legumes, e.g., alfalfa, are fed, these extremes do not exist (Monroe and Perkins, 1939; Myburgh and Quin, 1943).

The importance of calcium ion on the contraction of rumen musculature has been demonstrated by the intravenous infusion of Na_2EDTA (Huber et al., 1981). Rumen stasis occurred when the mean serum diffusible calcium concentration reached 2.61 mg/dl. That calcium ion is essential for muscle contraction has been well documented (Huxley, 1969). However, it is highly improbable that ruminants consuming bloat-provoking pasture, especially alfalfa, would be hypocalcemic. The place of other cations in the bloat syndrome is unknown.

Recently, Horn and Bruce (1983) have indicated that an unknown substance in the rumen fluid of cattle grazing wheat pasture might influence the circular muscle layer of the ruminant esophagus (table 3). Isolated circular muscle near the cardiac orifice of the rumen contracted in a tetanic manner when exposed to the wheat pasture rumen fluid. Muscle samples taken slightly more anterior had no such response and were similar to the controls. Control ingesta were taken from a steer being fed alfalfa hay and corn.

As the result of these findings, Horn and Bruce (1983) suggested that because of the proximity of their distal esophageal sample to the cardiac orifice, the musculature associated with this orifice might be spasmodically contracted and eructation hampered following exposure to certain compounds of rumen ingesta origin, in their case, wheat pasture rumen fluid.

SUMMARY

The cessation or infrequency of ruminal contractions is not one of the etiological factors of bloat development. To the contrary, rumen contractions increased in frequency during the onset of bloat, especially those associated with eructation. However, an increase in intraruminal pressure was shown to cause a depression of contraction amplitude. If amplitude can be related to force of contraction, the contractions of bloating animals may be less effective than those of non-bloated.

In steers grazing wheat pasture, the frequency and amplitude of rumen contractions were similar to values determined during pre- and post-grazing periods.

The rumen ingesta of steers grazing wheat pasture may contain a substance having an inhibitory effect on esophageal smooth muscle near the cardiac orifice of the rumen.

Gas insufflated into the rumen to a high pressure caused no deleterious effects and was rapidly eructated. However, if eructation was impeded and a high intraruminal pressure sustained, myoelectric activity and rumen contractions ceased. The recovery to pre-insufflation levels for the latter was slow.

Although ruminal motility may actually be increased during the development of foamy bloat, in the later stages it may be completely absent.

AREAS OF NEEDED RESEARCH

1. Ruminal motility of bloated cattle on wheat pasture has not been measured. Measurements of (A) intraruminal pressure, (B) amplitude and frequency of ruminal contractions and (C) eructation of bloated and nonbloated cattle should be made with regard to the etiology of bloat of cattle grazing wheat pasture.

2. Studies to clarify the possible etiological involvement of the mineral status (particularly calcium and magnesium) of cattle on wheat pasture with ruminal dysfunction and bloat should be conducted.

LITERATURE CITED

Bide, R. W. and W. J. Dorward. 1983. Excess rumen product anions in cattle. II. Toxic and lethal effects with butyrate. Can. J. Comp. Med. 47:230.

Borgatti, G. and R. Matscher. 1958. Voies et signification du reflexe oral du reseau. Arch. Ital. Biol. 96:38.

Brody, S. 1945. Bioenergetics and Growth. Reinhold Publ. Co., New York.

Bueno, L., V. Doulou and M. Candau. 1977. Ammoniogenese et motricite du rumen chez le mouton. Ann. Biol. Anim. Bioch. Biophys. 17:509.

Clark, R. 1950. The paralytic action of histamine on the ruminal musculature. J. So. Afric. Vet. Med. Assoc. 21:13.

Clark, R. and W. A. Lombard. 1951. Studies on the alimentary tract of the Merino sheep in South Africa. XXII. The effect of the pH of the ruminal contents on ruminal motility. Onderstepoort J. Vet. Res. 25:79.

Clark, R. and J. I. Quin. 1945. Studies on the alimentary tract of the Merino sheep in South Africa. XIII. The role of prussic acid in the etiology of acute bloat. Onderstepoort J. Vet. Sci. Anim. Ind. 20:209.

Clarke, R. T. J. and C. S. W. Reid. 1974. Foamy bloat of cattle. A review. J. Dairy Sci. 57:753.

Cole, H. H., C. F. Huffman, M. Kleiber, T. M. Olson and A. F. Schalk. 1945. A review of bloat in ruminants. J. Anim. Sci. 4:183.

Cole, H. H. and M. Kleiber. 1945. Bloat in cows on alfalfa pasture. Amer. J. Vet. Res. 6:188.

Colvin, H. W., Jr. 1957. Eructation studies in cattle. Ph.D. Thesis, University of California, Davis.

Colvin, H. W., Jr., J. M. Boda and T. Wegner. 1959. Studies on the experimental production and prevention of bloat in cattle. III. The effect of vegetable oil and animal fat on acute legume bloat. J. Dairy Sci. 42:333.

Colvin, H. W., Jr., L. Bueno and Y. Ruckebusch. 1982. Elevated intrarumen pressure and rumen myoelectric activity in sheep. J. Dairy Sci. 65(Suppl. 1):193.

Colvin, H. W., Jr. P. T. Cupps and C. R. Thompson. 1955. The effect of alfalfa saponin on rumen activity in sheep. J. Dairy Sci. 38:606.

Colvin, H. W., Jr., P. T. Cupps and H. H. Cole. 1958a. The efficacy of oat hay as a legume bloat preventative in cattle. J. Dairy Sci. 41:1557.

Colvin, H. W., Jr., P. T. Cupps and H. H. Cole. 1958b. Dietary influences on erucation and related ruminal phenomena in cattle. J. Dairy Sci. 41:1565.

Colvin, H. W., Jr., R. D. Digesti and J. A. Louvier. 1978. Effect of succulent and nonsucculent diets on rumen motility and pressure before, during, and after eating. J. Dairy Sci. 61:1414.

Colvin, H. W., Jr., J. D. Wheat, E. A. Rhode and J. M. Boda. 1957. Technique for measuring eructated gas in cattle. J. Dairy Sci. 40:492.

Dougherty, R. W. 1942. Analyses of gas and ingesta of bloated cattle. Amer. J. Vet. Res. 3:401.

Dougherty, R. W., J. L. Riley and H. M. Cook. 1975. Changes in motility and pH in the digestive tract of experimentally overfed sheep. Amer. J. Vet. Res. 36:827.

Horn, G. W. and D. F. Frost. 1982. Ruminal motility of stocker cattle grazed on winter wheat pasture. J. Anim. Sci. 55:976.

Horn, G. W. and L. A. Bruce. 1983. In vitro contractility response of bovine esophageal and rat antral tissues to ruminal fluid of cattle grazing wheat pasture. Unpublished data.

Huber, T. L., R. C. Wilson, A. J. Stattleman and D. D. Goetsch. 1981. Effect of hypocalcemia on motility of the ruminant stomach. Amer. J. Vet. Res. 42:1488.

Hungate, R. E., R. W. Dougherty, M. P. Bryant and R. M. Cello. 1952. Microbiological and physiological changes associated with acute indigestion in sheep. Cornell Vet. 42:423.

Huxley, H. E. 1969. The mechanism of muscular contraction. Science 164:1356.

Juhasz, B. and B. Szegedi. 1983. Az ammonia es a sav-bazis-egyensulyzavarok hatasa az elogyomrok motorikajara. Magyar Allatorvosok Lapja 38:22.

LeBars, H., J. Lebrument, R. Nitescu and H. Simonnet. 1954. Recherches sur la motricite du rumen chez les petits ruminants. IV. Action de l'injection intraveineuse d'acides gras a courte chaine. Bull. Acad. Vet. 27:53.

LeBars, H., J. Molle and H. Simonnet. 1957. Influence de l'administration d'uree sur le motricite du rumen. J. de Physiol. 49:259.

Leek, B. F., J. P. Ryan and P. K. Upton. 1976. On the acid-induced abolition of reticulo-ruminal motility in sheep. J. Physiol. 263:234P.

Lindahl, I. L., A. C. Cook, R. E. Davis and W. D. Maclay. 1954. Preliminary investigations on the role of alfalfa saponins in ruminant bloat. Science 119:157.

Louvier, J. A. and H. W. Colvin, Jr. 1978. Effect of pressure on the amplitude of primary rumen contractions. J. Anim. Sci. 47(Suppl. 1):374.

Louvier, J. A., H. W. Colvin, Jr., G. Ishizaki, G. A. Iwamoto and H. R. Parker. 1979. Effect of rumen insufflation on ruminal contraction rate in sheep. J. Anim. Sci. 48:934.

Mader, T. L., G. W. Horn, W. A. Phillips and R. W. McNew. 1983. Low quality roughages for steers grazing wheat pasture. 1. Effect on weight gains and bloat. J. Anim. Sci. 56:1021.

Meyer, J. H., G. P. Lofgreen and N. R. Ittner. 1955. Further studies on the utilization of alfalfa by beef steers. J. Anim. Sci. 15:64.

Monroe, C. F., and A. E. Perkins. 1939. A study on the pH values of the ingesta of the bovine rumen. J. Dairy Sci. 22:983.

Myburgh, S. J. and J. I. Quin. 1943. Studies on the alimentary tract of Merino sheep in South Africa. IX. The H-ion concentration in the forestomachs of fistula sheep under different experimental conditions. Onderstepoort J. Vet. Sci. Anim. Ind. 18:119.

Quin, J. I., J. G. Van Der Wath and S. Myburgh. 1938. Studies on the alimentary tract of the Merino sheep in South Africa. IV. Description of experimental technique. Onderstepoort J. Vet. Sci. Anim. Ind. 11:341.

Ruckebusch, Y., M. L. Grivel and R. Santini. 1968. Technique de derivation chronique de l'activite electrique et mecanique du tractus digestif chez l'animal eveille. Bull. Soc. Vet. Med. Comp. Lyon 70:337.

Ruckebusch, Y., and T. Tomov. 1973. The sequential contractions of the rumen associated with eructation in sheep. J. Physiol. 235:447.

Schalk, A. F., and R. S. Amadon. 1928. Physiology of the ruminant stomach (Bovine). Study of the dynamic factors. N. Dakota Agric. Expt. Sta. Bull. 216.

Shinozaki, K. 1957. Studies on experimental bloat in ruminants. 4. Identification of amines of rumen ingesta and passage of histamine across the rumen epithelium. Tohoku J. Agric. Res. 8:149.

Shinozaki, K. 1958. Studies on experimental bloat in ruminants. 5. Effects of various volatile fatty acids introduced into the rumen on the rumen motility. Tohoku J. Agric. Res. 9:237.

Weiss, K. E. 1953. Physiological studies on eructation in ruminants. Onderstepoort J. Vet. Res. 26:251.

Wester, J. 1926. Die Physiologie und Pathologie der Vormagen beim Rinde. R. Schoetz, Berlin.

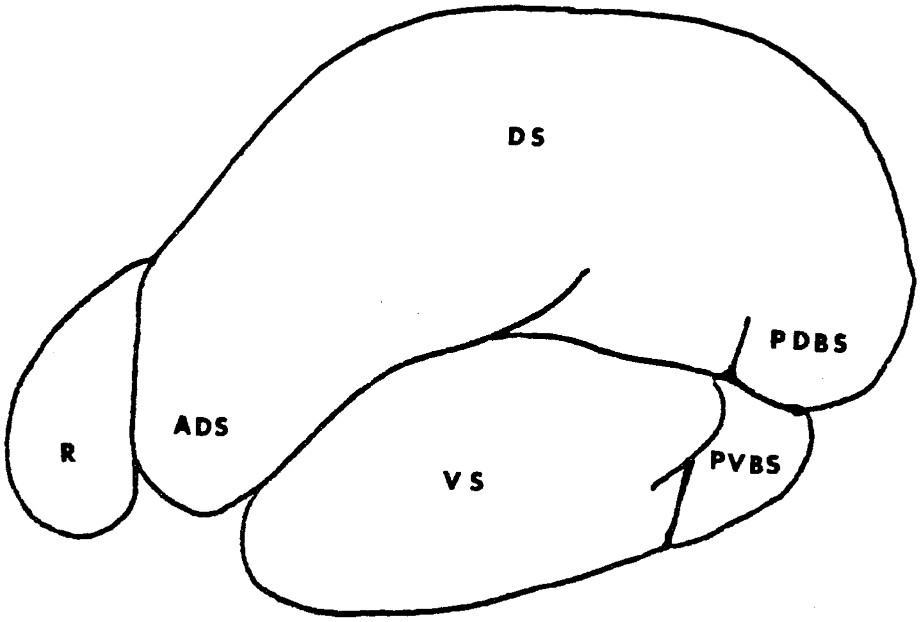


Figure 1. Reticulorumen, left lateral view. Abbreviations: R, reticulum; ADS, anterior dorsal sac; DS, dorsal sac; VS, ventral sac; PDBS, posterior dorsal blind sac; PVBS, posterior ventral blind sac.

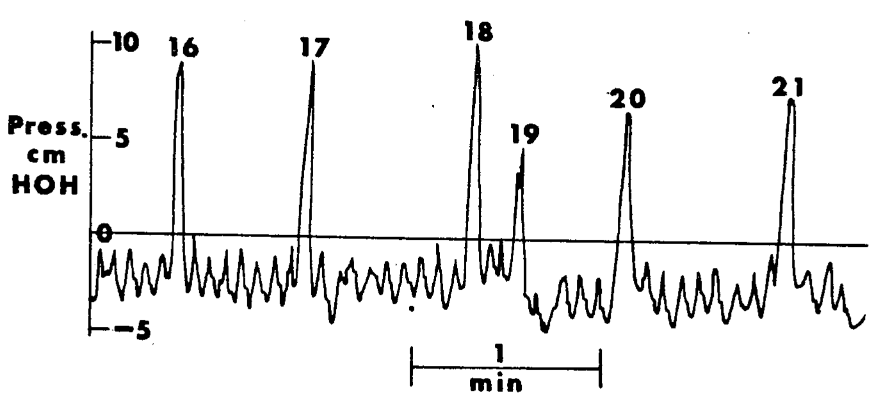


Figure 2. Normal ruminal motility of a sheep. The "0" line refers to atmospheric pressure. The largest deflections, numbers 16, 17, 18, 20, and 21, refer to mixing ruminal contractions. Contraction number 19 refers to an eructation contraction. The smallest deflections are respiratory efforts.

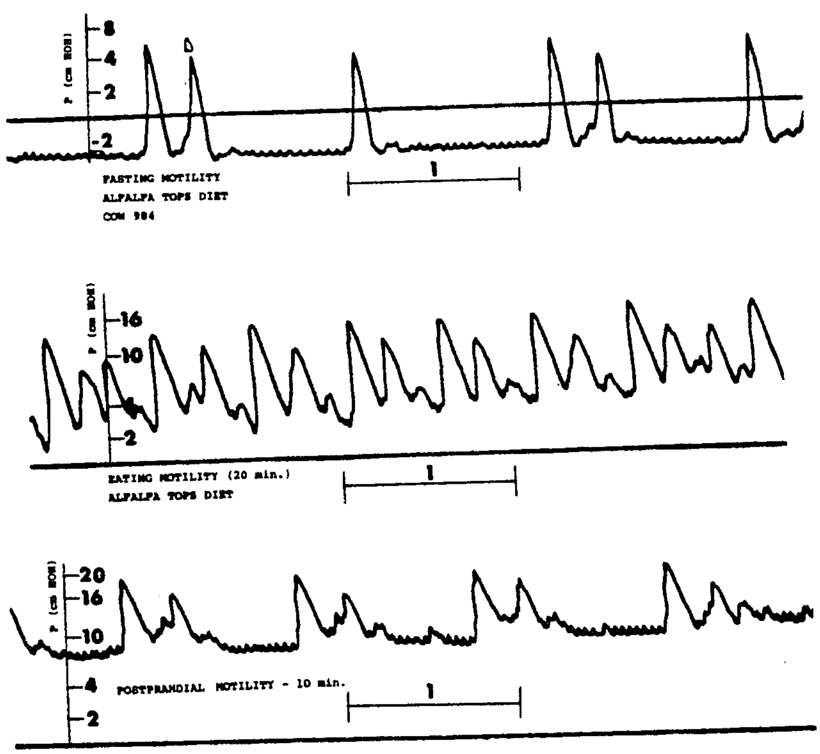


Figure 3. Ruminal motility of a cow fed bloat-provoking tops of alfalfa plants. The small circles over the contractions refer to eructations.

Upper record: Preprandial motility.

Middle record: Eating motility.

Bottom record: Motility 10 min. postprandial.

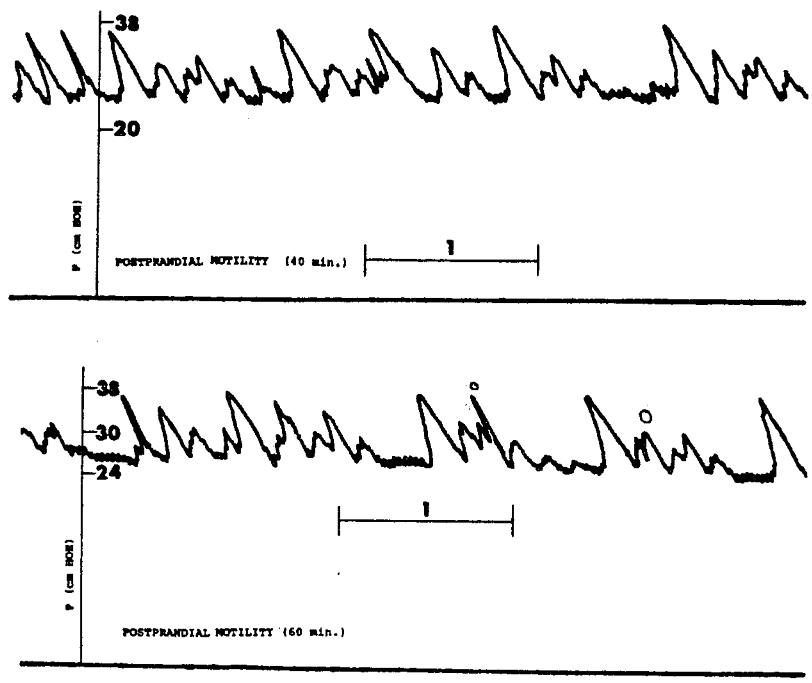


Figure 4. Ruminal motility of a cow fed bloat-provoking tops of alfalfa plants. The small circles over the contractions refer to eructations.
Top record: 40 min. postprandial.
Bottom record: 60 min. postprandial.

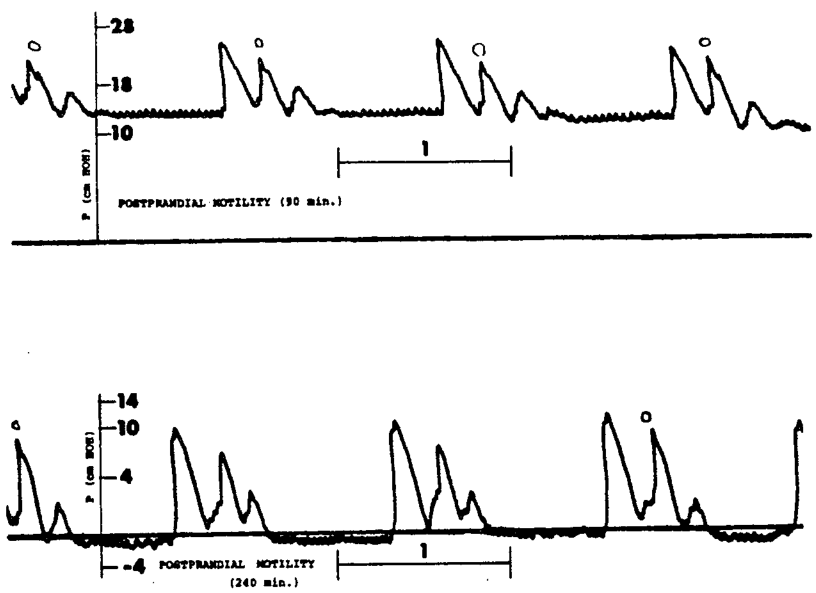


Figure 5. Ruminal motility of a cow fed bloat-provoking tops of alfalfa plants. The small circles over the contractions refer to eructations.

Top record: 90 min. postprandial.

Bottom record: 240 min. postprandial.

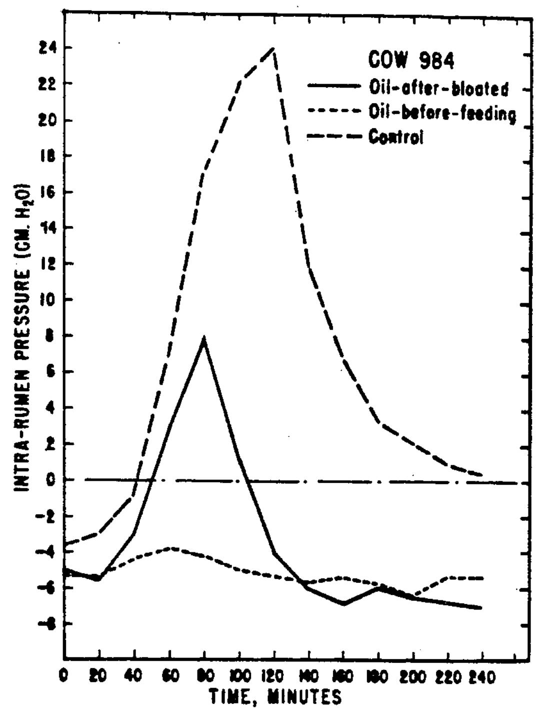


Figure 6. Effect of administering a vegetable oil into the rumen before and after feeding the fresh tops of alfalfa plants. In the trials where the cow was permitted to bloat before it was treated, the oil was administered at 70 min. From Colvin et al., 1959.

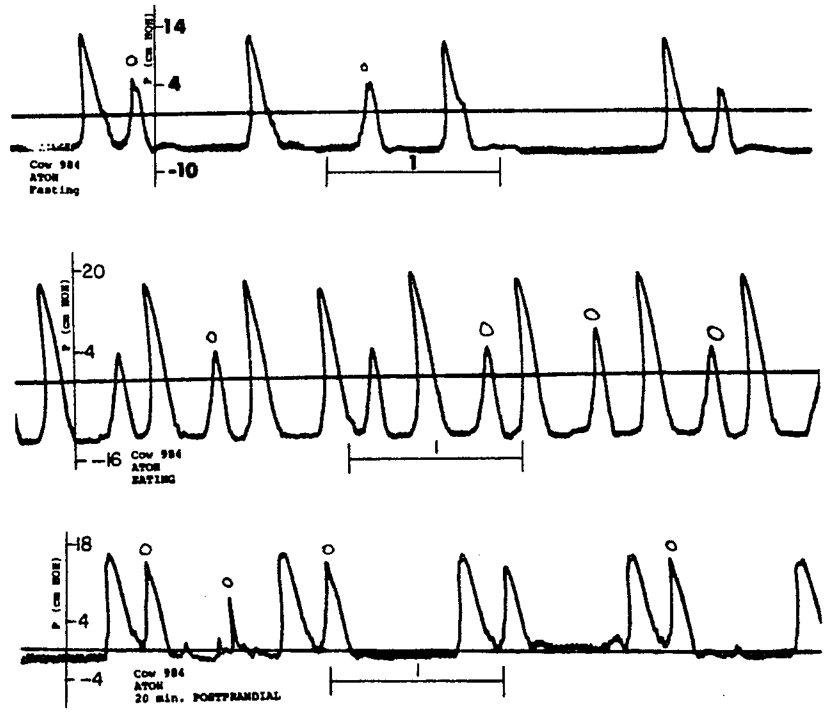


Figure 7. Ruminal motility of a cow fed oat hay the night before being fed bloat-provoking tops of alfalfa plants. The small circles over the contractions refer to eructations.

Upper record: Preprandial motility.
Middle record: Eating motility.
Bottom record: Motility 20 min. postprandial.

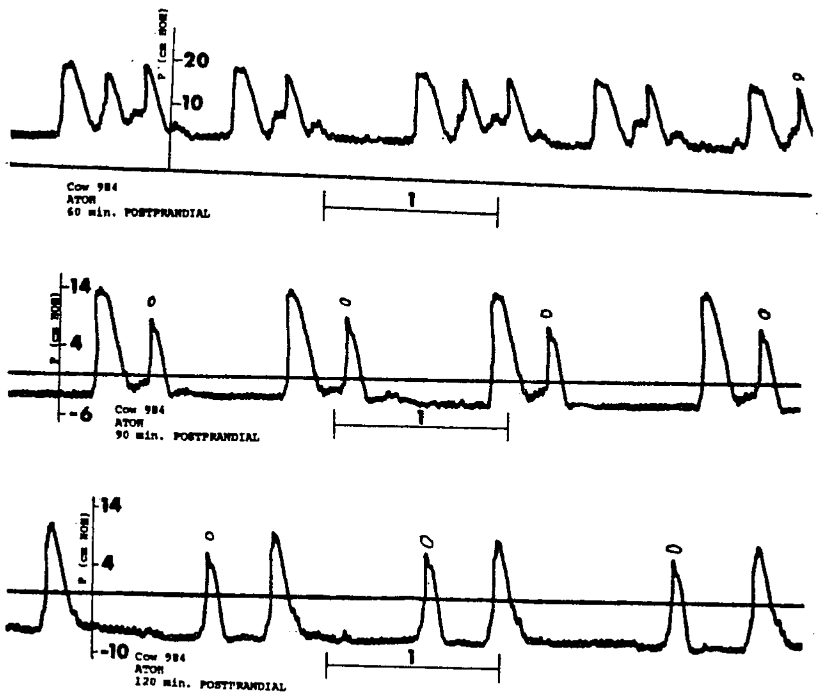


Figure 8. Ruminal motility of a cow fed oat hay the night before being fed bloat-provoking tops of alfalfa plants. The small circles over the contractions refer to eructations.

Upper record: Motility 60 min. postprandial.
Middle record: Motility 90 min. postprandial.
Bottom record: Motility 120 min. postprandial.

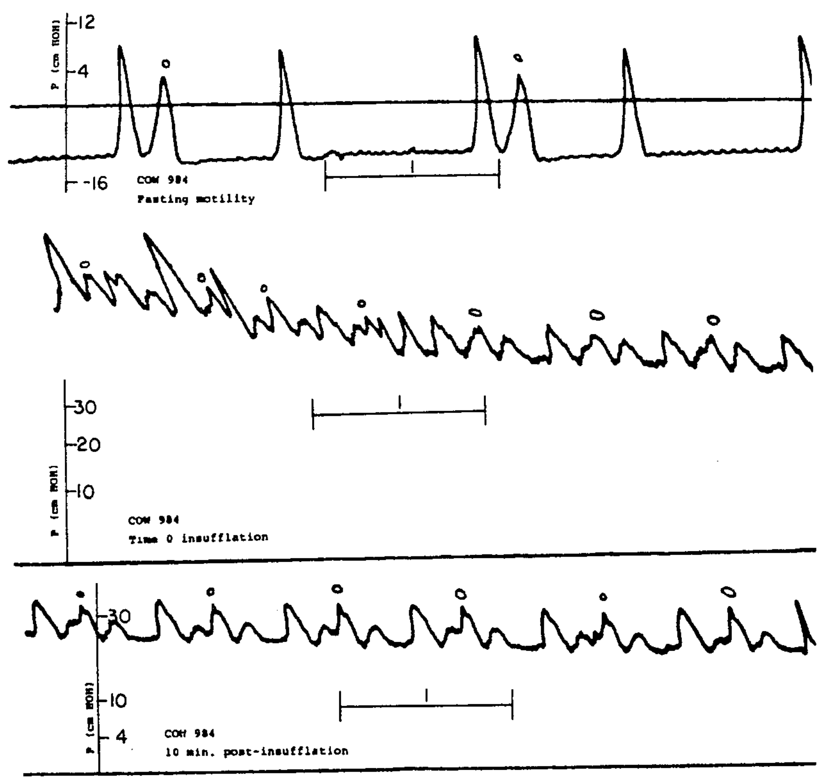


Figure 9. Ruminal motility of a cow during the insufflation of air into the rumen to simulate bloat. The small circles over the contractions refer to eructations.

Upper record: Preinsufflation motility.
Middle record: Motility immediately following insufflation.
Bottom record: Motility 10 min. postinsufflation.

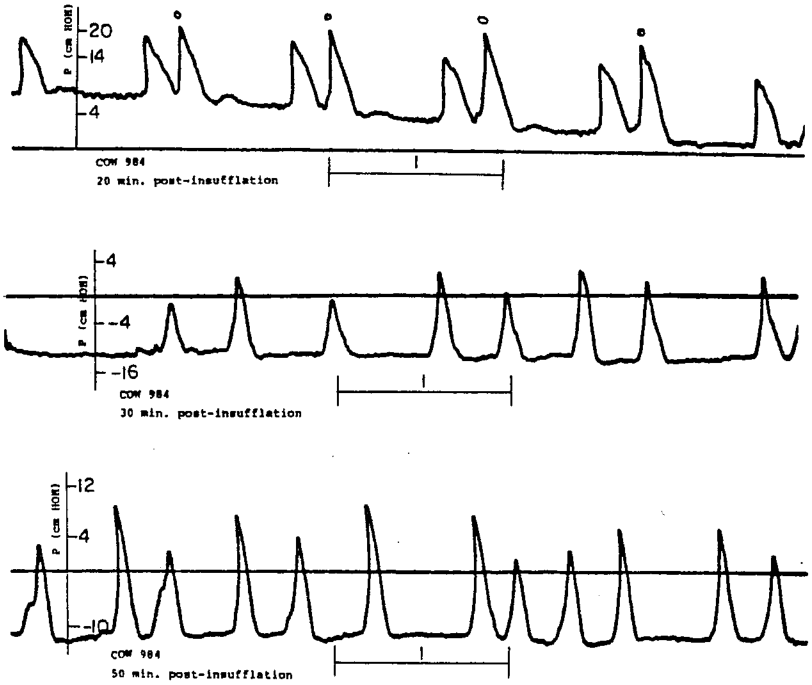


Figure 10. Ruminal motility of a cow during the insufflation of air into the rumen to simulate bloat. The small circles over the contractions refer to eructations.

Upper record: Motility 20 min. postinsufflation.
Middle record: Motility 30 min. postinsufflation.
Bottom record: Motility 50 min. postinsufflation.

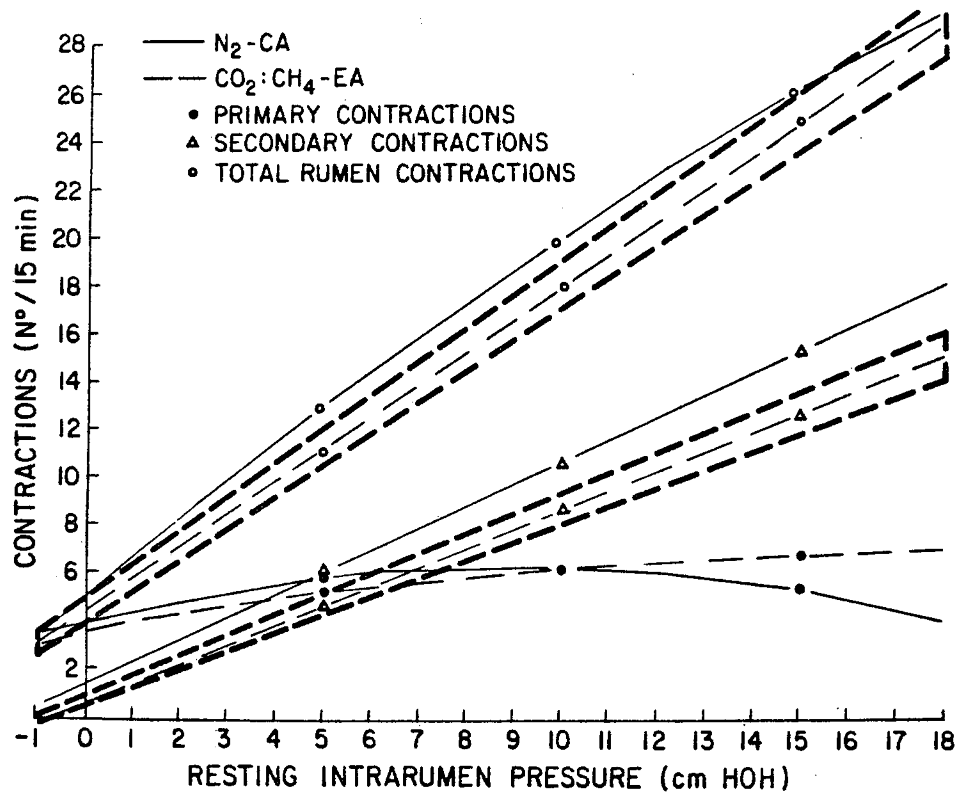


Figure 11. Effect of resting intrarumen pressure on primary, secondary, and total rumen contraction frequency after rumen insufflation with either carbon dioxide-free (N_2 or compressed air) or carbon dioxide contaning (CO_2:CH_4 or expired air) gases. The broad dashed lines indicate the 95% confidence limits around the CO_2-CH_4-expired air regressions. From Louvier et al., 1979.

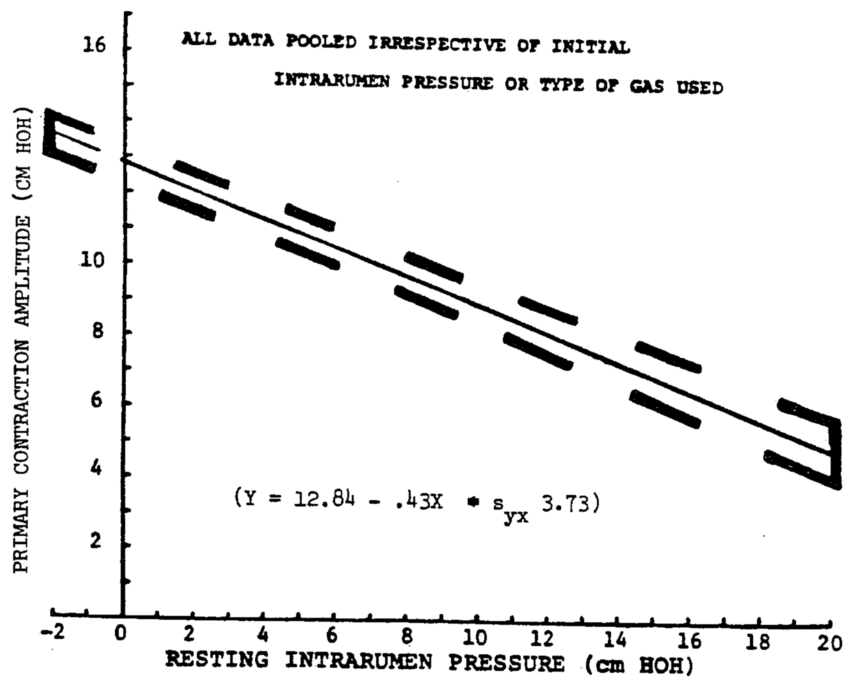


Figure 12. Effect of resting intraruminal pressure on the amplitude of primary ruminal contractions in sheep. The dashed line indicates the 95% confidence limits around the regression.

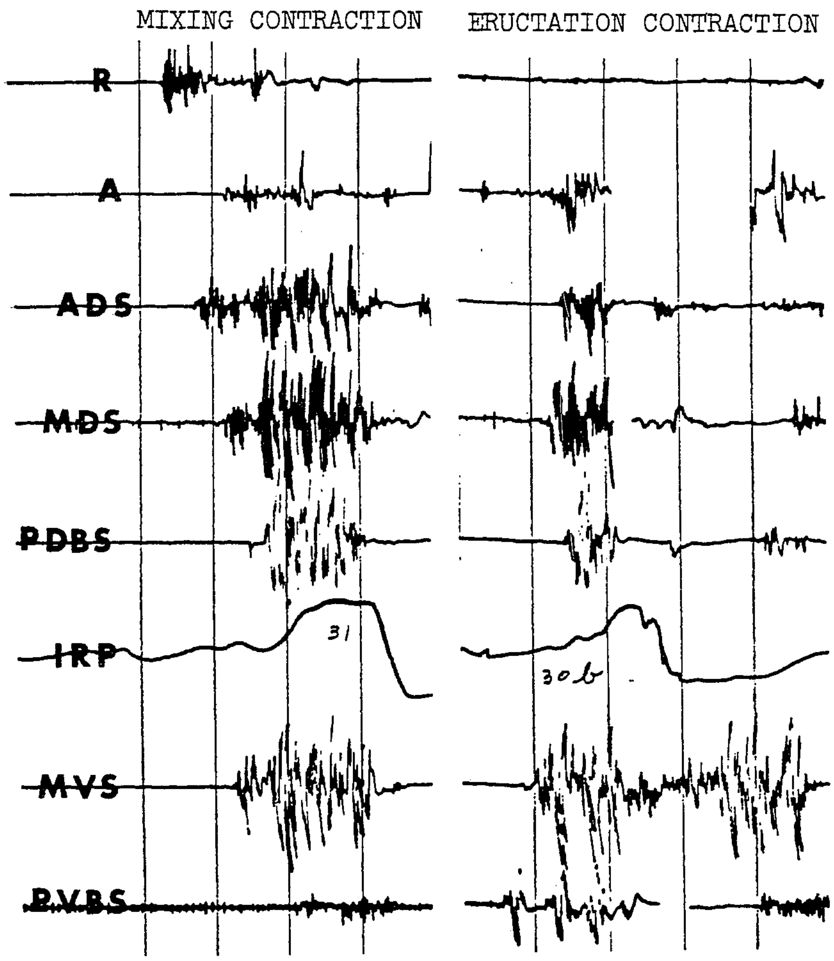


Figure 13. Electrical activity in various areas of the reticulorumen during a mixing (primary) and and eructation (secondary) contraction. Abbreviations: R, reticulum; A, atrium; ADS, anterior dorsal sac; MDS, medial dorsal sac; PDBS, posterior dorsal blind sac; IRP, intraruminal pressure; MVS, medial ventral sac; PVBS, posterior ventral blind sac. The distance between the vertical bars equals 3 sec.

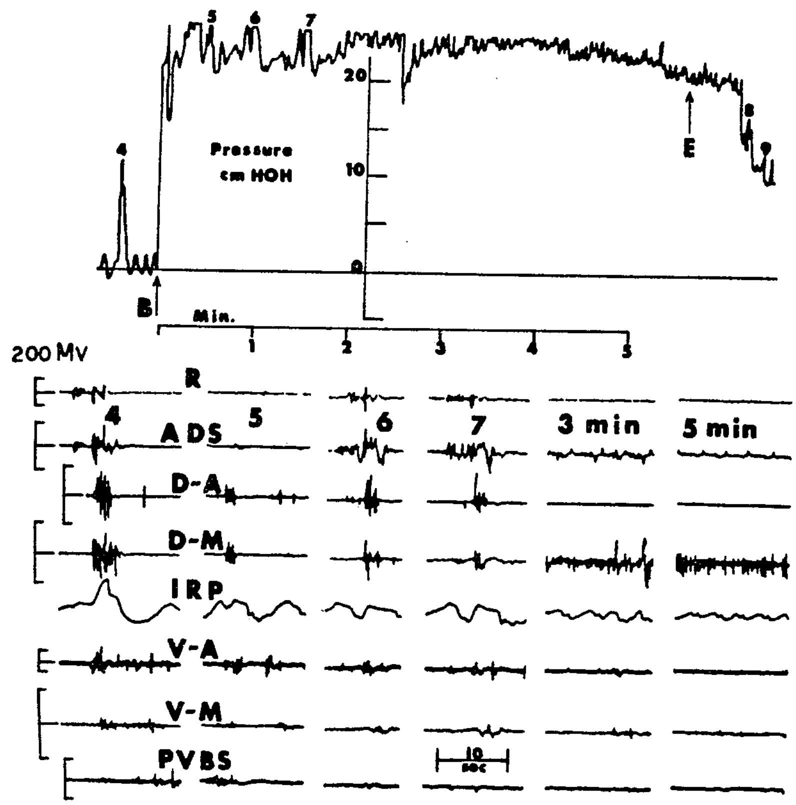


Figure 14. Effect of a sustained intraruminal pressure of 20 cm HOH on ruminal motility and ruminal myoelectrical activity in sheep. Abbreviations: B, beginning of nitrogen insufflation; E, end of insufflation; R, reticulum; ADS, anterior dorsal sac; DA, dorsal sac, anterior; DM, dorsal sac, medial; IRP, intraruminal pressure; VA, ventral sac, anterior; VM, ventral sac, medial; PVBS, posterior ventral blind sac.

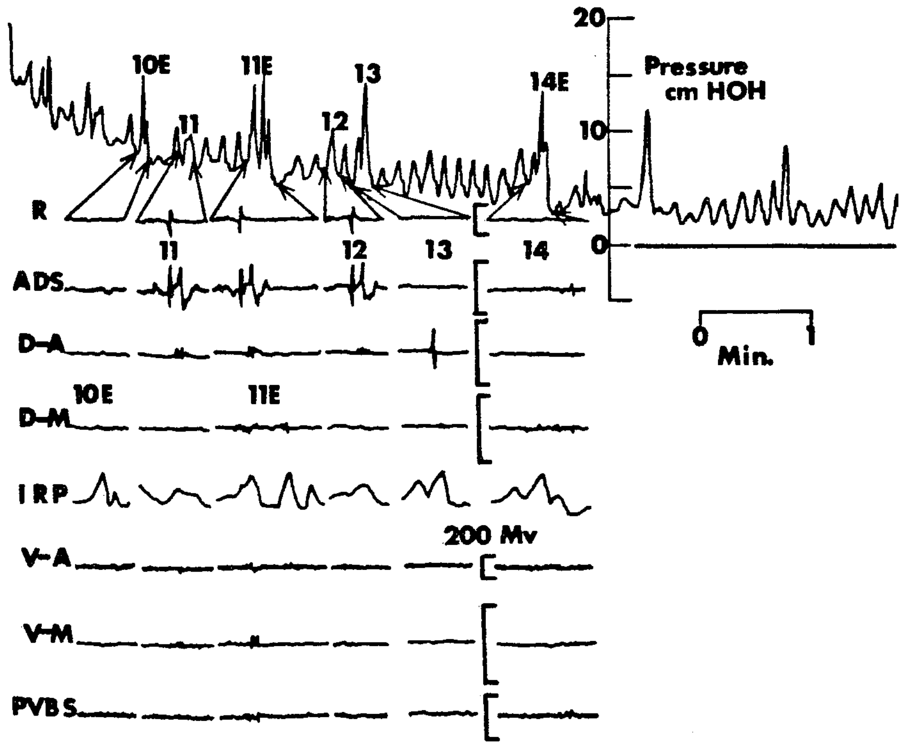


Figure 15. Effect of a sustained intraruminal pressure of 20 cm HOH on ruminal motility and ruminal myoelectrical activity in sheep. Contraction 10E is 3-4 min. postinsufflation. Abbreviations: Refer to figure 14.

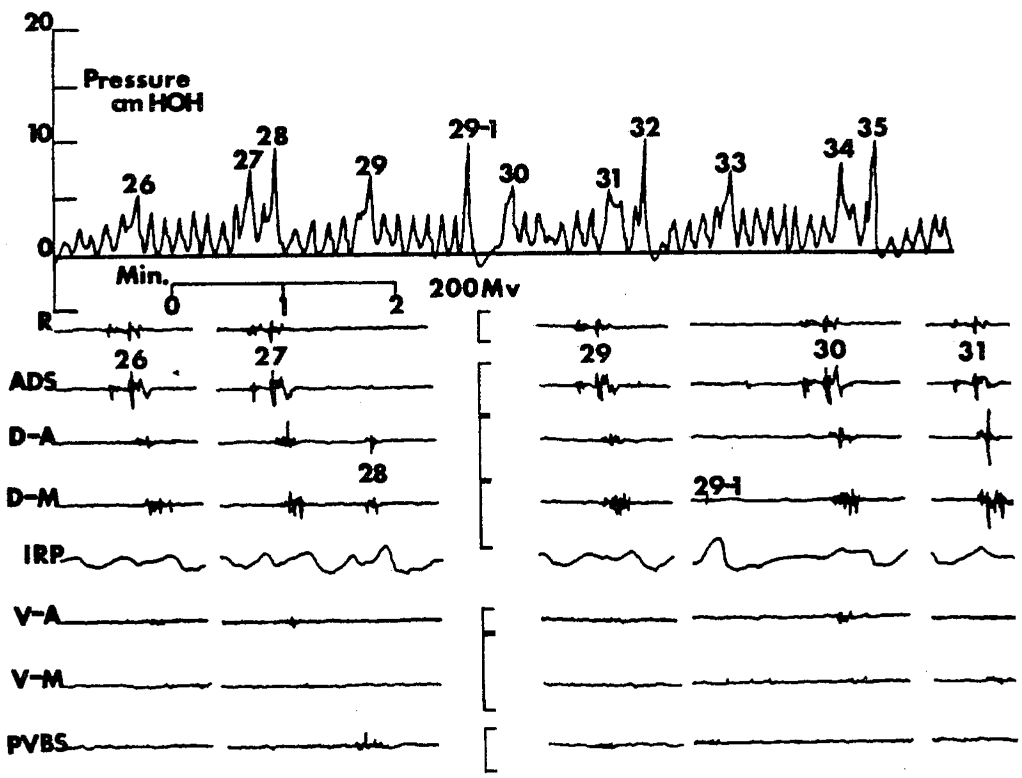


Figure 16. Effect of a sustained intraruminal pressure of 20 cm HOH on ruminal motility and ruminal myoelectrical activity in sheep. Contraction 30 is 20 min. postinsufflation. Abbreviations: Refer to figure 14.

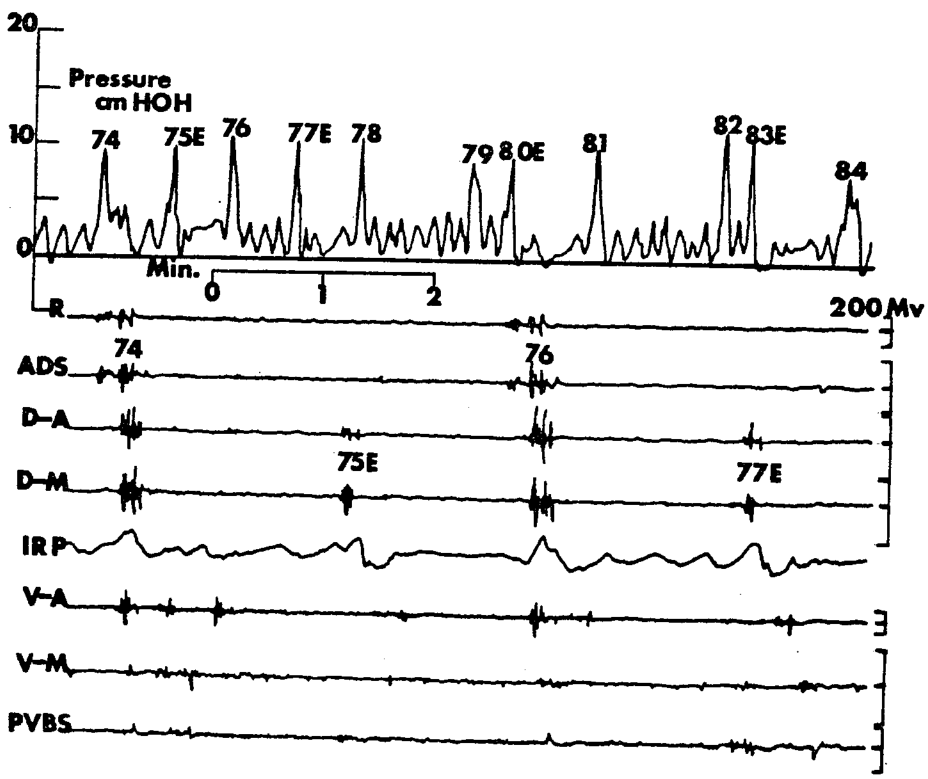


Figure 17. Effect of a sustained intraruminal pressure of 20 cm HOH on ruminal motility and ruminal myoelectrical activity in sheep. Contraction 76 is 47 minutes postinsufflation. Abbreviations: Refer to figure 14.

TABLE 1. LEAST-SQUARE MEANS FOR AMPLITUDE (AMPL), FREQUENCY (FREQ) AND AMPL X FREQ OF RUMINAL CONTRACTIONS (YEAR 1)

Method of measurement	Period: Pre- or Post-wheat pasture	Period: Wheat pasture	Observed significance level: Period	Observed significance level: Day within period
Surgically implanted pressure transducers[a]				
Ampl, mm Hg/contraction	6.7	20.5	.0001	.157
Freq, contractions/min	1.97	1.79	.392	.279
Ampl x freq, mm Hg/min	13.4	37.6	.001	.154
Water-filled balloon cannulas[b]				
Ampl, mm Hg/contraction	12.9	21.6	.002	.435
Freq, contractions/min	1.94	1.68	.075	.250
Ampl x freq, mm Hg/min	25.0	36.5	.060	.681

[a]N = 6 and 15 for pre-wheat pasture and wheat pasture periods, respectively.

[b]N = 9 and 15 for post-wheat pasture and wheat pasture periods, respectivley.

TABLE 2. RUMINAL MOTILITY OF STEERS (YEAR 2)

Period	Amplitude (mm Hg)	Frequency (Contr/min)	Amplitude x frequency (mm Hg/min)
Pre- and Post-Wheat Pasture Mean	16.5	2.43	39.5
Wheat pasture	[10/14][a]11-18(N.S.)[b]	[4/14]1.66-1.80(.05)	[12/14]19.2-60.2(N.S.)
	[8/14] 23.5-33.5(.05)	[8/14]1.90-2.99(N.S.)	[2/14] 62.7-79.8(.05)
		[2/14] 3.22-3.88(.05)	

[a][ ] number of trials.

[b]( ) statistical significance.

TABLE 3. MEAN CONTRACTION FORCE[a] (G-SEC/MIN) OF BOVINE ESOPHAGEAL TISSUE IN RESPONSE TO CONTROL AND WHEAT PASTURE RUMEN FLUID

Tissue	Ruminal fluid		
	Control	Wheat pasture[b]	n[c]
Distal esophageal tissue[d]	13.3	30.1[f]	10
Esophageal tissue[e]	12.7	7.6	5

[a]Total integrated area under the contractile curve divided by the number of min/recording period.

[b]Samples of April 1.

[c]Number of tissue preparations/sample.

[d]0 to 3 cm above the esophageal-rumen junction.

[e]4 to 6 cm above the esophageal-rumen junction.

[f]Different ($P<.05$) from response to control rumen fluid.

OBSERVATIONS OF WHEAT PASTURE SUDDEN DEATH SYNDROME

Dee Griffin, DVM, MS
Hitch Agribusiness, Inc.
Guymon, Oklahoma

During the fall and winter wheat pasture grazing season of 1982 and 1983, approximately 5000 steers and heifers grazed in the Oklahoma Panhandle were received and backgrounded in a drylot situation. Vaccines for these 300 to 500 lb animals included Clostridium sp. (chauvoei-septicum), IBR, and Leptospirosis Pomona. They were also implanted with estridiol-17B.

The wheat pasture fertilization included 50 to 100 lb of nitrogen per acre in the form of ammonium phosphate. Potash was not included in the fertilization program. The stocking rate was one animal per 1 1/2 acre of pasture. A daily supplement of five pounds of corn silage per animal was fed. Poloxalene blocks and a 1:1 mix of dicalcium phosphate and salt were also made available.

Through the first 120 days of grazing ten animals were lost to bloat. During the last part of March a severe snow storm covered the wheat for a three day period. As the melting snow left the wheat uncovered eight percent of one group of animals were found dead during a 24 hour period. The death loss in other groups ranged for 0 to 3 percent with the majority of groups suffering no death loss. Samples were collected from the pasture and dead animals, and sent to two laboratories. During two other non-consecutive days the episode was repeated during which the total death loss accumulated to one percent due to "wheat pasture sudden death syndrome".

The wheat growth seemed extremely lush and the consumption of corn silage and poloxalene during these times was very low. There were some sporatic losses in between the three worst days. On two occasions animal deaths were observed. The wind was in excess of 20 mph, which was not uncommon. It was late morning, between 10 am and 12 noon. The animals had been laying down, got up, grazed for approximately 50 yards. In both cases the animals appeared bloated but not as severe as others in the group. They appeared weak yet alert, stumpled and fell dead. Blood samples were taken and necropsies performed immediately.

Post-mortem findings from the animals included the following: No gross lesions in the spleen, liver, brain, musculature and esophagus. The hearts in these animals were severely contracted, as were their urinary bladders. The lungs of both animals were normal in size and weight, however they had a purplish mottled appearance. The rumens were distended and contained free gas and froth. The contents contained essentially no corn silage.

Post-mortem findings on other animals included no gross lesions in spleen, liver and brain. The hearts of all animals were contracted as were their urinary bladders. Some of the animals, especially those that had been dead longer had pale areas on the kidneys, pale posterior musculature and an esophageal "bloat line". The lungs in all animals were normal size and weight, however they all had a purplish mottled appearance. Again the rumen in all animals seemed to contain no corn silage.

Wheat pasture samples were analyzed for nitrates several times during these episodes. The highest level obtained came from a sample taken from underneath a snow bank on the day and from the same field we found the 8 percent dead. It was 9000 ppm with a dry matter of 22 percent. Occular fluid nitrate was negative from animals found dead on that pasture at the same time forage samples were collected. The nitrate level was also checked in the tailwater pits of that field and found to be 14 ppm, which was considered quite low.

The serum electrolyte profile in these animals had a very consistant pattern of high normal to elevated K, glucose, LDH and CPK. The serum Mg was consistantly low normal while the serum Na and Cl were in the normal to low normal range.

OBSERVATIONS ON DEATHS OF STOCKER CATTLE ON WHEAT PASTURE

L. C. Hollis

Texas Veterinary Medical Diagnostic Laboratory
Amarillo, Texas 79116-3200

SUMMARY

Acute death losses in stocker cattle grazing winter wheat pastures were numerous during the spring of 1983. Attempts to identify a cause consistent with the clinical signs observed indicated that the problem was not classic bloat, Clostridial infection, nitrate toxicity, hypomagnesemia or hypocalcemia as originally suspected. The most significant finding was elevated potassium levels in the wheat, and corresponding elevated serum potassium levels in the cattle.

OBSERVATIONS

Unusually high death losses occurred in stocker cattle grazing on wheat pastures in the Texas and Oklahoma panhandles, western Oklahoma, and southwestern Kansas during the early spring of 1983. Following an extremely wet, cold, cloudy, prolonged winter, spring was generally characterized by a rapid warming trend, bright sunny days, and extremely rapid, lush wheat growth. The onset of the unusually high death losses coincided with this period of accelerated growth of the wheat.

During the late winter months, only a few isolated death losses occurred in the majority of the stocker cattle operations in the area previously mentioned. Many of these death losses were attributed to bloat, and were occurring in cattle showing clinical signs of bloat. In most of the affected herds, the addition of surfactants incorporated into blocks, lick tanks, or added directly to the drinking water appeared to bring both the clinical bloat problem and the death losses attributable to bloat under control.

Beginning on March 16, stocker cattle operations to the south and west of Amarillo, Texas, began reporting high numbers of death losses in previously healthy stocker cattle on wheat pastures. The area of involvement seemed to move rapidly northward on a daily basis, with reports of high death losses coming in from areas of southwest Kansas within a week after the problem originally appeared near Amarillo.

Death losses occurred on both dryland and irrigated wheat pastures, on both non-fertilized and heavily fertilized pastures, and on pastures where cattle had access to wheat and either corn or sorghum stalks. Both steers and heifers appeared to be similarly affected.

Most of the cattle involved were found dead with no sign of struggle. Some groups of cattle were observed to appear entirely normal, only to have individual animals found dead when the cattle were reobserved a few minutes to a few hours later. Some cattle were reported to have virtually "dropped in their tracks" by observers who witnessed their death.

Various body fluids from live cattle, necropsy tissues from dead cattle, and wheat samples from problem pastures were submitted by area veterinarians to the Texas Veterinary Medical Diagnostic Laboratory, Amarillo, Texas, for analysis in an effort to determine the cause of the observed death losses. The most apparent list of differential diagnoses to be considered included bloat, Clostridial infection, nitrate toxicity, hypomagnesemia, and hypocalcemia.

Affected herds did not appear to have an obvious bloat problem, although the carcasses were observed to bloat rapidly after death. Several of the herds experiencing death losses had bloat preventatives available to the cattle prior to and during the time when the death losses were occurring. Bloat as a major causative factor in the heavy death losses observed was also heavily discounted because of the reports indicating that most of the cattle were not bloated at the time of death, the common observation that the remainder of the cattle in the pasture did not appear bloated, and the lack of a typical esophageal "bloat line" or anterior cervical musculature congestion with posterior musculature blanching at necropsy indicative of ante-mortem bloat. It was interesting to note that the clinical bloat cases that were observed after March 16 were dry bloat rather than frothy bloat that would normally be anticipated in cattle grazing on wheat pasture (Clay, 1973).

Most of the cattle involved had been previously immunized against Clostridial infections, and in one case, had been revaccinated with a 7-Way Clostridial product approximately one week prior to the time that death losses dramatically increased in that particular herd as well as in neighboring herds. Bacterial isolation attempts and histopathological examinations of tissues from 6 different calves that were necropsied revealed no evidence of Clostridial infection.

Forage nitrate levels above 1% are considered potentially toxic, and analysis of wheat samples from several problem pastures suggested the possibility of nitrate toxicity (see Table 1). However, diphenylamine and imipramine spot tests on ocular fluid from 14 different dead calves were all negative, indicating that the calves had not died from nitrate toxicity (Householder, et al., 1966).

Serum samples were collected from several calves grazing on problem wheat pastures where death losses had occurred earlier the same day. Four of eleven calves tested had serum magnesium values below the normal range (see Table 2). However, only one calf had a serum magnesium value at the level where uncomplicated hypomagnesemia is commonly observed (1 mg% or less)(Boling, 1982). Serum calcium values for all calves were normal or slightly above normal. Serum phosphorus values were normal or above normal. Of special significance were serum potassium values, which were consistently above normal in all calves tested. It was interesting to note that several of the herds involved had magnesium or magnesium/calcium containing mineral supplements or mineral blocks available prior to and at the time death losses were occurring. No clinical symptoms of hypomagnesemia or hypocalcemia were reported in any cattle death losses observed.

TABLE 1. WHEAT FROM PROBLEM PASTURES

	AVERAGE	OBSERVED RANGE	NO. OF SAMPLES
Dry Matter %	21.27	17.90 - 25.61	(19)
Crude Protein %	27.75	2.60 - 31.0	(4)
Nitrate %	.85	.42 - 1.36	(21)
Calcium %	.32	.25 - .39	(4)
Phosphorus %	.28	.18 - .37	(4)
Magnesium %	.13	.100 - .156	(11)
Potassium %	3.56	3.15 - 4.15	(12)

TABLE 2. SERUM ELECTROLYTES FROM CATTLE GRAZING PROBLEM WHEAT PASTURES

	AVERAGE	OBSERVED RANGE	NORMAL RANGE	NO. OF SAMPLES
Calcium (mg %)	10.49	8.8 - 12.0	6.8 - 11.4	(10)
Phosphorus (mg %)	9.02	7.3 - 11.5	4.9 - 8.5	(10)
Magnesium (mg %)	2.27	1.00 - 3.50	2.0 - 4.0	(11)
Potassium (meq/L)	7.56	6.8 - 8.88	3.9 - 5.8	(11)

In addition to electrolyte determinations, serum profiling was done on these same calves (see Table 3). While no clear-cut conclusions could be drawn, it was remarkable that essentially all values were normal or elevated.

TABLE 3. SERUM PARAMETERS FROM CATTLE GRAZING PROBLEM WHEAT PASTURES

	AVERAGE	OBSERVED RANGE	NORMAL RANGE	NO. OF SAMPLES
TSP (%)	7.21	6.1 - 9.2	7.0 - 8.9	(10)
Albumen (g %)	3.58	3.3 - 4.1	2.6 - 4.3	(10)
Glucose (mg %)	139.3	85 - 305	40 - 140	(10)
BUN (mg %)	29.	26 - 33	0 - 35	(6)
Creatinine (mg %)	1.32	1.2 - 1.8	0 - 2.2	(10)
T. Bili (mg %)	.09	0 - .02	0 - 1.6	(10)
SAP (IU/L)	241.	207 - 305	25 - 250	(10)
CPK (IU/L)	384.	185 - 630	0 - 350	(4)
LDH (IU/L)	1600.	1600 - 1600	800 - 1360	(10)
SGPT (IU/L)	8.7	0 - 25	0 - 40	(10)
SGOT (IU/L)	183.8	155 - 225	55 - 180	(10)

Of particular interest are the values obtained from samples collected immediately prior to death from what appeared to be a typically affected animal (see Table 4). The negative nitrate value, normal magnesium value, and tremendously elevated potassium value are especially noteworthy.

TABLE 4. DYING ANIMAL

OCULAR FLUID - Negative for nitrate.

SERUM PARAMETERS:

Calcium (mg %)	11.4	Creatinine (mg %)	1.2
Phosphorus (mg %)	12.0	T. Bili. (mg %)	.1
Magnesium (mg %)	3.48	SAP (IU/L)	375.
Potassium (meq/L)	17.41	CPK (IU/L)	480.
Chlorine (meq/L)	101.	LDH (IU/L)	1600.
TSP (%)	8.2	SGPT (IU/L)	20.
Albumen (g %)	4.1	SGOT (IU/L)	320.
Glucose (mg %)	325.		

While initial findings did not indicate a cause for the death losses incurred, they coincided with the onset of accelerated growth of the wheat. Initial recommendations were to either prevent cattle from grazing problem pastures by moving them off these pastures, or to reduce the percentage of wheat in the diet by supplementing with readily acceptable feeds. Either approach resulted in an immediate termination of death losses, while death losses continued in surrounding pastures where these approaches were not implemented.

In one instance, cattle were moved off two different problem wheat pastures and placed in an adjacent feedlot where they began receiving a high silage grower ration. Serum samples were collected for serum electrolyte, metabolite and enzyme profiling from several of these calves as they were being moved from the problem pasture to the feedlot, and consitute the majority of observations reported in Tables 2 and 3. Nine of these calves were retested 5 days after being removed from the problem pastures (see Table 5). By that time, most of the serum values had returned to normal. It was interesting to note that groups of calves left grazing two adjacent wheat pastures continued to experience death losses until they too were moved to the feedlot.

TABLE 5. SERUM ELECTROLYTES AND OTHER PARAMETERS FROM CATTLE 5 DAYS AFTER REMOVAL FROM PROBLEM WHEAT PASTURE

	AVERAGE	OBSERVED RANGE	NORMAL RANGE	NO. OF SAMPLES
Calcium (mg %)	10.22	9.7 - 11.3	6.8 - 11.4	(9)
Phosphorus (mg %)	8.27	7.2 - 9.4	4.9 - 8.5	(9)
Magnesium (mg %)	2.32	1.84 - 2.64	2.0 - 4.0	(9)
Potassium (meq/L)	4.89	4.30 - 5.44	3.9 - 5.8	(9)
TSP (%)	7.04	7.7 - 7.3	7.0 - 8.9	(9)
Albumen (g %)	3.21	2.8 - 3.5	2.6 - 4.3	(9)
Glucose (mg %)	96.7	65 - 132	40 - 140	(9)
BUN (mg %)	4.8	3 - 8	0 - 35	(9)

TABLE 5. (Continued)

	AVERAGE	OBSERVED RANGE	NORMAL RANGE	NO. OF SAMPLES
Creatinine (mg %)	.93	.7 - 1.1	0 - 2.2	(9)
T. Bili. (mg %)	.05	0 - 0.1	0 - 1.6	(9)
SAP (IU/L)	175.	122 - 230	25 - 250	(9)
CPK (IU/L)	137.	100 - 235	0 - 350	(9)
LDH (IU/L)	1475.	1280 - 1650	800 - 1360	(9)
SGPT (IU/L)	15.6	12 - 20	0 - 40	(9)
SGOT (IU/L)	119.	95 - 140	55 - 180	(9)

In other instances, where it was impossible or undesirable to move the calves off the problem wheat pastures, supplementation was utilized. One supplement being fed (see Table 6) in a Rumensin-limiting diet at the rate of 1 pound/head/day stopped death losses in pastures where it was utilized, while non-supplemented cattle in adjacent pastures continued to experience heavy death losses (Hutcheson, 1983).

TABLE 6. SUPPLEMENT SPECIFICATIONS

INGREDIENTS	%
Corn	71.45
Tallow	.50
Molasses	3.00
Calcium	12.00
Mag Ox	1.50
Dical	4.00
Salt	6.00
Trace Minerals	.40
Sulfur	.50
Rumensin 60	.30
Vit. A&D 10 Million Units	.30
Vit. E 40	.05
TOTAL	100.00

DISCUSSION

Of all the observations made, the discovery that supplementation with the above mentioned ration would stop the death loss problem is the most intriguing. It has been speculated that several components of this ration may individually be responsible for the results observed. Mere dilution caused by providing an alternate source of dry matter intake may have been responsible (a 500 pound steer consuming 3% of its body weight would have to eat 15 pounds of dry matter daily or 70.5 pounds of as-grazed wheat forage per day. Supplementation with one pound of supplement would theoretically reduce its daily intake of as-grazed wheat forage to 65.8 pounds.) The presence of monensin may have altered the dry matter intake, may have reduced the tendency for development of bloat, or may have altered some other aspect of rumen metabolism to produce a life-sparing effect. The energy provided by the ration may have altered body metabolism sufficiently to produce a life-sparing effect. The magnesium and/or calcium could have altered neuromuscular electroconductivity, or the sodium in the salt may have altered cell membrane activity (K: Na gradient) sufficiently to produce a life-sparing effect.

AREAS OF NEEDED RESEARCH

Additional research needs include (1) determining which component or combination of components from the above mentioned ration was responsible for producing the life-sparing effect, and (2) evaluating more animals that are on the verge of death in order to determine and further document the physical and biochemical alterations present.

LITERATURE CITED

Boling, J. A. 1982. Grass tetany in beef cattle. Animal Nutri. & Hlth. 37(7):20.

Clay, B. R. 1973. Stocker cattle losses on small grain pastures. J. Okla. Vet. Med. Assn. 25(4):15.

Householder, G. T., J. W. Dollahite, and R. Hulse. 1966. Diphenylamine for the diagnosis of nitrate intoxication. J.A.V.M.A. 148(6):662.

Hutcheson, D. P. 1983. Personal communcation.

III. GRAZING MANAGEMENT CONSIDERATIONS

EFFECTS OF SWARD STRUCTURE ON FORAGE INTAKE.
IMPLICATIONS FOR INCREASING PERFORMANCE OF CATTLE ON WHEAT PASTURE.

T. D. A. Forbes

Southwestern Livestock and Forage Research Station
El Reno, Oklahoma

Introduction

The inevitable increase of the world population with its concomitant decrease in the land area available for cropping and the subsequent reduction in availability of grain based feeds for animals, will lead to a much greater emphasis on forages as the basis for animal production. The greater part of this increased forage based production will be from grazing, and the use of wheat and other cereals as a forage crop prior to being harvested for grain will take on even greater importance. Many of the limitations to grazing animal production are sward related and of these probably the most important is restricted herbage intake. Hodgson (1982) states that whilst the digestibility and metabolisability of the diet selected by grazing animals may vary by about a factor of two, the herbage intake of grazing animals may vary by about a factor of at least four. It is thus obvious that an understanding of those factors that influence the herbage intake of grazing animals is of the utmost importance. Anyone who has been involved with grazing systems either as a farmer, rancher or scientist will be aware of the problems associated with grazing-based systems.

This paper deals with those factors associated with the structure of the sward, and those ingestive behaviours which are known to influence the amount and rate of herbage consumption of grazing animal.

Sward structure and ingestive behaviour

The structure of a sward is a function of its mass, height, botanical and morphological composition and the distribution of these latter components through the canopy. The structure of a sward influences herbage intake (I) by its influence on three ingestive behaviours namely, intake per bite (IB), rate of biting (RB) and grazing time (GT) such that:

$$I = IB \times RB \times GT$$

It should be noted that to use continuously variable parameters as single means or totals is to create a model of ingestive behaviours that is probably unrealistically mechanistic and simplistic (Hodgson 1982). However, even with these reservations the model is still important as it does enable the influence of sward conditions on herbage intake to be examined.

Intake per bite is considered to be the dominant influence on herbage intake with rate of biting and grazing time acting as compensatory behaviours, (Hodgson and Milne, 1978). Intake per bite generally is substantially more variable than either rate of biting or grazing time (Stobbs, 1973b; Hodgson, 1981), with the consequence that though rate of biting and grazing time may increase in response to a decline in intake per bite, this increase is seldom sufficient to avoid some reduction in herbage intake (Chacon and Stobbs, 1976; Jamieson and Hodgson 1979b, Hodgson 1981) (figure 1).

The importance of intake per bite in relation to the herbage intake of grazing animals has been stressed by Stobbs (1973a) who calculated that cattle weighing 400 kg LW grazing tropical swards might have restricted intakes if the mean intake per bite fell below 0.3 g OM. Table 1 shows intakes per bite from cattle grazing a range of sward types.

Intake per bite has been shown to increase linearly with increasing sward height in both cattle and sheep grazing both temperate and tropical grass swards (Allden and Whittaker, 1970; Stobbs, 1975; Chacon and Stobbs, 1976; Chacon, Stobbs and Dale, 1978; Hodgson, 1981; Forbes, 1982) (figure 2). Stobbs (1973a&b), however, found that on some tall tropical grass swards the relationship between intake per bite and sward height was negative rather than positive and he (Stobbs, 1975) ascribed this to the low density of leaf at the sward surface. In fact in tropical grass swards intake per bite appears more closely related to leaf density at the sward surface or to the leaf/stem ratio, than to sward height (Stobbs, 1973a&b; Stobbs, 1975; Chacon and Stobbs, 1976) (figure 3), and a similar conclusion was drawn by Hendricksen and Minson (1980) from the results of cattle grazing on tropical legumes. Forbes (1982), however, found no relationship between intake per bite and sward surface density with cattle and sheep grazing indigenous pastures in Scotland. The influence of intake per bite on herbage intake is illustrated by the results of Hendricksen and Minson (1980) who found that a reduction in intake per bite from 410 mg OM to 90 mg OM over a 12 day period resulted in a linear reduction in herbage intake of over 925 g OM/day (figure 4). In this study the cattle concentrated their grazing on the green leaf fraction of the sward and by the end of the experiment were probably at the stage of selecting individual leaves. The evidence of Stobbs (1975) suggests that the cattle in his experiment were virtually grazing individual leaves. Hodgson and Milne (1978) have reported a positive linear relationship between intake per bite of sheep and herbage mass. Subsequently Hodgson (1981) suggested that the bite volume must have declined markedly as the swards were grazed down since the density of herbage increased towards the bottom of the swards. Recent evidence (Barthram, 1980) has shown that the depth of the sward horizon in which grazing takes place declines, as the horizons containing dead leaf and vegetative stem are approached.

Forbes (1982) showed that as sward height declined so the length of leaf removed decreased (figure 5) in both cattle and sheep. The results of Barthram (1980) and Forbes (1982) both suggest that grazing animals are capable of varying bite depth. Any reduction in the depth of the bite is likely to reduce intake per bite since the width of the bite is a constant determined by the width of the mouthparts. In any circumstances where animals are grazing selectively the intake per bite is likely to be less than maximal, and thus measurements of width across incisors or buccal cavity volume are likely to be unreliable indicators of intake per bite, particularly since both cattle and, though to a leaner extent, sheep frequently grip and tear off groups of leaves or tillers before drawing them into their mouths, (Hodgson 1982). There is no evidence available to suggest what the theoretical maximum bite volume might be.

The measurement of rate of biting as an indicator of sward conditions has been carried out for at least 40 years (Johnstone-Wallace and Kennedy, 1944), but it is only recently that rate of biting has been used as a parameter which can be used, together with grazing time and intake per bite, to determine herbage intake.

Rate of biting by sheep grazing a ryegrass sward was observed to increase as sward height decreased until an apparent maximum of 73 bites per minute was reached at a sward height of 5 cm, at which point rate of biting declined sharply (Allden and Whittaker, 1970) (figure 6), and Forbes (1982) found that both cattle and sheep reduced biting rate with increasing sward height (figure 2). Hodgson (1981), however, found no relationship between rate of biting and sward height in either calves or lambs set-stocked on a temperate ryegrass sward, whilst in one experiment strip-grazed calves were found to reduce rate of biting with declining sward height. Hodgson and Jamieson (1981) have suggested that the low rates of biting found in lactating cattle (19.7 bites per minute) were due to the very tall swards, (extended heights between 79 and 88 cm). J. Wadsworth (personal communication) found that sheep and lamb bite rates declined curvilinearly rather than rectilinearly. The trend follows that found by Allden and Whittaker (1970), even though the range of sward heights were not comparable. Rates of biting have also been found to increase with declining herbage mass (Hodgson and Wilkinson, 1967; Chacon and Stobbs, 1976; Jamieson and Hodgson, 1979a&b; Forbes, 1982). Chacon and Stobbs (1976) found that rate of biting was negatively correlated with the proportion of leaf and the leaf/stem ratio of tropical grass swards. Cattle have been found to increase their rate of biting in response to the increasing density of some sward components such as green mass and stem, whilst reducing their rate of biting in response to an increasing leaf:stem ratio, (Forbes, 1982). This apparent conflict of results is explained in relation to the structure of the swards in that on those swards with the highest leaf:stem ratios the animals took very large bites which tended to reduce rate of biting. The increase in rate of biting on swards of high stem density occurred on swards where the stem component was mainly at the base of the sward and thus was in fact seldom grazed.

A small number of studies have examined grazing time as a variable involved in the determination of herbage intake. They include studies on cattle grazing tropical swards in Australia (Stobbs, 1970, 1974, 1975, 1977; Stobbs and Hutton, 1974; Chacon and Stobbs, 1976; Chacon, Stobbs and Sandland, 1976; Chacon, Stobbs and Dale, 1978), on sheep in Australia (Arnold, 1960; Allden, 1962; Arnold and Dudzinski, 1966; Allden and Whittaker, 1970; Arnold and Birrel, 1977), and on cattle and sheep in the United Kingdom (Hodgson and Wilkinson, 1967; Jamieson and Hodgson, 1979a&b; Le Du, Combellas, Hodgson and Baker, 1979; Hodgson and Jamieson, 1981). In general there is a negative correlation between time spent grazing and sward height or herbage mass. Allden and Whittaker (1970) found that grazing time increased rapidly with a decline in herbage mass below 1000 kg DM/ha. Chacon and Stobbs (1976) found poor correlations between grazing time and sward characteristics when a tropical grass sward was grazed down over two weeks. However, there was evidence that grazing time was negatively correlated with herbage mass in the first week of the two but then became positively correlated in the second week. Jamieson and Hodgson (1979b) reported significant negative relationships between grazing time and green herbage mass for both calves and lambs. J. Wadsworth (personal communication) found a significant quadratic relationship between grazing time and herbage mass in sheep with short grazing times at both low and high herbage masses. He found a similar quadratic relationship between grazing time and sward height, whilst the relationship between grazing time and sward density was positive but non-significant. A similar quadratic function was found by Hendricksen and Minson (1980) for the regression of grazing time by cattle on the yield of leaf of a tropical legume.

Relationships between ingestive behaviour variables and sward structure and their combined influence on herbage intake

The ingestive behaviour variables reviewed above do not act on intake in isolation, but rather, their individual responses to changing sward conditions are modified by the extent of the change of the other variables.

Allden and Whittaker (1970) showed that as rate of intake (intake per bite x rate of biting) declined with declining herbage mass so their sheep began to increase grazing time in compensation; at very low levels of herbage mass, however, compensation becomes progressively more incomplete. Hendricksen and Minson (1980) found that as intake per bite declined in parallel with the yield of green leaf their cattle increased rates of biting and grazing time, but not sufficiently to compensate for the increasingly smaller intakes per bite. Grazing time was reduced at green leaf yields below 1200 kg/ha and thus intakes fell even faster. While grazing certain swards particularly those with a low herbage mass animals may be faced with the decision of whether to continue grazing for long periods at low rates of intake. Under conditions of severely limited food intake, whether this shortage is due to a physical absence of feed or a lack of desire on the animals part to graze unappetizing herbage, it may be advantageous for animals to reduce energy expenditure by reducing grazing activity. Young and Corbett (1972) reported maintenance requirements of grazing sheep to be 60-70% greater than those for housed sheep of similar liveweight, and that animals that had been on good pasture when put on poor pasture reduced their daily energy expenditure by about 70kJ/kg $LW^{0.75}$. Though rate of biting declines at low herbage mass and low sward height, it is not possible to distinguish between the effects of fatigue or the effects of diet selection, both of which might reduce rate of biting.

Changes in sward conditions lead to different responses in ingestive behaviour, and thus it can be difficult to obtain a clear picture of the overall change in herbage intake in response to changes in sward conditions. Many workers have found that the relationship between herbage intake and herbage mass is asymptotic, although the actual herbage mass below which herbage intake is depressed varies between experiments

(Johnstone-Wallace and Kennedy, 1944; Tayler, 1966; Hodgson, Tayler and Lonsdale, 1971; Hodgson, 1977). However, Hodgson and Milne (1978) and Jamieson and Hodgson (1979b) found no evidence that the relationship between intake and herbage mass deviated from linearity, even at herbage masses over 3000 kg/ha. Hodgson and Milne (1978) suggested that other sward variables such as sward height, leaf:stem ratio or herbage density may modify the overall relationship between intake and herbage mass, thus leading to the variation in the critical mass that has been found. Jamieson and Hodgson (1979b) suggested that the lack of an asymptote reflected either the higher potential nutrient intakes or the greater sensitivity to sward conditions of their young cattle and sheep. Though Jamieson and Hodgson (1979b) reject the second alternative as being unlikely, Allden and Whittaker (1970) found that lambs were better at maintaining intake on very short swards than older animals, and Hodgson and Jamieson (1981) suggest that calves that are experienced grazers may be particularly sensitive to variations in herbage mass.

Sward height has also been found to be an important influence on herbage intake. When comparing results obtained by different workers allowance must be made for difference in measurement techniques. Sward height has been measured in a variety of ways, which have been reviewed recently (Rhodes, 1981). Hodgson (1981) suggested that in temperate swards the surface height of the sward determines rate of herbage intake to a greater extent than the density of herbage or proportion of live material at the surface. This is not the case with tropical swards where tall swards generally have low surface densities and thus intake per bite is low and hence rate of intake is depressed (Stobbs, 1973a&b). Allden and Whittaker (1970) found in one experiment that sward height was closely associated with rate of intake (figure 6) and that herbage mass and intake were only barely related. The influence of herbage density on intake, either in the sward as a whole or in individual sward horizons, has been described by Spedding and Large (1957), Chacon and Stobbs (1976), Chacon, Stobbs and Dale (1978), Hodgson (1981) and Wade and Le Du (1983). Swards of low density reduce the ease of prehension of the herbage and thus rate of intake declines.

Implications for grazing wheat

Wheat has an extremely simple structure, at least up until jointing which corresponds to the period of its greatest importance for grazing. It has an upright growth habit, a morphology which not only allows the most efficient use of incident light and hence promotes maximum growth (Cooper and Breeze, 1971), but which also allows greater levels of herbage intake and animal performance and greater efficiency of grazing. (Jackson 1975, Hodgson 1977, Jamieson and Hodgson, 1979a). Hodgson (1980) suggests that the traditional view of the plant morphology most suited to grazing (prostrate growth habit, and a high population of small tillers per plant), may need some revision, and the wheat plant certainly fits Hodgson's alternative model.

All the evidence, from other environments admittedly, suggests that during the main grazing season the wheat plant or wheat sward has no structural components that are likely to limit intake other than reduced mass or height.

At jointing the farmer has two choices; either to stop grazing and allow the development of a grain crop, or to continue grazing. The state of the grain and cattle markets will determine which choice is made, but if the decision is made to continue grazing it is important for the farmer to have some information as to potential intakes during the graze-out period. The available information suggests that even during this period of stem elongation and seed-head appearance herbage intake is not adversely affected (Horn et al., 1981; Made et al., 1981; Ford et al., 1983), presumably because the herbage digestibility remains relatively high.

There is, however, almost no information on herbage intake by animals grazing wheat either before or after jointing. This lack of information is, no doubt, a reflection of the simplicity of the wheat forage grazing system. This does not mean, however, that there is no need for a body of information from which management decisions can be made. Increased costs resulting in the need for increased efficiency of utilization of wheat both for forage and grain will in fact lead to a demand for such a body of information. This conference is the first step to its achievement.

Literature Cited

Allden, W. G. (1962). Rate of herbage intake and grazing time in relation to herbage availability. Proc. Aust. Soc. Anim. Prod., 4:163.

Allden, W. G. and Whittaker, I. A. McD. (1970). The determinants of herbage intake by grazing sheep: The interrelationships of factors influencing herbage intake and availability. Aust. J. Agric. Res., 21:755.

Arnold, G. W. (1960). The effect of quantity and qualityof pasture available to sheep on their grazing behaviour. Aust. J. Agric. Res., 11:1034.

Arnold, G. W. and Birrel, H. (1977). Food intake and grazing behaviour of sheep varying in body condition. Anim. Prod., 24:343.

Arnold, G. W. and Dudzinski, M. L. (1966). The behavioural responses controlling the food intake of grazing sheep. p. 367-370. Proc. 10th Int. Grassld. Congr. Helsinki.

Barthram, G. T. (1980). Sward structure and the depth of the grazed horizon. pp. 6.1-6.2. Proc. Br. Grassld. Soc. Winter Meeting 1980.

Chacon, E. A. and Stobbs, T. H. (1976). Influence of progressive defoliation of a grass sward on the eating behaviour of cattle. Aust. J. Agric. Res., 27:709.

Chacon, E. A., Stobbs, T. H. and Dale, M. B. (1978). Influence of sward characteristics on grazing behaviour and growth of Hereford steers grazing tropical grass pastures. Aust. J. Agric. Res., 19:89.

Chacon, E. A., Stobbs, T. H. and Sandland, R. L. (1976). Estimation of herbage consumption by grazing cattle using measurements of eating behaviour. J. Br. Grassld. Soc. 31:81.

Cooper, J. P. and Breeze, E. L. (1971). Plant breeding: Forage grasses and legumes. In: P. F. Wareing and J. P. Cooper (Eds.), Potential Crop Production. A Case Study. pp. 295-318. Heinemann Educational Books Ltd. London.

Forbes, T. D. A. (1982). Ingestive behaviour and diet selection in grazing cattle and sheep. Ph.D. Thesis. Edinburgh University, Edinburgh.

Ford, M. J., Phillips, W. A., Horn, G. W. and Worthington, A. K. (1983). Supplementation of wheat pasture and bermuda grass stocker cattle with silage. Okla. Agr. Exp. Sta. Res. Rep. MP.-114:226.

Hendricksen, R. and Minson, D. J. (1980). The feed intake and grazing behaviours of cattle grazing a crop of <u>Lablab purpureus</u> cv. Rongai. J. Agric. Sci. (Camb.) 95:547.

Hodgson, J. (1977). Factors limiting herbage intake by the grazing animal. In: B. Gilsenan (Ed.) Proc. Int. Meeting on Anim. Prod. from Temperate Grassland. Dublin 1977. pp. 70-75. Irish Grassland and Anim. Prod. Assoc./An Foras Taluntais.

Hodgson, J. (1980). Testing and improvement of pasture species. In: F. H. W. Morley (Ed.) World Animal Science B. Disciplinary Approach. I. Grazing animals. pp. 309-317. Elsevier Scientific Publishing Company.

Hodgson, J. (1981). Variations in the surface characteristics of the sward and short-term rate of herbage intake by calves and lambs. Grass and Forage Sci., 36:49.

Hodgson,J. (1982). Influence of sward characteristics on diet selection and herbage intake by the grazing animal. In: J. B. Hacker (Ed.) pp. 153-166. Nutritional limits to animal production from pastures. Commonwealth Agricultural Bureaux. Farnham Royal, U.K.

Hodgson, J. and Jamieson, W. S. (1981). Variations in herbage mass and digestibility, and the grazing behaviours and herbage intake of adult cattle and weaned calves. Grass and Forage Sci., 36:49.

Hodgson, J., Tayler, J. C. and Lonsdale, C. R. (1971). The relationship between intensity of grazing and the herbage consumption and growth of calves. J. Br. Grassld. Soc., 26:231.

Hodgson, J. and Milne, J. A. (1978). The influence of weight of herbage per unit area and per animal upon the grazing behaviour of sheep. pp. 4.31-4.38. Proc. 7th General Meeting European Grassland Federation. 1978, Ghent.

Hodgson, J. and Wilkinson, J. M. (1967). The relationship between liveweight and herbage intake in grazing cattle. Anim. Prod., 7:365.

Horn, G. W., Mader, T. L., McNew, R. W., Streeter, C. L. and Armbruster, S. L. (1981). Effect of initial weight on daily gain of stocker cattle grazed on wheat pasture. Okla. Agr. Exp. Sta. Res. Rep. MP.-108:94.

Jackson, D. K. (1975). The influence of patterns of defoliation on sward morphology. In: J. Hodgson and D. K. Jackson (Eds.), Pasture Utilization by the Grazing Animal. pp. 51-60. Occ. Symp. No 8 Br. Grassl. Soc.

Jamieson, W. S. and Hodgson, J. (1979a). The effect of daily herbage allowance and sward characterstics upon the ingestive behaviour and herbage intake of calves under strip-grazing management. Grass and Forage Sci., 34:261.

Jamieson, W. S. and Hodgson, J. (1979b). The effects of variation in sward characteristics upon the ingestive bahaviour and herbage intake of calves and lambs under a continuous stocking management. Grass and Forage Sci., 34:273.

Johnstone-Wallace, D. B. and Kennedy, K. (1944). Grazing management practices and their relationship to the behaviour and grazing habits of cattle. J. Agric. Sci. Camb., 34:190.

Le Du, Y. L. P., Combellas, J., Hodgson, J. and Baker, R. D. (1979). Herbage intake and milk production in grazing dairy cows. 2. The effects of level of winter feeding and daily herbage allowance. Grass and Forage Sci., 34:249.

Mader, T. L., Horn, G. W. and Phillips, W. A. (1981). Effect of feeding wheat straw or sorghum sudar hay on gains and wheat forage utilization of stocker cattle. Okla. Agr. Exp. Sta. Res. Rep. MP.-108:96.

Rhodes, I. (1981). Canopy structure. In: J. Hodgson et al. (Eds.) Sward Measurement Handbook. pp. 141-158. Br. Grassld. Soc. Hurley, England.

Spedding, C. R. W. and Large, R. V. (1957). A point-quadrat method for the description of pasture in terms of height and density. J. Br. Grassld. Soc. 12:229-234.

Stobbs, T. H. (1970). Automatic measurement of grazing time by dairy cows on tropical grasses and legume pastures. Trop. Grassl., 4:237.

Stobbs, T. H. (1973a). The effect of plant structure on the intake of tropical pastures. I. Variation in the bite size of grazing cattle. Aust. J. Agric. Res., 24:809.

Stobbs, T. H. (1973b). The effect of plant structure on the intake of tropical pastures. II. Differences in sward structure, nutritive value and bite size of animals grazing Setaria anceps and Chloris gayana at various stages of growth. Aust. J. Agric. Res., 24:821.

Stobbs, T. H. (1974). Rate of biting by Jersey cows as influenced by the yield and maturity of pasture swards. Trop. Grassl., 8:81.

Stobbs, T. H. (1975). The effect of plant structure on the intake of tropical pasture. III. Influence of fertilizer nitrogen on the size of bites harvested by Jersey cows grazing Setaria anceps cv. Kazungula swards. Aust. J. Agric. Res., 26:997.

Stobbs, T. H. (1977). Seasonal changes in the preference by cattle for Macroptilium atropurpureum cv. Siratro. Trop. Grassl., 11:87.

Stobbs, T. H. and Hutton, E. M. (1974). Variations in canopy structurs of tropical pastures and their effects on the grazing behaviour of cattle. Proc.12th Int. Grassld. Congr. Moscow. Vol. 2. pp.680-684.

Tayler, J. C. (1966). Relationships between the herbage consumption or carcass energy increment of grazing beef cattle and the quantity of herbage on offer. Proc. 10th Int. Grassld. Congr., Helsinki. pp.463-470.

Wade, M. H. and Le Du, Y. L. P. (1983). The influence of sward structure upon the herbage intake of cattle grazing a perennial ryegrass sward. Proc. 14th Int. Grassld. Congr., Lexington 1981. pp. 525-528.

Young, B. A. and Corbett, J. L. (1972). Maintenance energy requirements of grazing sheep in relation to herbage availability. 2. Observations on grazing intake. Aust. J. Agric. Res., 23:77.

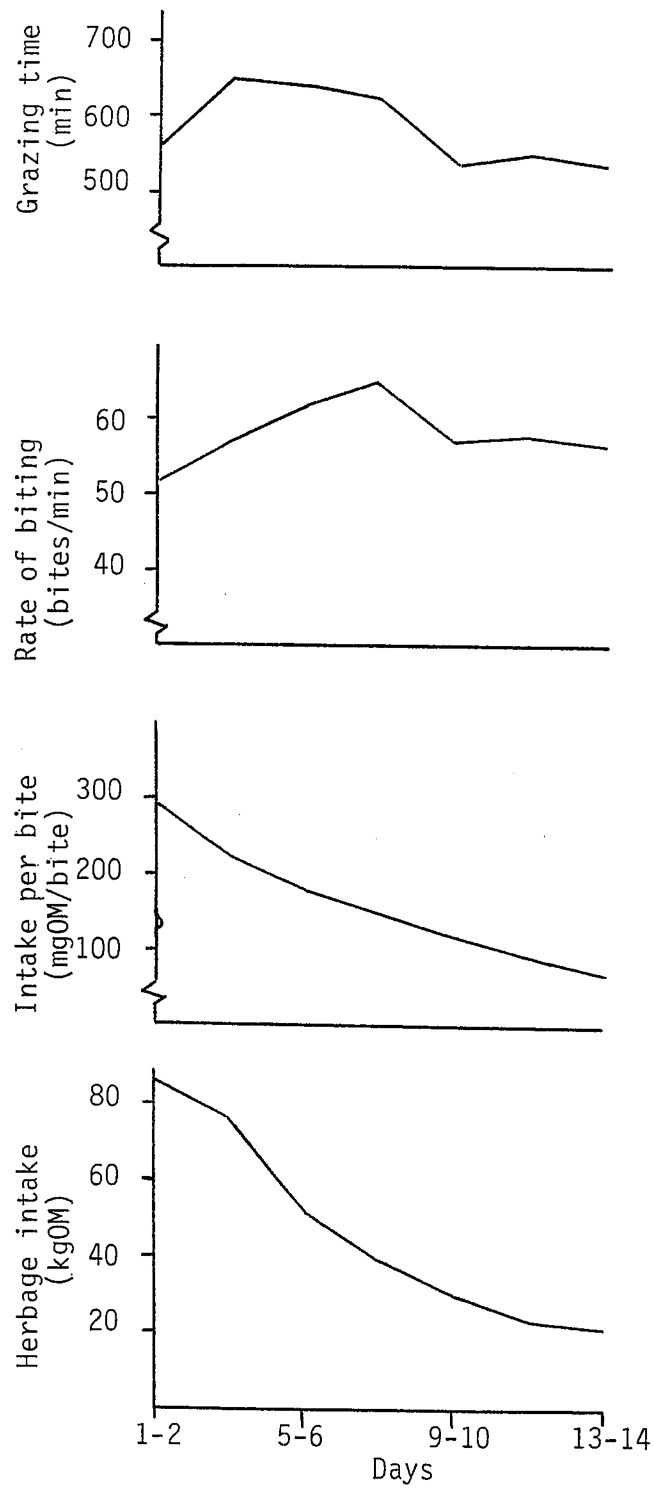


Figure 1. Relationships between grazing behaviour measurements and herbage intake of cattle grazing tropical pastures (From Chacon and Stobbs, 1976).

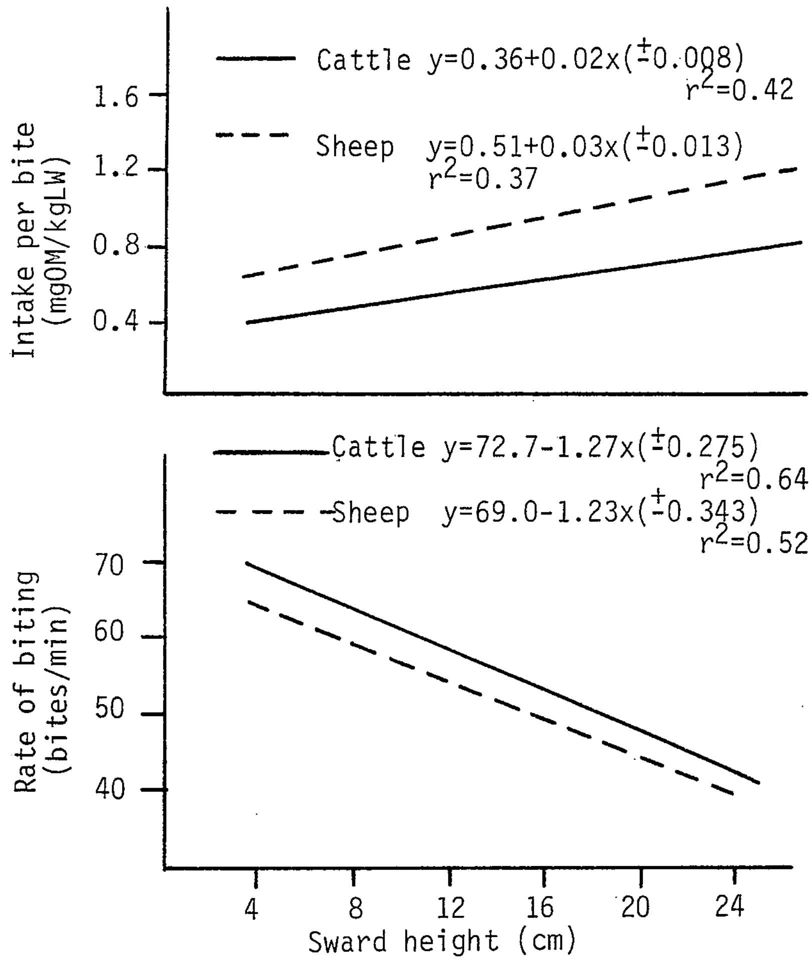


Figure 2. The relationships between cattle and sheep intakes per bite (mgOM/kgLW) and rates of biting (bites/min), and sward height (Forbes,1982).

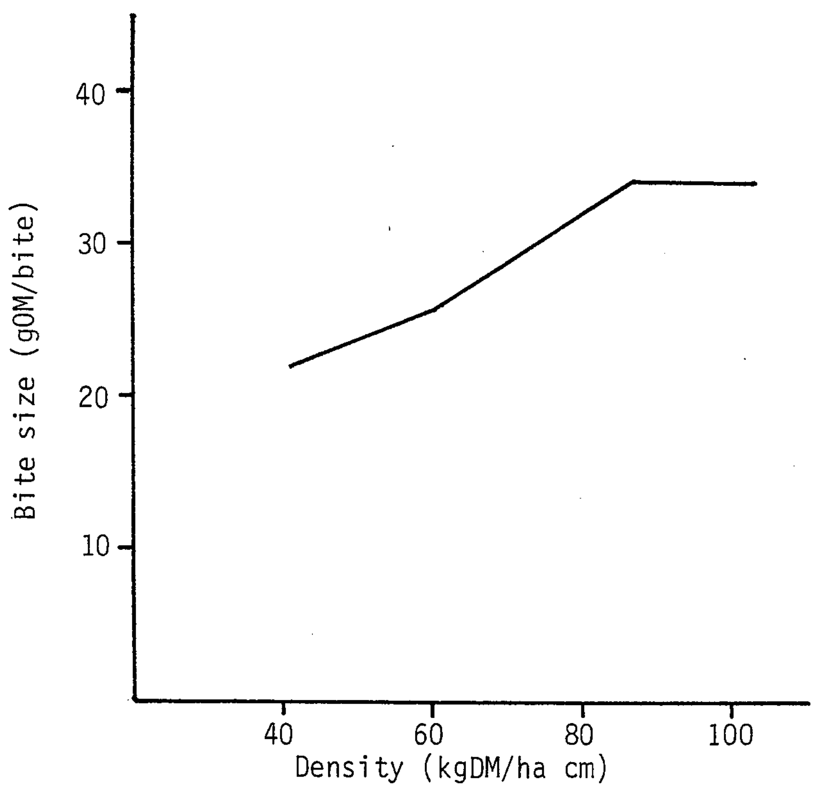


Figure 3. The relationship between the bite size (gOM/bite) of cattle grazing tropical pasture and sward bulk density (kgDM/ha cm). (From Stobbs, 1975)

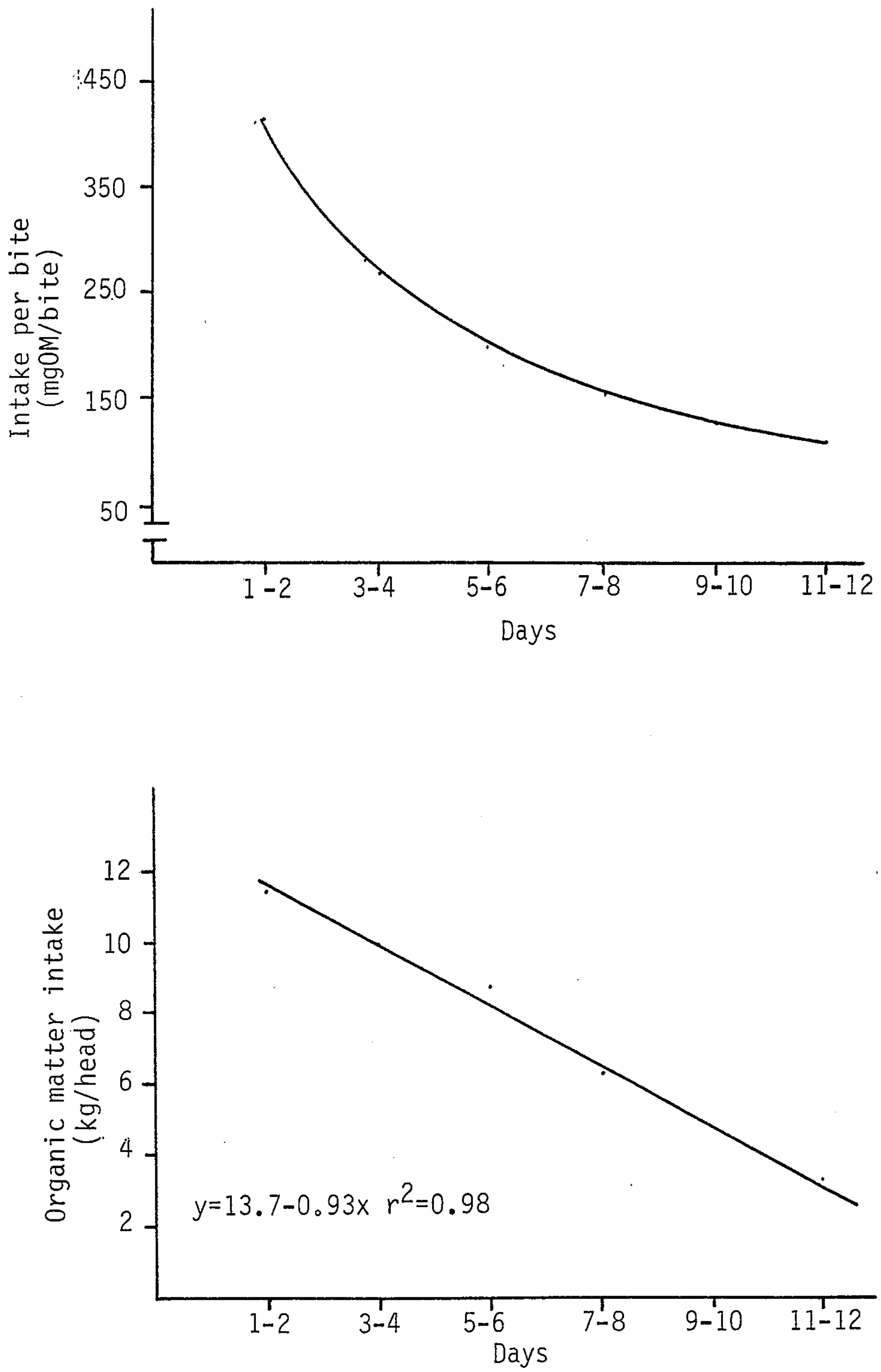


Figure 4. The decline in intake per bite (mgOM/bite) and intake (kgOM/head) over time of cattle grazing Lablab purpurea (Hendricksen and Minson, 1981)

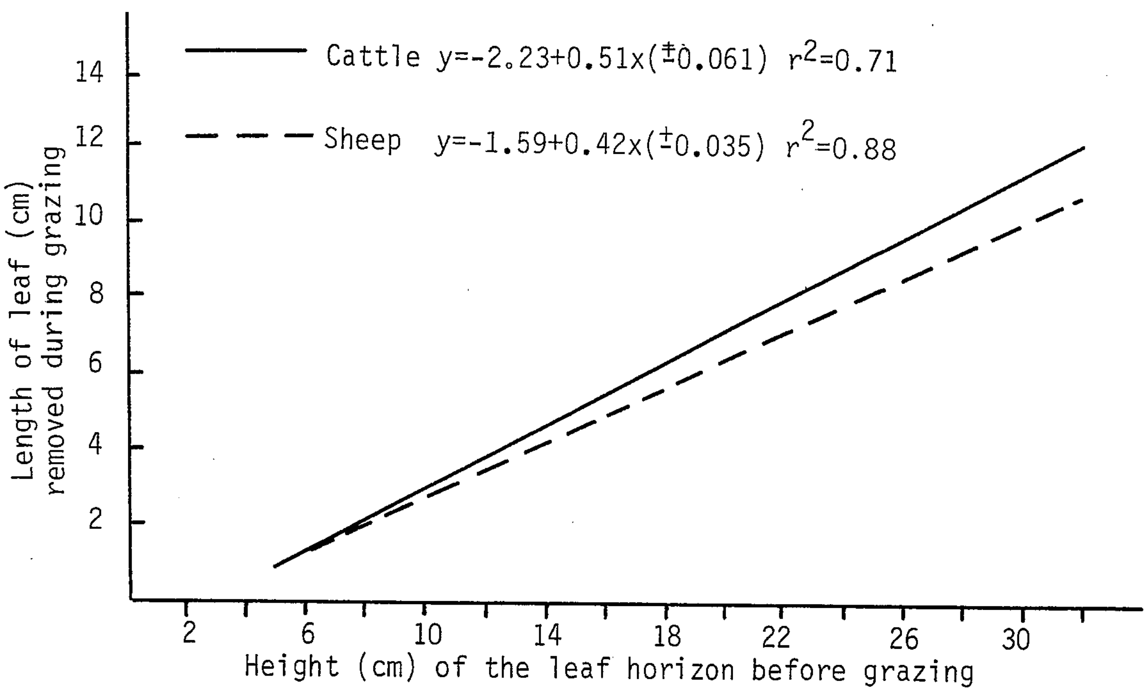


Figure 5. The depth of the grazed leaf horizon regressed on the pre-grazing leaf length (Forbes, 1982)

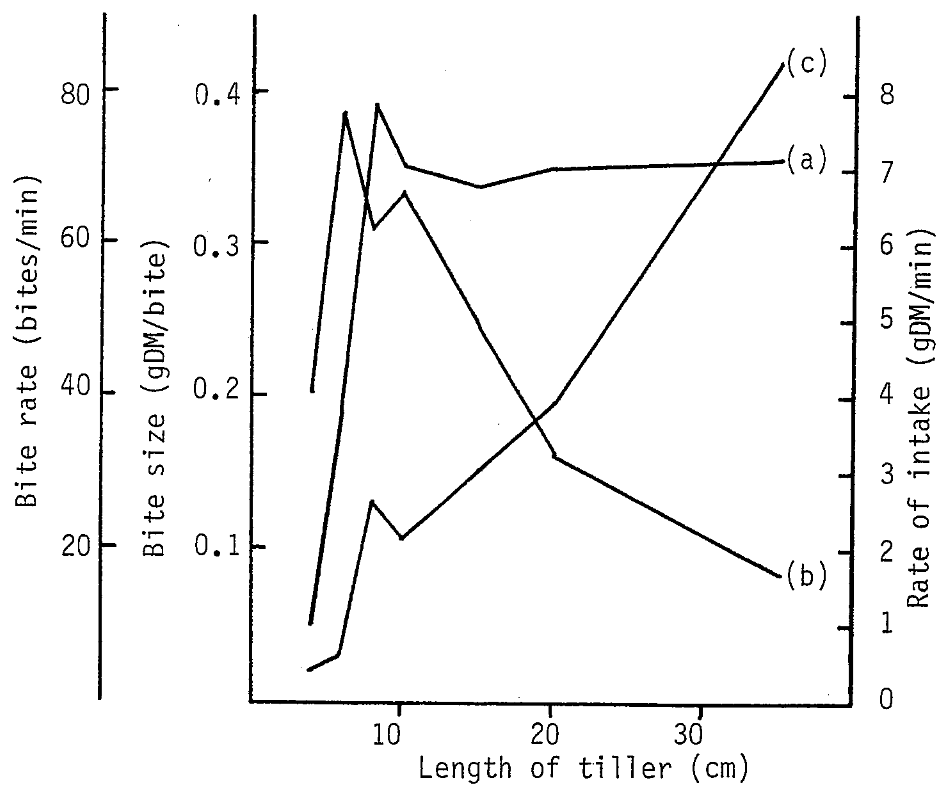


Figure 6. Relation of (a) rate of intake, (b) rate of biting and (c) bite size to length of tiller (Allden and Whittaker, 1970).

Forage and grazing effects on intake and utilization of annual ryegrass by cattle.

W.C. Ellis[1], J.P. Telford[2], H. Lippke[3] and M.E. Riewe[4]
Texas Agricultural Experiment Station

Summary and Conclusions

Temperate, cool season, annual and perennial grasses such as wheat and ryegrass are highly digestible in their vegetative states. Results of extensive and intensive grazing trials with annual ryegrass were reviewed for information on the effects of grazing this forage which might be applicable to wheat pastures. Responses in animal productivity to varied forage availabilities (forage/area) produced by varied grazing pressure (animal/forage) on ryegrass were of a similar general form as observed for other classes of forages. The magnitude of the responses suggest ryegrass may be insufficient to completely meet the growing animals' nutrient requirements for maximum production. Grazing the vegetative ryegrass plant below a critical availability or height reduces the digestibility of the consumed forage and this is associated with reductions in forage intake but not fecal output by the animal. Selective grazing alters the potential digestibility of the residual forage and is associated with reduced intake. In the experiment, fecal output by the grazing animal was not different and indicates the quantity of prehensible forage was not the factor limiting forage intake. These results indicate that attributes of ryegrass related to its digestibility are involved in regulating its intake by the grazing animal. This conclusion is contrary to the concept that intake of forages of greater than 65% digestibility is regulated by metabolic means. By analogy, the wheat plant may have some limitations in its "nutritional quality." These results suggest the need for an improved understanding of the regulation of intake of such highly digestible forages and nutritional interaction with grazing management.

Introduction

By most nutritional criteria the vegetative wheat plant and wheat pasture should be an extremely high quality feedstuff. A direct assessment of this nutritional quality in terms of animal productivity is difficult since animal productivity is not the sole economic objective for most wheat planted and grazed in the Southwest. Animal production research with wheat pastures has only briefly considered the nutritional attributes of the forage as grazed and generally has not

----

1. Professor, Department of Animal Science.
2. Former graduate student, Department of Animal Science.
3. Associate Professor, Texas Agricultural Research Station at Angleton.
4. Professor, Texas Agricultural Research Station at Angleton.

distinguished effects of quantity and quality of wheat pasture upon the observed production. More extensive studies have been conducted concerning effects of grazing management and forage availability upon the nutritive value of other temperate species related to the wheat plant however. These will be reviewed here as the basis for identifying needed information on the grazed wheat plant.

Review of Literature

Two dominant factors normally determine the level of production of an individual animal:

1. The animal's genetically determined capacity to utilize nutrients which establishes its requirement for dietary nutrients and
2. The animal's ability to acquire nutrients from its feed supply to contribute to such nutrient requirements.

The ability to acquire nutrients is the factor most frequently limiting ruminant productivity from forages and especially from less digestible (<65%) forages (Conrad et al., 1964 and Forbes, 1980). The major constraint to nutrient acquisition from an adequate supply of less digestible forages is the relatively low digestibility and bulky nature of their undigested residues relative to the rumen volume available for their occupancy during digestion (Forbes, 1980). This is schematically depicted in figure 1.

Forbes (1980) has proposed a model for the regulation of feed intake by the ruminant based on regulating the frequency and size of individual meals. Individual meals are proposed to be initiated when the rate of absorption of nutrients falls below a certain threshold value. The meal may then be either metabolically terminated when the rate of nutrient absorption exceeds a certain upper threshold value or physically terminated when the currently ingested forage residues plus the pre-existing, undigested forage residues equal the volume available for such in the rumen. According to these concepts, the daily intake of less digestible forages is largely controlled by physical termination of meals to conform with the physical balance of volume available in the rumen. The daily intake of more digestible forages is largely, if not entirely, controlled by metabolic termination of meals to conform with short term (< than daily) metabolic balances between digested and required nutrients. Both metabolic and physical termination of meals occur for forages of intermediate digestibility (60-70% for example).

In the grazing animal, additional factors associated with forage supply may directly or indirectly limit forage intake. As the supply of prehensible forage is reduced (relative to the demand for digested nutrients) ruminants increase their grazing time (Allden and Mc D. Whittaker, 1970) to compensate for reduced size of bite. However as the animal extends its grazing time the compensation becomes progressively more incomplete and forage intake decreases. At extremely high grazing pressures, forage intake would conceptually equal forage growth rate which may be materially supressed due to extreme removal of photosynthetically active leaf area (figure 1).

At intermediate grazing pressures, forage intake may be indirectly influenced through selective grazing by the animal. Increasing quantities of prehensible forage provides greater opportunities for the animal to selectively consume more nutritious plant parts until some maximum selectivity is achieved (Allden and McD. Whittaker, 1970 and Hamilton et al., 1973). By this means, forage intake may be increased due to the increased digestibility and reduced volume occupied by the undigested residues derived from the more highly selected diet.

Based on the brief view summarized in figure 1, it is clear that performance by grazing animals may be the result of a number of interactions involving the forage, the animal and grazing management. This is illustrated in figure 2 which summarizes results of a four year study in which four different levels of grazing pressure were maintained to yield variable levels of availability (forage/area) of ryegrass (Riewe, 1976). The form of the animal gain response to varied forage availability is typical of that obtained with a wide array of forages and its interpretation has been extensively discussed (Peterson et al., 1965 and Hart, 1972). Figure 2 is presented here primarily to document that performance of steers grazing ryegrass is less than their potential performance when forage supply is not a contributing factor. This interpretation is supported by the higher gains made by steers grazing ryegrass plus clover as compared to ryegrass alone at all levels of equivalent availabilites of the two forages. This suggests that ryegrass alone has some attributes which limited its level of nutrient acquisition or efficiency of nutrient utilization. This is in contrast to the concept that the intake of such highly digestible (>65) forages is regulated solely by metabolic balance so that the productive capacity of the animal should be realized from forages such as ryegrass (Conrad et al., 1964).

It should be noted that the animal responses reported in figure 2 are means for those occuring over the entire grazing season. Measurement of such "long term" responses are necessary to minimize effects of short term changes in the gastrointestinal fill component of liveweight. However, Taylor (1966) has shown similar responses to forage availability for perennial ryegrass when animal responses were measured as digesta free body weight, energy gain, forage intake or intake of digestible organic matter. Some results of his studies are summarized in table 1 to indicate the forage availabilities or height required for specified levels of animal performance. These and other data (Allden and McD. Whittaker, 1970) emphasize the importance of forage height rather than forage/area in determining the quantity of prehensible forage. These and other aspects of grazing prehension of forage are discussed in greater detail in the preceeding paper of this symposium and by Hodgson (1982).

The effects of progressive defoliation of annual ryegrass via grazing upon its intake and digestibility has been intensively studied. Successive first, second and third grazer cattle were used to measure effects of progressive reductions in the daily herbage allowance (quantity of forage/quantity of animal/time) of rotationally grazed annual ryegrass (Telford and Ellis, 1981). These effects on the intake and digestibility of the forage and fecal output by cattle are summarized in figure 3.

The progressive reduction in daily herbage allowance from 70 to 10 kg dry matter per 100 kg animal body weight had no significant effect on daily fecal output which averaged 0.84 kg/100 kg body weight. In contrast, dry matter digestibility and daily intake were significantly (P<.01) and progressively reduced when daily herbage allowance was reduced below 30 kg/100 kg body weight. The lack of a significant effect on fecal output suggests the quantity of prehensible forage was not limiting in these studies and that quality effects were dominant in determining intake of grazed ryegrass. The effects on digestibility indicate progressive harvest of the forage by grazing occured by selective grazing and resulted in depressed digestibility of the subsequent diet when daily herbage allowance was reduced to less than 20-30 kg DM/100 kg BW.

Of equal if not greater significance is the high correlation occuring between intake and digestibility of these relatively highly digestible forages. This relationship is further illustrated in figure 4 and emphasizes that most of the variation in observed intake was linearly related to the digestiblity of the consumed forage. This is surprising since such highly digestible forages contribute relatively small amounts of undigested dry matter in the rumen required (figure 1) to affect physical regulation of intake (Conrad et al., 1964 and Forbes, 1980). Alternatively, the volume contributed by the ingested and masticated ryegrass on entering the rumen may be effective in a stratigraphic manner in reducing rumination and thereby forage intake as was observed by Deswysen and Ehrlein (1981).

A number of investigators have reported significant correlations between intake of perennial ryegrass and its digestibility when such digestibility was in the order of 65-80% and altered by grazing management (Hodgson, 1967, Hodgson et al., 1977 and Hodgson, 1982). This relationship has also been reported for highly digestible temperate forages other than ryegrass (Demarquilly and Weiss, 1970 and Minson, 1982). Thus regulation of intake of highly digestible, cool season, temperate forages by means related to their digestibility appears to be a general phenomenom which would be applicable to wheat pasture as well.

Areas of Needed Research

This paper suggests there may be limitations in the nutritional "quality" of wheat pasture which is accentuated by reduced opportunities for selective grazing by cattle. However, the grazing utilization of wheat pasture is not usually the sole objective for most of the wheat planted in the Southwest and these other objectives must also be considered. The objectives of producing grain together with the usually occuring weather patterns result in a growth-harvest situation. By mid-winter and until cattle are removed from the pastures to allow grain production, the quantity of prehensible forage may frequently be the first limiting factor. Hence the need for increasing production of the plant during this period by agronomic or other practices in concert with grain production remains of paramount importance. Grazing studies are also needed during this period concerning the effects of grazing management upon the growth rate of the wheat plant. A second need is for an improved understanding of the mechanism involved in the intake-digestibility association of highly digestible forages. Such an improved understanding could identify possibilities for appropriate supplementation to alleviate this "quality" limitation.

Literature Cited

Allden, W.G. and I.A. McD. Whittaker. 1970. The determinants of herbage intake by grazing sheep: The interrelationship of factors influencing herbage intake and availability. Aust. J. Agric. Res.21:755-766.

Conrad, H.R., A.D. Pratt and J.W. Hibbs. 1964. Regulation of feed intake in dairy cows. 1. Changes in importance of physical factors with increasing digestibility. J. Dairy Sci. 47:54-61.

Demarquilly, C. and Ph. Weiss. 1970. Tableaux de la valeur alimentaries des fourrages. Ministere de l'Agriculture Institute National de la Recherche Agronomique, Servies d'Experimentation et d'Information I.N.R.A., Versailles. p. 65.

Deswysen, A.G. and H.J. Ehrlein. 1984. Silage intake, rumination and pseudo-rumination activity in sheep studied by radiography and jaw movement recording. Brit. J. Nutr., 46:327-335.

Forbes, J.M. 1980. A model of the short term control of feeding in the ruminant: Effects of changing animal or feed characteristics. Appetite, 1:21-41.

Hamilton, B.A., K.J. Hutchinson, P.C. Annis and J.B. Donnelly. 1972. Relationships between the diet selected by grazing sheep and the herbage on offer. Aust. J. Agric. Res., 24:271-277.

Hart, R.H. 1972. Forage yield, stocking rate, and beef gains on pasture. Herbage Abstracts 42:345-353.

Hodgson, J. 1967. The relationship between the digstibility of a sward and the herbage consumption of grazing calves. J. Agric. Sci. Camb. 70:47-51.

Hodgson, J., J.M. Rodrigues Capriles and J.S. Fenlon. 1977. The influence of sward characteristics on the herbage intake of grazing calves. J. Agric. Sci. (Camb.) 89:743.

Hodgson, J. 1982. Influence of sward characteristics on diet selection and herbage intake by grazing animals. In: J.B. Hacher (Ed) Nutritional Limits to Animal Production from Pastures. (Symposium) Brisbane, Aust. pp. 153-166. Commonwealth Agriculture Bureau, Slough, U.K.

Minson, D.J. 1982. Effects of chemical and physical composition of herbage eaten upon intake. In: J.B. Hacher (Ed) Nutritional Limits to Animal Production from Pastues. (Symposium) Brisbane, Aust. pp. 167-182. Commonwealth Agriculture Bureau, Slough, U.K.

Petersen, R.G., H.L. Lucas and G.O. Mott. 1965. Relationship between rate of stocking and per animal and per acre performance on pasture. Agronomy Journal 57:27-30.

Riewe, M. E. 1976. Principles of grazing management. Chapter in: Grasses and legumes in Texas - Development, production and utilization. pp. 169-206. Research Monograph 6C, Texas Agricultural Experiment Station, College Station, TX.

Taylor, J.C. 1966. Relationships between the herbage consumption or carcass energy increment of grazing beef cattle and the quantity of herbage on offer. Proc. Int. Grassland Conf. 10:463-470.

Telford, J.P. and W.C. Ellis. 1981. Effect of frequency and duration of grazing annual ryegrass on diet composition and its intake and digestibility. Beef Cattle Research in Texas, Progress Report 3758. pp. 11-13.

Table 1. Estimated availability[a] of perennial ryegrass required for maximum and maintenance levels of performance by growing cattle (from Taylor, 1966).

Index of herbage availability	Maximum gain per head	Maintenance of liveweight
Kg O.M./ha		
All residue[b]	2466	841-1457
"Grazed" residue[c]	1906	673-1233
Mean height, cm		
All residue[b]	13.5	5.1
"Grazed" residue[c]	9.7	3.0

a. Availability measured as above ground level.
b. Includes areas contaminated with dung which were avoided by grazing activities.
c. Includes only areas being actively grazed, does not include dung contaminated areas.

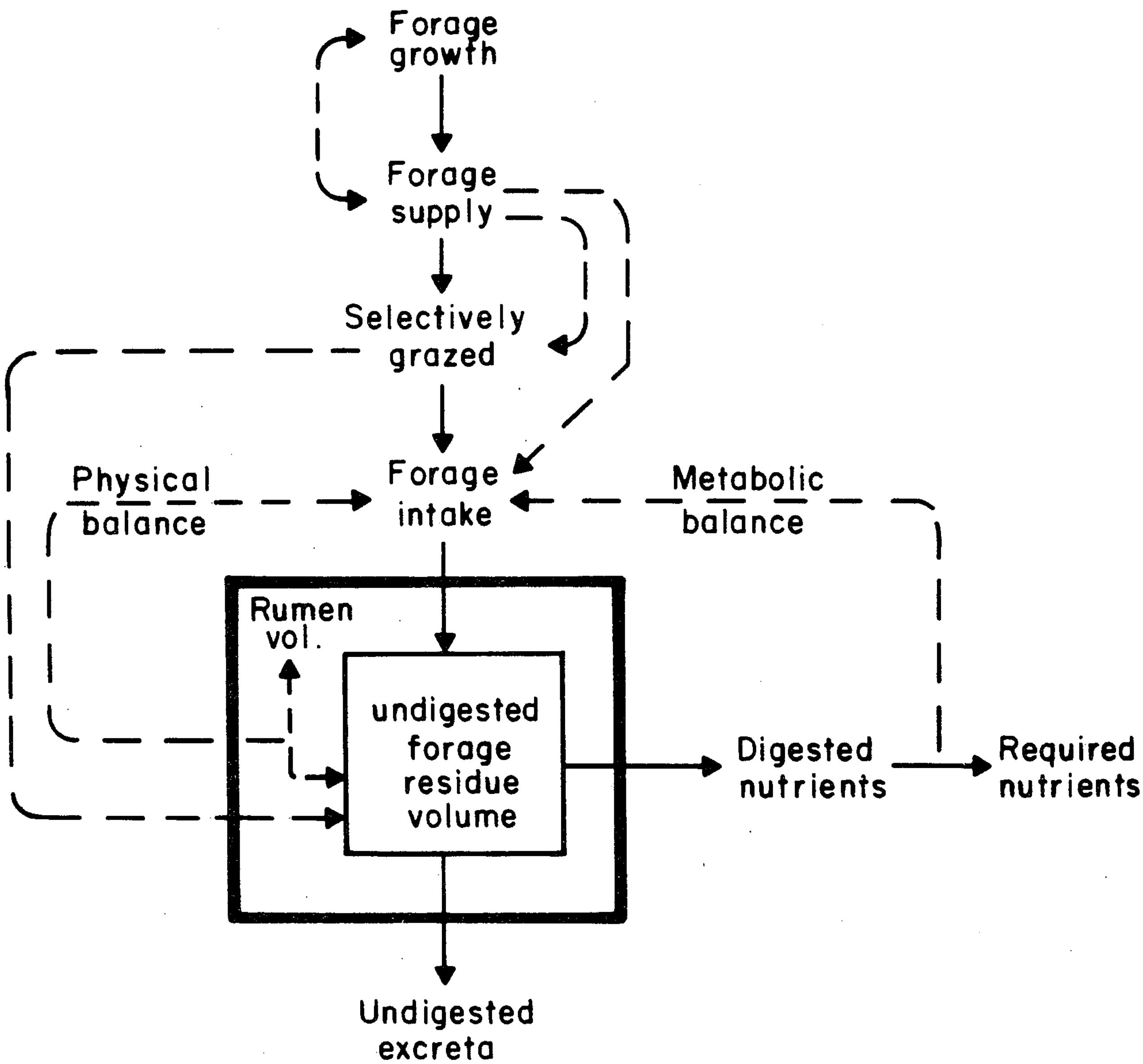


Figure 1. Regulation of intake in the grazing ruminant and its interactions (— —) with forage availability and forage/animal attributes

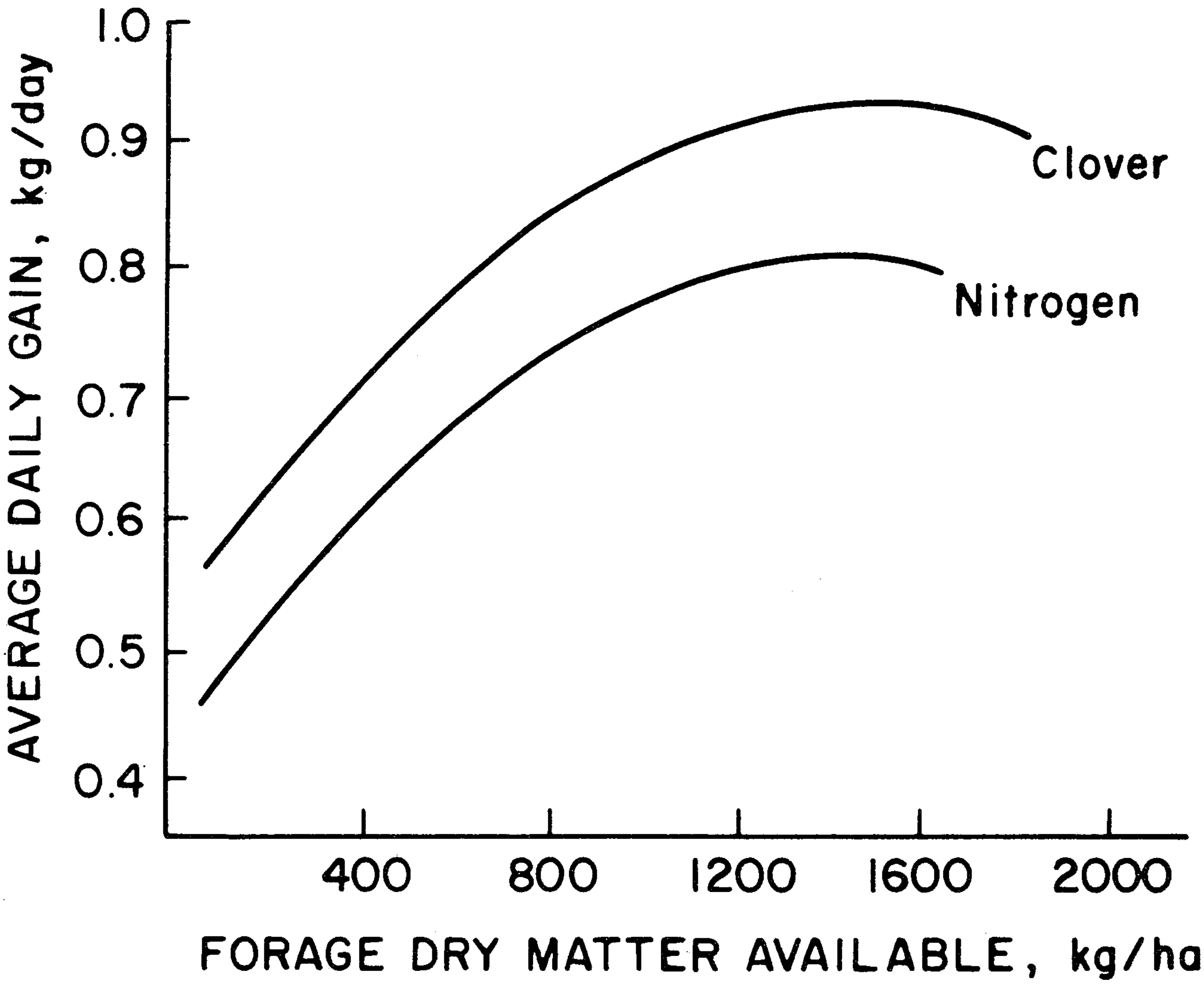


Figure 2. The relative relationships of average kg forage dry matter available per ha to 4-year average daily gain for steers grazing Gulf ryegrass fertilized with nitrogen or grown with Abon Persian clover (Angleton, Texas)

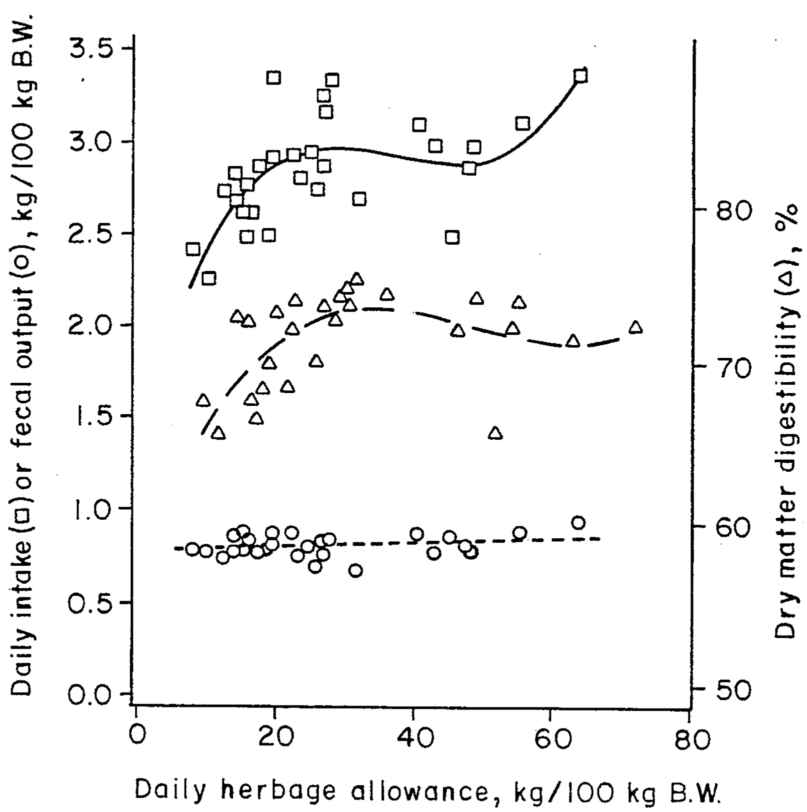


Figure 3. Relationships for daily intake, fecal output and dry matter digestibility to changes in daily herbage allowance due to duration of grazing.

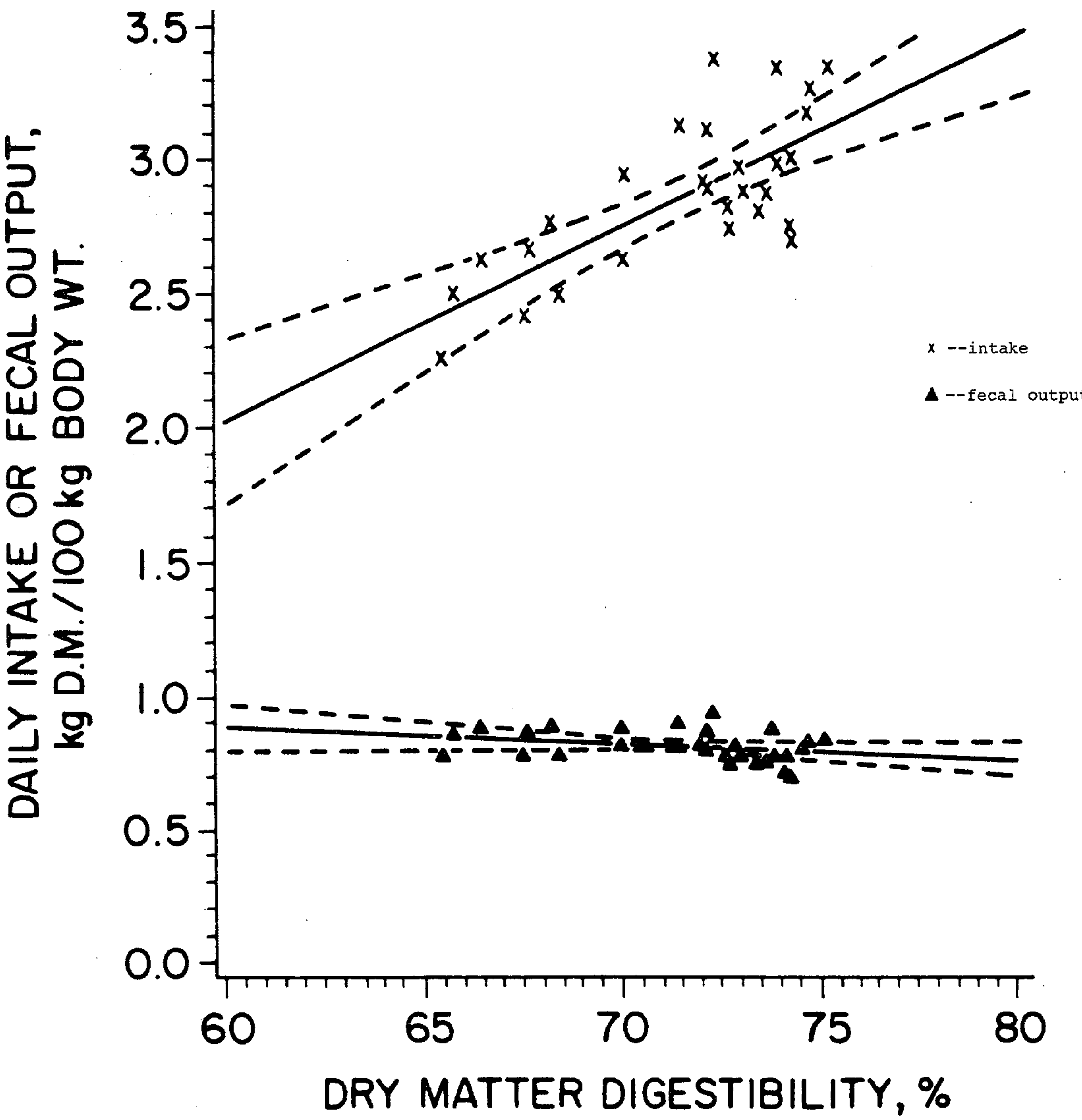


Figure 4. . Intake of ryegrass and fecal output of steers grazing ryegrass of varied digestibility due to the maturity and grazing management of the ryegrass.

RESPONSE OF THE WHEAT PLANT TO NON-ANIMAL STRESSES

Betty Klepper
USDA-ARS, Pendleton, Oregon

SUMMARY

A good measure of wheat plant stress can be derived from the growth pattern of the plant. Unstressed wheat produces tillers at set windows in time, but stressed plants delay or omit tillers. Leaf-by-leaf development of wheat can be timed using accumulated heat units. Therefore, careful examination of leaf numbers on main stems and identified tillers, coupled with weather data, can provide information on both the timing and the relative severity of plant stresses.

INTRODUCTION

Forage crops can be subjected to non-animal stresses at almost any point in the year. In summer, heat and drought stresses occur regularly especially under dryland conditions. In winter, growth is slowed by cold and plants may be damaged by frost. Pathogens are potentially damaging at any time. For each pathogen, there is a window of time when the crop is especially vulnerable. Plant nutritional stresses may decrease potential production in any season and are potentially damaging at times of rapid growth.

Non-animal stresses are complex and variable. For example, one cultivar of wheat may remain healthy and even grow under conditions which would cause another cultivar to cease growth or even to die. Therefore, a plant-centered definition of stress is more useful than are references to environmental measurements. For example, we could define a plant as stressed if the rate of increase in dry matter accumulation is depressed from some optimal rate or if plant water potential has become sufficiently low to cause midday stomatal closure. This approach says much more about current plant stresses than does a determination of soil water potential or atmospheric condition. Although plant-centered measures of stress are valid and useful, they are difficult to integrate into meaningful crop stress assessments because they usually involve occasional "spot" measurements at selected times and meaningful data sets are rare because of the time and labor required to get them. In addition, the plant may be stressed at one point in its life history by a condition which is innocuous at a later time for that same plant. This paper describes a plant-centered method for assessing both the timing and relative severity of stress for cereal seedlings. The method is plant-centered and retrospective so that it permits the previous stress history of a crop to be evaluated.

REVIEW OF LITERATURE

The wheat embryo comprises the coleoptile, a coleoptilar tiller bud, 3 to 4 well-formed leaf primordia, the shoot apex, and 3 to 6 primordia for root axes (Esau, 1965; Mackey, 1973). During seedling development, the formation of new leaf primordia and the enlargement of these primordia into visible leaves occur concurrently. Leaf formation proceeds at a faster rate than leaf enlargement. Thus, by the time that the apical meristem ceases production of vegetative primordia and begins to initiate spikelets, there may be, for example, 11 vegetative nodes on the plant. Typically, 5 of these bear visible leaves and six have leaves awaiting development. Stresses during the vegetative phase primarily affect the enlargement process (Boyer, 1970; Barassi et al., 1980). Aberrations in this process are sensitive indicators of ongoing stresses. All that is needed is a systematic way of examining the sequence of events during development and an accurate way to time these events as a function of weather variables.

The orderly development of cereal nodes, leaves, tillers, and roots can be described using a naming system which assigns a unique designation to each node on the plant (Klepper et al., 1982). For example, the first foliar leaf (L1) is attached to Node 1 and bears a tiller bud (T1) in its axil (Fig. 1). Also related to Node 1 are roots which have different letter names depending on their direction of growth with respect to the leaf at Node 1. These letters and their directions are A (to the left), B (to the right), X (toward), and Y (away from). For example, root 2A is to the left of the midrib of L2 (Klepper et al., 1984). The coleoptile (L0) is borne at Node 0. There are two nodes in the wheat seed: the epiblast node (-1) and the scutellar node (-2). Thus plant components can be associated with each node on the main stem by a unique number.

Similarly, nodes on tillers and subtillers are given unique numbers, with two-digit designations for tillers and three-digit designations for subtillers (Klepper et al., 1983). Each tiller has a prophyll at its base to protect the young shoot as it emerges from the leaf sheath. This prophyll is a modified leaf (analagous to the coleoptile) and bears a bud in its axil. The prophyll is given a "0" designation. Thus, the prophyll node on T1 would be Node 10 and would bear T10 in its axil. The first foliar leaf on T1 is L11 and it bears T11 in its axil. In like manner, prophyll tiller on T10 is called T100. In actual practice, very few subtillers are seen in commercial plantings because tillering usually ceases prior to the time when these nodes become active in the tillering process.

Figure 2 shows the sequence of events in wheat seedling development expressed in phyllochron units. A phyllochron is the amount of time it takes to enlarge a leaf, or stated another way, it is the amount of time between equivalent developmental points on successive leaves. Notice that the diagram shows the same developmental time interval for all leaves on the plant, regardless of the culm which bears them. It takes just as long to enlarge a leaf on the main stem

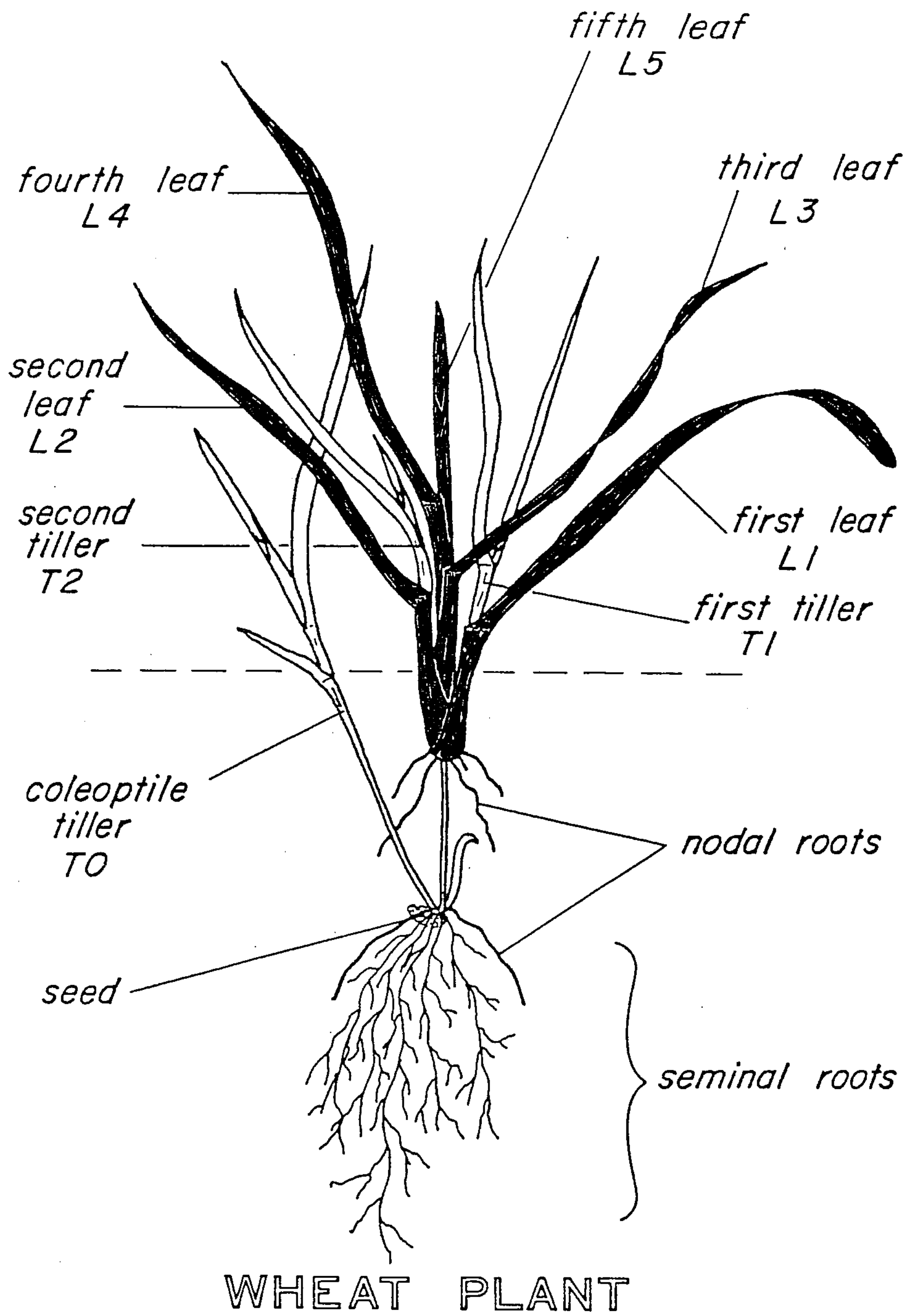


Figure 1. A well-developed wheat seedling showing the leaf and tiller identification system described by Klepper et al. (1982).

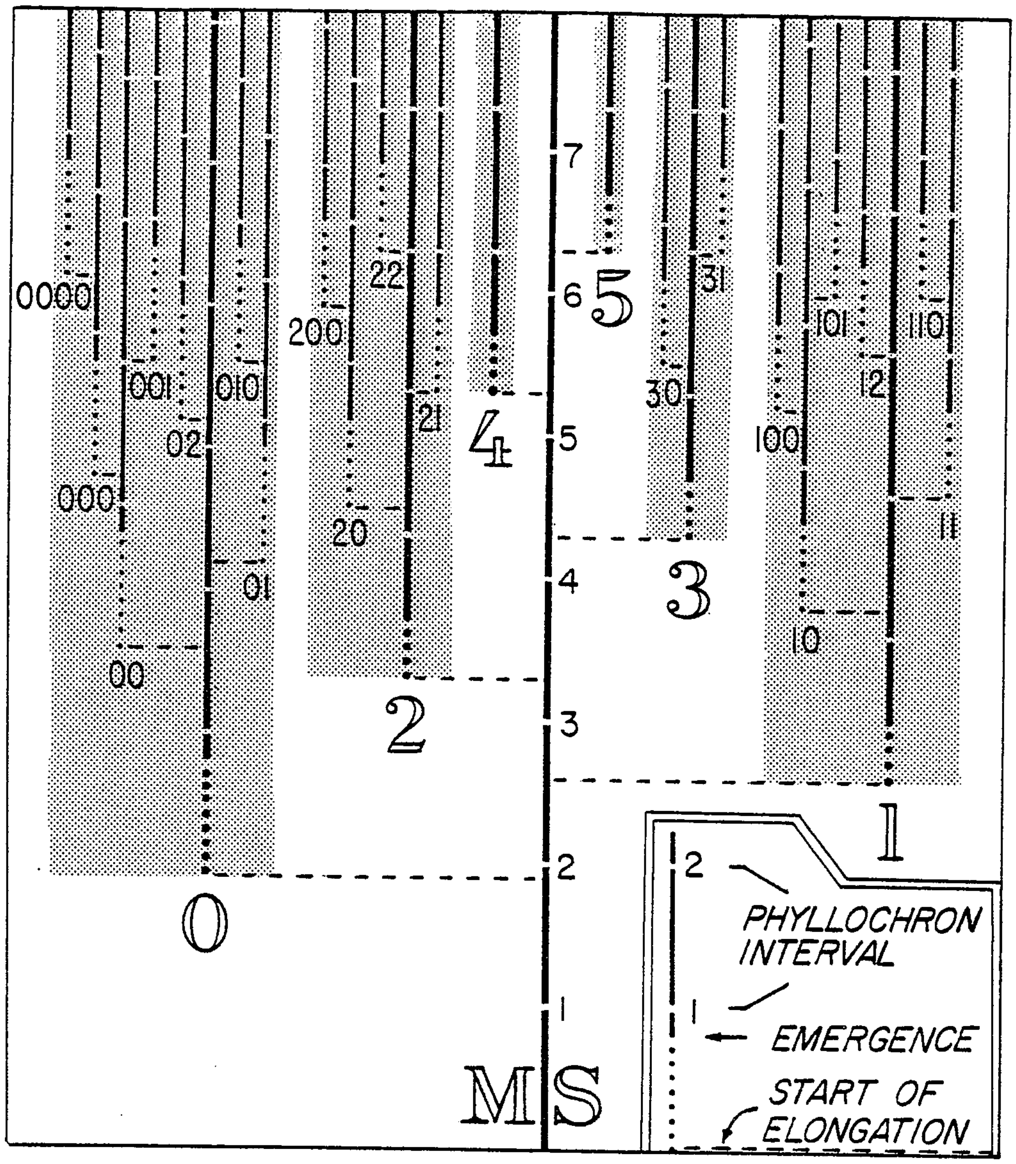


Figure 2. The relationship of leaf and tiller development on unstressed wheat plants. Each bar represents one phyllochron. The dotted lines show time when the tiller leaves have started enlargement but are not yet visible above the leaf sheath.

as it does on the smallest subtiller. Also it is important to realize that Fig. 2 says nothing about leaf size. It only refers to developmental events and predicts which leaves will be elongating at a certain time.

When plants are grown under controlled conditions, calendar days can be used to time plant development. For example, at 18°C, on a 12-hour photoperiod, with 500 μE m^{-2} s^{-1} photosynthetically active radiation, it takes 5 days per leaf. Therefore, referring to Fig. 2, we would expect that plants placed in such a chamber at the 1.5 leaf stage would be well-tillered at the end of 20 days. We would expect, in fact, that there would be 5.5 leaves on the main stem and that each plant would have up to 10 tillers. This information was obtained by laying a ruler across the diagram at the 5.5 point on the main stem and counting the number of solid lines (visible tillers) transected by that ruler.

The development of the root system of wheat can also be predicted using phyllochron concepts (Fig. 3) (Klepper et al., 1984). Here the passage of developmental time is shown on the X-axis and the number of leaves on individual culms is shown on the Y-axis. In this figure, one can lay a ruler vertically at the number of phyllochrons elapsed since emergence and read off the number of leaves to be expected on each culm. To take the example used above, if 5.5 phyllochrons have elapsed since emergence, then we expect to find about 2.2 leaves on T1, 2.3 leaves on T2, and 1.3 leaves on T3. This information was obtained by laying a ruler vertically on Fig. 3 at 5.5 elapsed phyllochrons. However, this diagram also has root information for the main stem nodes. The vertical bars represent named root axes. Their time of initial elongation

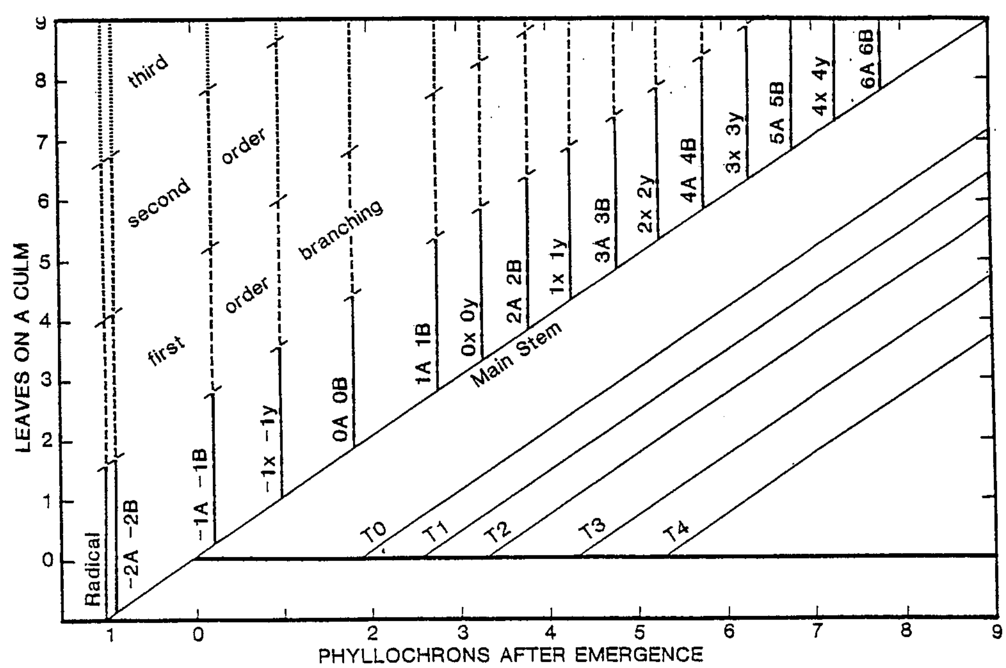


Figure 3. The relationships among leaf, tiller, and root development on the main stem of wheat.

is shown by their relative position on the graph. The radical (R) is the first root to elongate, followed very soon by the -2A and -2B roots which are associated with the scutellar node. Each root axis then develop branches at a certain point in developmental time. This is shown by the hatchings on the vertical bars in Fig. 3. Now we can see that we would expect the seedling with 5.5 leaves and up to 10 tillers to have up to 18 root axes. This information was obtained by placing a ruler horizontally on Fig. 3 at a level showing 5.5 main stem leaves. Some of these axes, especially the seminal ones, will be highly branched and others will not. Note, however, that Fig. 3 makes no reference to the number of branches or to their length; it only denotes that branches will be present.

Under field conditions, the passage of biological time (phyllochrons) for wheat can be measured in cumulative growing degree-days (GDD's) (Rickman et al., 1983). To calculate GDD's, one sums up the average daily air temperature for each day of growth, omitting all negative (below freezing) values. It takes approximately 100 GDD's for each phyllochron, but the actual value varies with cultivar, planting date, and possibly other variables such as snow cover. Also a base temperature of 1 to 4°C may be needed for some crops. The base temperature is subtracted from each day's average temperature prior to summation. Usually weather station air temperatures are used even though the most relevant temperature would probably be that of the crown (Watts, 1972).

Figure 4 shows numbers of leaves on the main stem related to degree days for Stephens wheat under Pacific Northwest growing conditions. Notice that the simple linear relationship holds through quite a range of environmental temperatures because the information in Fig. 4 covers the autumn, winter and early spring.

The description of wheat plant development given so far shows how an unstressed wheat plant develops. Stress can cause plant morphological units to be undersized. For example, short, narrow leaves instead of long, wide ones may appear in response to stress (Turner and Begg, 1981). In fact, leaf size will be similarly affected by stress for all of the leaves growing on separate shoots of a given plant during the stress period (Kemp, 1981). Therefore, comparisons of leaves which have been produced during the same phyllochron interval can be made by referring to Fig. 2.

Stress also causes tillers to be omitted or delayed from their normal time windows (Peterson et al., 1982). This response of the plant to stress permits us to "read" stress in plants by observing how severe are the delays in tiller development relative to the development of the main stem. For example, early seedbed stresses can be detected by the presence or absence of T0 in the seedling (Peterson et al., 1982). The presence or absence of T0 has been used also to assess seedling "vigor" (Lewis and Garcia, 1979; Wilkins et al., 1982).

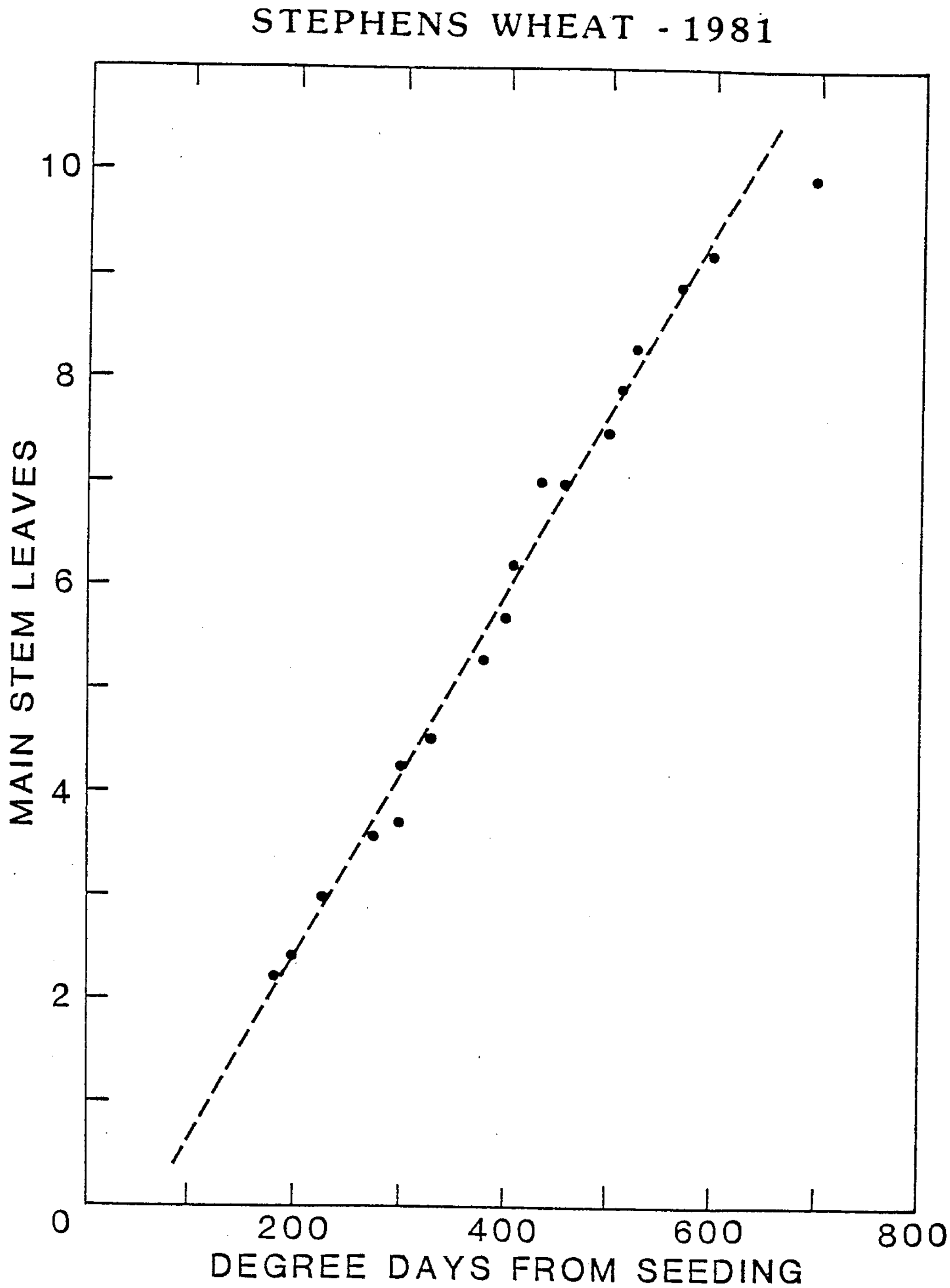


Figure 4. The appearance of leaves on wheat main stems as related to degree-days from seeding.

The use of degree-day concepts allows us to determine the time frame of stress. For example, if a plant has 5.5 leaves on the main stem and has a healthy T0, a moderate-sized T1, a weak, delayed T2, and no T3, we would be able to refer to Fig. 2 and infer that this plant had a good seedbed but has been stressed during the past two phyllochrons or 200 GDD's. We might suspect a nitrogen deficiency because of some previous management decision. After top dressing the field with nitrogen, we might find that 150 GDD's later we have 7 leaves on the main stem with a T0, T1, T2 (still delayed from normal), T4, and T5. T3 was skipped because of stress. The fact that T4 and T5 appeared would show that the stress had been relieved.

AREAS OF NEEDED RESEARCH

The techniques presented here have been developed using one variety of soft white winter wheat in the Pacific Northwest. Information is needed on the differences among cultivars of wheat and among other forage grasses in their comparative sensitivity to controlled levels of imposed stress. Most of the work has been done with stresses associated with seedbed conditions and early fertility and needs now to be extended to other environmental factors such as low soil water potential, grazing stress, and temperature stresses.

LITERATURE CITED

1. Barassi, C. A., M. Crupkin, R. J. Sveldo, and A. Invernati. 1980. Osmotic stress in coleoptiles and primary leaves of wheat. 1. Effects on size, weight, total protein, DNA, and phosphorus. J. Exp. Bot. 31:1565-1572.

2. Boyer, J. S. 1970. Leaf enlargement and metabolic rates in corn, soybean, and sunflower at various leaf water potentials. Plant Physiol. 46:233-235.

3. Esau, K. 1965. Plant Anatomy. 2nd Ed. Wiley. New York.

4. Kemp, D. R. 1981. Comparison of growth rates and sugar and protein concentrations of the extension zone of main shoot and tiller leaves of wheat. J. Exp. Bot. 32:151-158.

5. Klepper, Betty, R. W. Rickman, and C. M. Peterson. 1982. Quantitative characterization of seedling development in small cereal grains. Agron. J. 74:789-792.

6. Klepper, Betty, R. W. Rickman, and R. K. Belford. 1983. Leaf and tiller identification on wheat plants. Crop Sci. 23: (in press).

7. Klepper, Betty, R. K. Belford, and R. W. Rickman. 1984. Root and shoot development in winter wheat. Agron. J. (in press).

8. Lewis, E. J. and J. A. Garcia. 1979. The effect of seed weight and coleoptile tiller development on seedling vigors in tall fescue, Festuca arundinacea Schreb. Euphytica 28:393-402.

9. Mackey, J. 1973. The Wheat Root. pp. 827-842. In (E. R. Sears and L. M. S. Sears, eds.). Proceedings of the Fourth International Wheat Genetics Symposium. Agric. Expt. Sta., Univ. of Missouri, Columbia.

10. Peterson, C. M., B. Klepper, and R. W. Rickman. 1982. Tiller development at the coleoptilar node in winter wheat (Triticum aestivum L.). Agron. J. 74:781-784.

11. Rickman, R. W., B. L. Klepper, and Curt M. Peterson. 1983. Time distributions for describing appearance of specific culms of winter wheat. Agron. J. 75:551-556.

12. Turner, N. C. and J. E. Begg. 1981. Plant-water relations and adaptation to stress. Plant and Soil 58:97-131.

13. Watts, W. R. 1972. Leaf extension in Zea mays. II. Leaf extension in response to independent variation of the temperature of the apical meristem, of the air around the leaves, and of the root-zone. J. Exp. Bot. 23:713-721.

14. Wilkins, D. E., B. Klepper, and R. W. Rickman. 1982. Effect of tillage on wheat tillering. Paper No. 82-1512. Amer. Soc. Agr. Eng., St. Joseph, MI.

GRAZING OF WHEAT IN THE VEGETATIVE STAGE : SHOOTS

Scott Christiansen*

SUMMARY

For more than fifty years midwestern agricultural institutions have studied the effects of grazing on subsequent wheat (Triticum aestivum L.) grain yields. Most regional research indicates grazing will not decrease yields as long as the wheat is moderately grazed and cattle are removed prior to stem elongation. Nevertheless, the lack of predictable weather patterns from year to year causes risk and instability in wheat stocking systems.

An index should be developed to characterize wheat phenological development according to moisture and accumulated thermal units. Common cultivars could be calibrated for development to important phenological stages using such an index. Forage data would need to be collected to provide regression relationships to describe wheat growth for a given location, fertility, moisture regime and cultivar. The predictive data could then be loaded into market forecasting models using "friendly" linear programming packages to assist managers in decisions on use of wheat pasture.

The plant reactions to grazing are described and the current research results to date are reviewed for tillering and assimilate reallocation.

INTRODUCTION

The study of grazed wheat and its subsequent grain production is complex. The development and growth of the wheat plant is governed by temperature, nutrient supply, solar radiation, moisture, insect predation and plant hormonal effects--all of which may be significantly altered due to the presence of grazing animals. Furthermore, the grazing treatments must be controlled, objectively measured and replicated in order to quantitatively describe the effects of the animal on the plant and to draw statistically significant conclusions.

Grazing or clipping of wheat can reduce grain yields if stress, resulting from defoliation, is severe and prolonged. More interestingly, some reports showed that grain production was increased due to defoliation. These studies will be discussed later in more detail.

*Research Forage Agronomist. USDA-ARS Southwestern Livestock and Forage Research Station. PO Box 1199 El Reno, OK 73036. Ph: (405) 262-5291. A contribution of the Forage-Livestock Systems Research Group.

Due to the complexity of the problem most research to date has characterized the plant response but has failed to explain the mechanisms of that response. Some questions might be: How much wheat can be grazed before reduction in grain yield will result? Can this critical period be defined and can its arrival in time be predicted with precision from year to year? How much grain yield will be sacrificed for each day the grazing period is extended past jointing? What is the best use combination between cattle and/or grain production for each year for optimum economic returns? This paper will review past research and survey the current ideas that could answer some of the above questions.

LITERATURE REVIEW

Grain yields: Grazing or clipping trials

Many authors have quantified the grazing effect on grain yield and the appropriate date in their geographic area for defoliation to be terminated to avoid removing growing points. Some authors also offered explanations for the yield response by reporting on portions of the three components that contribute to cereal yield i.e., number of headed tillers per area, number of kernals per spike, and weight per kernal.

The general plant reaction was summarized by Swanson and Anderson (1951) who state "Well established wheat with vigorous, leafy top growth on a good seed bed nearly always can be pastured with benefit to grain yield, if grazed moderately" (p. 10). They also noted that the majority of Kansas farmers did not graze wheat when conditions were unfavorable for normal growth. Regardless of how favorable environmental conditions could be, it was the rule rather than the exception that excessive grazing reduced grain yields, especially if pastured beyond April 10.

In Oklahoma, the recommendation was not to graze beyond "the last of March or the first of April" (Daane et al., 1923; p. 16) or when the soil was too wet. Staten and Elder (1946), also from Oklahoma, reported on results from four years' work which determined that a final forage clipping on 25 March reduced the average yields for five hard red wheat cultivars 14 percent. Clipping last on 15 April reduced grain yields 72 percent. The clipping may have removed growing points on both dates. Perhaps the above results led experiment station scientists to later adjust their recommendations to 15 March (Hubbard and Harper, 1949).

Clipping trials conducted by Hubbard and Harper (1949) at the USDA station at Woodward, Oklahoma showed that moderate defoliation did not generally reduce yields for five varieties of wheat. Moderate clipping in the fall, late winter and on 15 March produced increased grain yields in good years. Yields were decreased in all years when a severe clipping treatment was used.

In Nebraska a lush and top heavy pasture was grazed continuously throughout April or mowed on 30 April (Kiesselbach, 1925). Grain yields increased by 15 percent due to mowing and 33 percent due to grazing compared to an ungrazed but lodged control. In normal years without lodging, the pastured treatment caused a 32 percent loss of grain yield compared to the control. Progressively lower clipping on 30 April at 12.5, 7.5, and 4 cm heights caused a 6, 12, and 30 percent reduction in grain yield, respectively. The lowest height of cut reduced the survival of clipped culms by 10 percent compared to a 2 percent loss for the other two treatments.

Washko (1947) used sheep in Tennessee to defoliate wheat once in the fall and once in the spring and found grain yields were reduced 34 and 23 percent, respectively, for an erect and prostrate variety of wheat. The grazing was completed by 15 March and the number of productive tillers was reduced an average of 23 percent.

In New Jersey trials (Sprague, 1954) wheat pastured in the fall averaged 19 percent more grain than control plots and in years of good growth the grazed wheat produced 50 percent more grain than ungrazed wheat. Spring grazing alone caused a 30 percent reduction whereas the combination of fall and spring grazing reduced yields by 12 percent.

Later, Morris and Gardner (1958) in Georgia determined that wheat grain yields were not affected to any appreciable extent by clipping as late as mid-February. However, extending the clipping period to 15 March reduced grain yields 75 percent or more.

Recently, Kilcher (1982) in Saskatchewan found that grazing rye (Secale cereale L.) in autumn reduced grain yields by 17 percent, spring grazing reduced grain yields by 10 percent and the combination of fall and spring grazing reduced grain yields by 25 percent. In addition, fall grazing reduced the number of seed bearing spikes. These results suggest that grazing small grains in autumn in Canada is generally more deleterious than grazing small grains in autumn in the Southern Great Plains.

Another recent study from Texas (Dunphy et al., 1982) gave results on clipped wheat throughout the vegetative stage with the final forage harvest timed to match early-, mid-, and late-joint stages of development. Delaying the final forage harvest resulted in a progressive reduction in grain yields from 4 to 84 percent. Since care was used to avoid removal of growing points, the data indicated that the adverse effect on grain yield was one of assimilates being spread too thin at too late a date. Average seed weights were not affected by clipping but number of seeds per head was reduced.

Environment controls the variable phenological development observed from year to year for any region, with some regions showing greater variation than others. Nevertheless, most of the above publications singled out an individual date to cease grazing. Presumably, these dates should have been synchronous with time of elongation or jointing in the same regions. As Dunphy et al.(1982) are wise to point out, studies that have discontinued forage harvests by some arbitrary date disregard the stage of development of the plant. This was particularly exemplified by the jointing times they found between years and among cultivars. Jointing varied by more than a month from one cultivar to another within a year and more than a month from year to year for a given cultivar. In Oklahoma, Hubbard and Harper (1949) likewise found that jointing date varied by three weeks in two consecutive measurement years.

The lack of a linkage between results from one experimental location to another is largely due to the noncomparability of growth stages. It is obvious that environmental influences are critical to the success or failure of a wheat crop. It is clear that good grain years are also good forage years and grazing can be used to a producer's advantage. In years of poor growth, the forage and grain yields respond concomitantly. Grazing or clipping in poor years reduces grain yields beyond the limits imposed by weather conditions.

Swanson and Anderson (1951) state that moisture relations allow a grazable crop of wheat forage in three of five years in western Kansas. If this liberal projection can be used for a large portion of the hard red winter wheat belt, it serves to illustrate the difficulty in preparing for the wheat grazing season. The near even odds lead to the question of whether wheat growth will be sufficient for grazing in the fall.

Predicting environmental effects on wheat development

A model for predicting forage yields on a daily basis could be derived by including the major variables that influence phenology and dry matter accumulation of wheat. Temperature is the most important factor influencing development. It is common to use the concept of degree days or thermal units accumulated from sowing to integrate the temperature effect over time (Rickman et al., 1983; Johnson and Kanemasu, 1983). Irradiance and daylength are also important factors but the soil moisture content is probably more important for predicting the stage and amount of wheat growth in the Great Plains (Swanson, 1935; Angus and Moncur, 1977). Lastly, the greatest factor influencing dry matter accumulation is nutrient availability, especially nitrogen (Aspinall, 1961, 1963; Simons, 1982).

The prospects for developing a model for forage and/or grain prediction are good. Generally, the State Agricultural Experiment Stations have branch centers where common wheat cultivars could be calibrated statewide for degree day accumulation to phenological stages. Variety trials could be expanded to include a low, medium, and high fertility and clipped for forage yield to establish regression relationships needed to predict dry matter yield from accumulated degree days for a range of fertilizer inputs.

Year to year forage and grain variability will be caused largely by variations in temperature and soil moisture, hence water relations should be integrated into the degree day index. One way of discounting degree days for conditions with limiting moisture would be to quantify the relationship between crop growth rate (CGR) (change in weight per change in time) and soil moisture from a 30 cm deep core. The degree day concept coupled with a limiting moisture factor that takes altered growth rates into account could be called the moisture adjusted degree day (MADD).

$$MADD = \frac{\text{Max C + Min C}}{2} \cdot \frac{\text{CGR at reduced moisture}}{\text{CGR well watered}}$$

The MADD concept is proposed on an experimental basis. It would be a mistake to think it could be readily incorporated into routine variety trials. However, if all wheat acted similarly to limitations of water (within a practical range) then a regression relationship between CGR and soil moisture could be used to provide the CGR factor in the MADD equation. The relationships will need to be tested in several readily identified phenological stages (see Large, 1954; Klepper et al., 1982), several soil types and for a range of fertilizer inputs.

Perhaps the above notions are oversimplified but the time has come for better forecasting of wheat forage and grain yields using environmental data at hand. It should be possible for producers to determine or know present accumulated degree days, soil moisture, fertilizer inputs, and the cultivar of wheat, along with statistically sound projections of expected weather senarios, in order to predict yields, phenological development and risks factors for the weeks ahead.

Similar efforts to model phenological development are underway in England using potential evaporation (Green et al., 1983), in Kansas using accumulated thermal units (Johnson and Kanemasu, 1983) and in Oregon using degree days (Klepper et al., 1982; Klepper et al., 1983; and Rickman et al., 1983). Conner (1975) in Australia found with his somewhat limited data that accumulative pan evaporation was an inferior phenological index compared to the more widely used heat summation technique.

Tillering

There is a need to study the physiology of wheat under grazing to validate grazing affects on grain yields. Many studies discussed in the first section of the review reported increased grain yields in the hard red winter wheat region of the Great Plains. High irradiance found in the Great Plains compared to other regions may cause increased leaf production, more total leaves, and a faster rate of tillering (Friend, 1965). An increase in tillering due to grazing could be expected, as shown with perennial ryegrass (Lolium perenne L.) (Edmond and Hoveland, 1972; Hodgson et al., 1981; Curll and Wilkins, 1982; Jones et al., 1982). In ungrazed wheat late-developed tillers are less likely to survive due to mutual shading (Friend, 1965; Ong, 1978; Ong et al., 1978; Chapman et al., 1983). Perhaps more tillers are given a better chance to produce grain in grazed than in ungrazed wheat where the main stem and primary tillers have more shading and more of a sequential development (Hay, 1978).

Holliday (1956) asks, "In a cereal crop, can vegetative growth be produced in excess of that required to support the grain yield?" (p. 211). Overwhelming evidence from Great Britain (Morris, 1969; Kays and Harper, 1974; Ong, 1978; Ong et al., 1978; Hodgson et al., 1981; Jones et al., 1982; Parsons et al., 1983 a,b) and New Zealand (Korte et al., 1982; Fraser et al., 1982) suggests that leaf and tiller turn-over are unavoidable, giving rise to the philosophy that grazing animals might as well utilize the tissue that would otherwise die.

In the spring when rainfall, daylength and temperature simultaneously increase, rapid growth rates occur that are associated with the phenological change to floral initiation. At this time, the action of IAA is presumably communicated throughout the plant to shut down tillering (Aspinall, 1963; Friend, 1965). Although the onset of elongation is delayed by defoliation, experiments have proved it to be only in the order of a few days (Kilcher, 1982) or 5-6 days (Washko, 1947). Grazing delayed internode elongation by an unspecified time interval for Sprague (1954).

It would be simple to advise producers how to look for growing point elongation by dissection, but evidence suggests that wheat grain yields are sensitive to depression by grazing at a point somewhat before elongation (Morris and Gardner, 1958; Dunphy et al., 1982). Competition for assimilate between leaf, stem, and growing points at or near the jointing phase is substantiated by McCaig and Clarke (1982). Their results show that the stem may act as a temporary storage organ for non-structural carbohydrate between the time of maximum photosynthate production by the plant and the time of maximum requirement of carbohydrate by the developing grain. Also, by removing the pseudostem, or whorl of sheaths, grazing might diminish an important carbohydrate reserve in the pre-jointing phase.

Compensatory growth and assimilate reallocation

There is a growing interest in the compensatory effects of plant growth as a response to herbivory (McNaughton, 1979,1983). Some examples of compensation are increased photosynthetic rates, prostrate morphologies, reallocation of substrates from elsewhere in the plant, reduction in the rate of leaf senescence, lowered transpiration (hence enhanced moisture relations), and hormonal redistributions that activate remaining meristems. McNaughton (1983) believes that "mechanisms have evolved that lead to compensatory growth of plants following herbivore damage and that these mechanisms are a major component of plants' evolutionary responses to their long existence with animals" (p. 331).

In keeping with the philosophy of evolutionary adjustment it was shown by Caldwell et al. (1981) that resource allocation for a grazing tolerant bunchgrass (*Agropyron desertorum* Fisch. ex Link (Schult.)) was more conservative or survivalistic than in a grazing sensitive bunchgrass (*Agropyron spicatum* (Pursh) Schribn. and Smith). Greater flexibility of resource partitioning was shown by *A. desertorum* for both nitrogen and carbohydrates. Greater allocation to the shoot system and curtailed allocation to the root system allowed a rapid reestablishment of a balanced root/shoot ratio.

The topic of mineral remobilization has been postulated in many plant systems. Aspinall (1963) studied the effect of removing newly senescent leaves at the first sign of yellowing. He found no evidence of nutrient exchange. It was not clear, however, whether the plants were provided nutrients to the extent that scavenging was unnecessary.

In perennial ryegrass, (Ong et al., 1978) young defoliated tillers could import radiocarbon from undefoliated vegetative tillers but later, at anthesis, reproductive tillers retained most of the carbon they had fixed. Quinlan and Sagar (1962) used wheat and found that radiocarbon was actively transported from the main shoot in early stages of development but after ear emergence there was little transference of labeled carbon between tillers. When defoliation stress was mild and the main shoot of annual ryegrass (Lolium multiflorum Lam.) was left intact, assimilate from the main stem was diverted to clipped tillers (Gifford and Marshall, 1973). When the stress continued, the assimilate support was sustained along with higher photosynthetic rates in main stem leaves. Thus it may be possible that photosynthate is more easily reallocated in the vegetative state.

A few basic rules for translocation in timothy (Phleum pratense L.) were suggested by Williams (1964): 1) Young growing leaves retain all their assimilates, using them for growth; 2) These leaves import from older leaves; 3) Import ceases, and export begins (or occurs simultaneously) before leaf expansion is complete; 4) Exports go at first upwards to younger leaves and the growing point, later, some move downwards, and finally movement is entirely downwards to the roots. Under assimilate deficiency, the growth of roots and buds would most likely be curtailed first. As Wardlaw (1968) puts it "roots and buds appear to be the poor relations among plant parts." (p. 86).

CONCLUSIONS

It is rather difficult to extrapolate some of the grazing management research done in other parts of the world to wheat grazing in the Southern Great Plains. The incongruency is that the management of wheat pasture in the United States concerns only one half of an annual cycle as opposed to a full perennial one. Hence, we don't worry much about the reproductive phase, even in a graze out. Furthermore, pasture management of wheat seems more directly involved with economics than it is with optimizing quality or quantity of herbage removal.

In wheat stocker operations using moderate to moderately heavy grazing it is likely that tillering is promoted. The rapid rates of photosynthesis in defoliated plants combined with weather conditions conducive to rapid growth at jointing allows the grazed plants to recover and even outyield ungrazed plants. Grazing may increase surviving tillers per plant, having somewhat fewer total grains per spike, but having no change in weight per grain. The result is more filled kernals per plant. The ungrazed wheat may have lower photosynthetic rates, fewer tillers, and greater shading in the canopy which can cause leaf and tiller death. The dominance of a few culms that will not readily share assimilate with smaller tillers may limit the total number of spikes and consequently lower the number of filled seeds per plant.

There has been abundant physiological research with many temperate, perennial grasses. The opposite is true for wheat grown for pasture in the field. Past research has done well to characterize the effects of grazing but few studies have conclusively explained their results physiologically. The entire grazing system is difficult to study because of varying environmental conditions from year to year and the inherent logistical problems that inhibit grazing research.

More predictability for the plant component in farm management models is needed. A model is needed to forecast the availability of wheat forage using readily available meteorological data, to support the use of existing economic linear programming models. Given current and speculated market prices for beef and grain a profit maximizing strategy could be planned for the season. The advantage of these management models is in simulating various senarios which broaden the producer's awareness. Greater predictive capabilities would reduce risk, stabilize fluctuating markets and increase efficiency of stocker enterprises in the region.

Areas of needed research

1. Physiological studies are needed to understand the fundamental biology of wheat that has been grazed.

2. Supportive research is needed from state experiment stations to provide dry matter yields of forage as well as grain in common wheat cultivars across a range of locations.

3. Environmental indices must be devised to characterize phenological development of wheat. Research results can then be compared and related over years and locations by stage of growth instead of calendar dates.

4. Models to predict wheat growth using the above three objectives can then be interfaced with linear programs for marketing cattle and wheat.

Acknowledgments

I would like to thank the wheat project personnel who have helped in making this effort possible:

Mary Brookman, Jim Browning, David Forbes, Lisa Griffin, Karen Keller, Bill Phillips, Tony Svejcar, and Jim Trent.

LITERATURE CITED

Angus, J. F. and M. W. Moncur. 1977. Water stress and phenology in wheat. Aust. J. Agric. Res. 28:177-181.

Aspinall, D. 1961. The control of tillering in the barley plant. I. The pattern of tillering and its relation to nutrient supply. Aust. J.Biol. Sci. 14:493-505.

Aspinall, D. 1963. The control of tillering in the barley plant. II. The control of tiller-bud growth during ear development. Aust. J. Biol. Sci. 16:285-304.

Caldwell, M. M., J. H. Richards, D. A. Johnson, R. S. Nowak and R. S. Dzurec. 1981. Coping with herbivory: Photosynthetic capacity and resource allocation in two semiarid Agropyron bunchgrasses. Oecologia 50:14-24.

Chapman, D. F., D. A. Clark, C. A. Land and N. Dymock. 1983. Leaf and tiller growth of Lolium perenne and Agrostis spp. and leaf appearance rates of Trifolium repens in set-stocked and rotationally grazed hill pasture. N. Z. J. Agric. Res. 26:159-168.

Conner, D. J. 1975. Growth, water relations and yield of wheat. Aust. J. Plant Physiol. 2:353-366.

Curll, M. L. and R. J. Wilkins. 1982. Frequency and severity of defoliation of grass and clover by sheep at different stocking rates. Grass and Forage Sci. 37:291-297.

Daane, A., G. C. Gibbons and W. E. Jackson. 1923. Wheat in Oklahoma. Oklahoma A&M College Ext. Service. Circ. 153. 21 pp.

Dunphy, D. J., M. E. McDaniel and E. C. Holt. 1982. Effect of forage utilization on wheat grain yield. Crop Sci. 22:106-109.

Edmond, D. B. and C. S. Hoveland. 1972. A study of the position of grass growing points in two species under different systems of management. N. Z. J. of Agric. Res. 15:7-18.

Fraser, J., C. T. Dougherty and R. H. M. Langer. 1982. Dynamics of tiller populations of standard height and semi-dwarf wheats. N. Z. J. Agric. Res. 25:321-328.

Friend, D. J. C. 1965. Tillering and leaf production in wheat as affected by temperature and light intensity. Can. J. Bot. 43:1063-1076.

Gifford, R. M. and C. Marshall. 1973. Photosynthesis and assimilate distribution in Lolium multiflorum Lam. following differential tiller defoliation. Aust. J. Biol. Sci. 26:517-526.

Green, C. F., L. V. Vaidyanathan and M. N. Hough. 1983. An analysis of the relationship between potential evaporation and dry-matter accumulation for winter wheat. J. Agric. Sci., Camb. 100:351-358.

Hay, R.K.M. 1978. Seasonal changes in the position of the shoot apex of winter wheat and spring barley in relation to the soil surface. J. Agric. Sci., Camb. 91:245-248.

Hodgson, J., J.S. Bircham, S. Grant, and J. King. 1981. The influence of cutting and grazing management on herbage growth and utilisation. In C.E. Wright (Ed.) Plant Physiology and Herbage Production. Occasional Symp. No. 13. Brit. Grassland Soc., Hurley, UK. pp. 51-62.

Holliday, R. 1956. Fodder production from winter-sown cereals and its effect upon grain yield. Field Crop Abstracts. 9:129-135; concluded 9:207-213.

Hubbard, V.C., and H.J. Harper. 1949. Effect of clipping small grains on composition and yield of forage and grain. Agron. J. 41:85-92.

Johnson, R.C., and E.T. Kanemasu. 1983. Yield and development of winter wheat at elevated temperatures. Agron. J. 75:561-565.

Jones, M.B., B. Collett, and S. Brown. 1982. Sward growth under cutting and continuous stocking managements: Sward canopy structure, tiller density and leaf turnover. Grass and Forage Sci. 37:67-73.

Kays, S., and J.L. Harper. 1974. The regulation of plant and tiller density in a grass sward. J. Ecol. 62:97-105.

Kiesselbach, T.A. 1925. Winter wheat investigations. Nebraska Agric. Exp. Sta. Bull. 31. 149 pp.

Kilcher, M.R. 1982. Effect of cattle grazing on subsequent grain yield of fall rye (Secale cereale L.) in southwestern Saskatchewan. Can. J. Plant. Sci. 62:795-796.

Klepper, B., R.W. Rickman, and C.M. Peterson. 1982. Quantitative characterization of vegetative development in small cereal grains. Agron. J. 74:789-792.

Klepper, B., T.W. Tucker, and B.D. Dunbar. 1983. A numerical index to assess early inflorescence development in wheat. Crop Sci. 23:206-208.

Korte, C.J., B.R. Watkin, and W. Harris. 1982. Use of residual leaf area index and light interception as criteria for spring grazing management of a ryegrass-dominant pasture. N. Z. J. Agric. Res. 25:309-319.

Large, E.C. 1954. Growth stages in cereals: Illustration of the Feekes' scale. Plant Path. 3:129.

McCaig, T.N., and J.M. Clarke. 1982. Seasonal changes in nonstructural carbohydrate levels of wheat and oats grown in a semiarid environment. Crop Sci. 22:963-970.

McNaughton, S.J. 1979. Grazing as an optimization process: Grass-ungulate relationships in the Serengeti. Am. Naturalist 113:691-703.

McNaughton, S.J. 1983. Compensatory plant growth as a response to herbivory. Oikos 40:329-336.

Morris, H.D., and F.P. Gardner. 1958. The effect of nitrogen fertilization and duration of clipping period on forage and grain yields of oats, wheat, and rye. Agron. J. 50:454-457.

Morris, R.M. 1969. The pattern of grazing in "continuously" grazed swards. J. Brit. Grassland Soc. 24:65-70.

Ong, C.K. 1978. The physiology of tiller death in grasses. 1. The influence of tiller age, size and position. J. Brit. Grassland Soc. 33:197-203.

Ong, C.K., C. Marshall, and G.R. Sagar. 1978. The physiology of tiller death in grasses. 2. Causes of tiller death in a grass sward. J. Brit. Grassland Soc. 33:205-211.

Parsons, A.J., E.L. Leafe, B. Collett, and W. Stiles. 1983a. The physiology of grass production under grazing. I. Characteristics of leaf and canopy photosynthesis of continuously-grazed swards. J. Appl. Ecol. 20:117-126.

Parsons, A.J., E.L. Leafe, B. Collett, P.D. Penning, and J. Lewis. 1983b. The physiology of grass production under grazing. II. Photosynthesis, crop growth and animal intake of continuously-grazed swards. J. Appl. Ecol. 20:127-139.

Quinlan, J.D., and G. R. Sagar. 1962. An autoradiographic study of the movement of 14-C-labelled assimilates in the developing wheat plant. Weed Res. 4:264-273.

Rickman, R.W., B.L. Klepper, and C.M. Peterson. 1983. Time distributions for describing appearance of specific culms of winter wheat. Agron. J. 75:551-556.

Simons, R.G. 1982. Tiller and ear production of winter wheat. Field Crop Abstracts. 35:857-870.

Sprague, M.A. 1954. The effect of grazing management on forage and grain production from rye, wheat and oats. Agron. J. 46:29-33.

Staten, H.W., and W.C. Elder. 1946. Forage production of winter small grain varieties and annual rye grass and effect of clipping upon grain yields. Oklahoma Agric. Exp. Sta. Mimeo Circ. M-161. 11 pp.

Swanson, A.F. 1935. Pasturing winter wheat in Kansas. Kansas State Agric. Exp. Sta. Bull. 271. 29 pp.

Swanson, A. F. and K. Anderson. 1951. Winter wheat for pasture in Kansas. Kansas State Agric. Exp. Sta. Bull. 344. 32 pp.

Wardlaw, I. F. 1968. The control and pattern of movement of carbohydrates in plants. Bot. Rev. 34:79-105.

Washko, J. B. 1947. The effects of grazing winter small grains. J. Am. Soc. Agron. 39:659-666.

Williams, R. D. 1964. Assimilation and translocation in perennial grasses. Ann. Bot. 28:419-425.

ROOTING DYNAMICS AND WATER STRESS IN WHEAT: POTENTIAL IMPACTS OF GRAZING

Tony Svejcar

U.S. Department of Agriculture, El Reno, OK 73036

Introduction

For many years the use of wheat (Triticum aestivum L.) for winter forage has been popular in the Southern Great Plains. The concept of using annual cereal crops for both forage and grain yield, provides the producer with an extra source of income in the form of animal weight gain. The timing of growth is particularly important because forage is produced during a period when conventional forage species are dormant. However, little information is currently available regarding the physiological response of annual grain crops to defoliation during the vegetative phase. Research concerning plant response to defoliation has centered around perennial range and pasture species. In these species the primary concern is stand survival; with annual cereals, the primary concern is grain available for harvest after grazing. This paper deals with some of the relationships known to exist among water stress, rooting patterns and grain yields in wheat and the ways these relationships may be altered by grazing.

Review of Literature

Water Stress

In many regions, water is the factor most limiting to crop production (Kozlowski, 1968). Few plants growing in natural environments escape water stress for more than a few days at a time (Hsiao et al. 1976). Leaf water potential declines during the day even in well irrigated wheat plants (Jones, 1977). The level of water stress induced by environmental variables influences grain yield in wheat.

During the flowering and grain-filling stages, the wheat plant must produce adequate assimilate to support grain growth. In order to produce the necessary assimilate, plants must maintain a reasonably high stomatal conductance, allowing CO_2 to diffuse into the photosynthetic tissues of the leaf. The level of stomatal conductance is important in controlling photosynthesis (Brix, 1962; Hinckley et al. 1978; Wong et al. 1979). Water stress tends to lower stomatal conductance, (Raschke, 1975). Johnson et al. (1974) found that transpiration was linearly related to flag leaf water potential in both wheat and barley (Hordeum vulgare L.). Thus, much of the reduction in yield caused by water stress can be associated with reduction in assimilate supply. The assimilate use pattern also changes. More current assimilate goes into grain in stressed than in non-stressed wheat plants (Johnson and Moss, 1976). Also, more stored assimilate is transferred to the grain in stressed plants (Gallagher et al. 1976).

The stage of plant development during which water stress occurs is critical in terms of the various yield components and total yield.

Fischer (1980) felt that seed number was the yield component most sensitive to water stress and that this yield component was most affected by stress near flowering. Johnson and Kanemasu (1982) also found reduced kernals/spikelet if preanthesis water levels were low. However, Johnson and Moss (1976) imposed water stress on wheat plants during grain- filling, and measured a 14% reduction in kernal weight and 20% reduction in grain yield. Thus, the component of grain yield most influenced by water stress will depend on the period during which stress is imposed.

A point not considered in the previous discussion is stress during the vegetative and early reproductive phases. During these periods, stress may cause reduction in tiller number. Thus assimilate supply during flowering and grain-filling would not completely explain yield reductions. Johnson and Kanemasu (1982) found that under field conditions head number per square meter was an important component of yield. The recent work of Klepper et al. (1982) indicates how tiller development and number can be influenced by prior stress.

Rooting Dynamics

There are a number of mechanisms the wheat plant might use to cope with stress. From a detailed greenhouse study, Blum et al. (1983) concluded that drought resistance in wheat was related to osmotic adjustment, maintenance of stomatal permeability and turgor under stress, and total root mass production under stress. As one would expect, the water available for plant growth is directly related to the volume of soil occupied by plant roots (Taylor and Klepper, 1978). By maintaining sufficient rooting density a plant is able to partially avoid the sudden drop in water potential associated with drought (Hurd, 1968; Townley-Smith and Hurd, 1979).

Many factors influence root growth; however, wheat roots have a definite pattern of development (Klepper et al. 1984). The number of roots on any culm can be predicted from the number of leaves on the culm ($r^2 = 0.9$), indicating that root and shoot development are linked. In their study the presence or absence of roots and relative order of branching wasn't affected by fertility, row spacing or planting density, whereas branch number and length were affected. Most studies of above- and below-ground dynamics have emphasized relative rates of phytomass production. Anderson-Taylor and Marshall (1983) found that spring barley root systems reached maximum phytomass 6 weeks from sowing when shoot weight was only 50% of its value at maturity. Growth of the barley root system was characterized by rapid increases in weight with time which ceased abruptly just before the ear of the main shoot emerged. Thus, tillers produced after that point were not well rooted and tended to die.

With winter wheat, Gregory et al. (1978) observed exponential increases in total root weight until the beginning of April, then linear increases until mid-June (anthesis), with a slight decrease after that point. Lupton et al. (1974) found that wheat root growth was relatively constant before flowering, compared to sigmoidal curves for the aerial parts. Thus it appears that root growth tends to be fastest during the vegetative phase, with a leveling out during the reproductive period. The magnitude of root growth will be very much influenced by species and environment.

The root/shoot ratio of plants increases with water stress (Turner, 1979). The mechanism for the increase lies in the sensitivity of leaf cell enlargement to small water deficits, causing reduction in crop growth rate and even leaf shedding (Turner and Begg, 1978). Thus the root/shoot ratio is altered because water stress reduces leaf growth more than root growth. However, Passioura (1981) listed a number of studies in which an absolute increase in root growth under water stress was observed. The adaptive significance of root/shoot adjustment lies in the fact that the plant must match water supply to water demand. Kummerow (1980) points out that the ratio of absorbing root surface to photosynthetically active leaf area may be more relevant to plant growth than simple root/shoot ratios. However, Kummerow was dealing with a much more complex system than that of a field crop.

There is some controversy concerning the optimum relationships between root growth and grain yield in cereals. Passioura (1976, 1972) has suggested that early water use in wheat should be limited to maintain sufficient soil water during the later reproductive stages. To limit water use, either rooting volume, or hydraulic conductance of the roots must decrease. This argument is intended for areas where stored soil water is important during reproductive growth. Passioura (1981) also pointed out that the "cost" of producing and maintaining an extensive root system can be considerable. Thus, it would follow that a plant should reduce leaf area to match rooting volume rather than increase rooting volume to match transpiring leaf area. With wheat growing on stored water, Richards (1983) found that removing leaf area during early growth reduced early water use and increased grain yields compared to control plants.

On the other side of the controversy, a number of studies have shown a positive link between early root production and the ability of wheat to produce grain under drought (Blum et al. 1983; Hurd, 1964, 1968, 1974; Sandhu and Laude, 1958). Hurd (1974) suggested that water distribution in the soil profile may help explain the controversy. He postulated that when moisture is available deep in the soil profile extensive root proliferation would allow the plant to use this resevoir of water for later growth. However, if rooting were restricted by a compaction layer or a soil profile were sufficiently shallow, Passioura's logic would apply. Distribution of precipitation is also very important in considering the two arguments. Conserving water early in growth is only important where rainfall is limited during critical growth stages.

Influence of Grazing on Rooting Dynamics

Most work on defoliation has dealt with perennial range and pasture species. In many cases clipping rather than grazing was used to remove leaf area. Much of the work relating defoliation to root growth was conducted 30-50 years ago in the central and southern Great Plains. The results are consistent in that defoliation (grazing or clipping) reduced rooting mass compared to unclipped controls (Crider, 1955; Albertson, et al. 1953; Weaver and Darland, 1947; Biswell and Weaver, 1933). Weaver (1950) found that several native grasses produced more roots on good compared to poor condition range, implying that heavy grazing reduced root production.

The pattern of defoliation has been shown to influence root growth. Carmen and Briske (1982) found that if dependent little bluestem (Schizachyrium scoparium [Michx.] Nash) tillers were defoliated they could still produce nodal roots. However, if the parent tiller was also defoliated, the rooting ability of the dependent tiller was impaired. In perennials, the number of seasons of defoliation also influences level of root reduction (Archer and Tieszen, 1983). The importance of maintaining a balance between root and shoot systems has been emphasized by Caldwell et al. (1981). They have shown that root growth stoppage following defoliation constitutes a mechanism by which the plant can conserve resources and reestablish necessary photosynthetic leaf area following defoliation.

If grazing influences root growth of wheat in a manner similar to perennial plants, we can assume that above a certain level of grazing rooting biomass will be reduced. The subsequent effect of reduced rooting on grain yield will depend on distribution of rainfall and the soil profile on which the wheat is growing. The effects may be positive or negative depending on specific environmental conditions and physiological adaptations of the plant. There are a number of potentially detrimental effects of grazing on yield (eg. growing point removal, trampling, etc.) which have not been considered in this discussion. Certainly water relations is only one of many factors that must be considered in assessing plant response to grazing.

Conclusions

Water relations is an important aspect of both forage and grain yield in wheat. The stage during which water stress occurs will greatly influence it's effect on grain yield components. Some authors have suggested that stress near flowering has the greatest influence on grain yield by reducing seed number. However, stress earlier in growth may reduce tiller numbers while stress after flowering can reduce seed size.

The dynamics of rooting is an important factor influencing water relations. Wheat roots have definite developmental patterns associated with above ground phenology. In terms of phytomass production, most studies have shown that root mass peaks and may even begin to decline before shoot mass reaches peak levels. There are contrasting philosophies concerning the ideal relationships between root growth and grain production under dryland conditions. One line of thought is that root growth and water use during the vegetative phase should be limited, thereby conserving water for the critical reproductive phase. However, if water is available deep in the soil profile, early proliferation of roots may be an advantage. The optimum root growth pattern will depend on seasonal water trends in a particular soil profile.

Grazing typically reduces rooting mass in perennial grasses, and it probably has the same effect in wheat. The influence of reduced rooting mass on grain yield depends on environmental conditions and the specific soil profile supporting the wheat. Factors other than rooting mass should also be considered in interpreting the effects of grazing on grain yield.

Areas of Needed Research

Grazing effects on rooting of annual cereals is a research topic that has received little attention. There are a number of questions research might attempt to answer:

1) What root length density and rooting depth is necessary to produce a crop under a particular climatic and soil regime?

2) What is the rooting response to various levels of leaf area removal?

3) How do different levels of leaf area removal influence water requirements?

4) Does the ratio of leaf area to root absorbing surface tend to remain constant among levels of leaf area removal?

A "whole plant" approach is needed to define critical growth factors and interactions. Factors such as water use, photosynthesis, energy partitioning and storage, growth morphology, and phenology may all be influenced by grazing and in turn interact with one another. Thus, as many plant factors as possible should be considered in research aimed at elucidating wheat response to grazing. Such information will also be useful to breeders, who in the future may attempt to optimize forage, as well as grain production of winter wheat varieties grown in wheat pasture regions.

Literature Cited

Albertson, F. W., Andrew Riegel and John L. Launchbaugh, Jr. 1953. Effects of different intensities of clipping on short grasses in west central Kansas. Ecol. 34:1-20.

Anderson-Taylor, G. and C. Marshall. 1983. Root-tiller interrelationships in spring barley (Hordeum distichum (L.) Lam.) Ann. Bot. 51:47-58.

Archer, S. and L. L. Tieszen. 1983. Effects of simulated grazing on foliage and root production and biomass allocation in an arctic tundra sedge (Eriophorum vaginatum). Oecologia 58:92-102.

Biswell, Harold H. and J. E. Weaver. 1933. Effects of frequent clipping on the development of roots and tops of grasses in prairie sod. Ecol. 14:368-390.

Blum, A., J. Mayer and G. Gozlan. 1983. Associations between plant production and some physiological components of drought resistance in wheat. Plant, Cell and Environ. 6:219-225.

Brix, H. 1962. The effects of water stress on the rates of photosynthesis and respiration in tomato plants and loblolly seedlings. Physiol. Plant. 15:10-20.

Caldwell, M. M., J. H. Richards, D. A. Johnson, R. S. Nowak and R. S. Dzurec. 1981. Coping with herbivary: photosynthetic capacity and resource allocation in two semiarid Agropyron bunchgrasses. Oecologia 50:14-24.

Carman, J. G. and D. D. Briske. 1982. Root initiation and root and leaf elongation of dependent little bluestem tillers following defoliation. Agron. J. 74:432-435.

Crider, F. J. 1955. Root-growth stoppage resulting from defoliation of grasses. USDA Tech. Bull. 1102.

Fischer, R. A. 1980. Influence of water stress on crop yield in semiarid regions. p. 323-329. In N. C. Turner and P. J. Kramer, (eds.). Adaptation of plants to water and high temperature stress. John Wiley and Sons, New York.

Gallagher, J. N., P. V. Biscoe and B. Hunter. 1976. Effects of drought on grain growth. Nature 264:541-542.

Gregory, P. J., M. McGowan, P. V. Biscoe and B. Hunter. 1978. Water relations of winter wheat. 1. Growth of the root system. J. Agric. Sci. 91:91-102.

Hinckley, T. M., R. G. Aslin, R. R. Aubuchan, C. L. Metcalf and J. E. Roberts. 1978. Leaf conductance and photosynthesis in four species of the Oak-Hickory forest type. Forest Sci. 24:73-84.

Hsiao, T. C., E. Acevedo, E. Fereres and D. W. Henderson. 1976. Stress metabolism: Water stress, growth and osmotic adjustment. Phil. Trans. R. Soc. Lond. B. 273:479-500.

Hurd, E. A. 1964. Root study of three wheat varieties and their resistance to drought and damage by soil cracking. Can. J. Plant Sci. 44:240-248.

Hurd, E. A. 1968. Growth of roots of seven varieties of spring wheat at high and low moisture levels. Agron. J. 60:201-205.

Hurd, E. A. 1974. Phenotype and drought tolerance in wheat. Agric. Meteorol. 14:39-55.

Johnson, R. C. and E. T. Kanemasu. 1982. The influence of water availability on winter wheat yields. Can. J. Plant Sci. 62:831-838.

Johnson, R. R., N. M. Frey and D. N. Moss. 1974. Effect of water stress on photosynthesis and transpiration of flag leaves and spikes of barley and wheat. Crop Sci. 14:728-731.

Johnson, R. R. and D. N. Moss. 1976. Effect of water stress on $^{14}CO_2$ fixation and translocation in wheat during grain filling. Crop Sci. 16:697-701.

Jones, H. G. 1977. Aspects of the water relations of spring wheat (Triticum aestivum L.) in response to induced drought. J. Agric. Sci. 88:267-282.

Klepper, B., R. W. Rickman and C. M. Peterson. 1982. Quantitative characterization of vegetative development in small cereal grains. Agron. J. 74:789-792.

Klepper, B., R. K. Belford and R. W. Rickman. 1984. Root and shoot development in winter wheat. Agron. J. (in press).

Kozlowski, T. T. 1968. Water deficits and plant growth. Vol. 1. Academic Press, New York. 390 p.

Kummerow, J. 1980. Adaptation of roots in water-stressed native vegetation. p. 57-73. In N. C. Turner and P. J. Kramer, (eds.) Adaptation of plants to water and high temperature stress. John Wiley and Sons, New York.

Lupton, F. G. H., R. H. Oliver, F. B. Ellis, B. T. Barnes, K. R. Howse, P. J. Welbank and P. J. Taylor. 1974. Root and shoot growth of semi-dwarf and tall winter wheats. Ann. Appl. Biol. 77:129-144.

Passioura, J. B. 1972. The effect of root geometry on the yield of wheat growing on stored water. Aust. J. Agric. Res. 23:745-752.

Passioura, J. B. 1976. Physiology of grain yield in wheat growing on stored water. Aust. J. Plant Physiol. 3:559-565.

Passioura, J. B. 1981. Water collection by roots. p. 39-53. In L. G. Paleg and D. Aspinall, (eds.). The physiology and biochemistry of drought resistance in plants. Academic Press, New York.

Raschke, K. 1975. Stomatal action. Ann. Rev. Plant Physiol. 26:309-340.

Richards, R. A. 1983. Manipulation of leaf area and its effect on grain yield in droughted wheat. Aust. J. Agric. Res. 34:23-31.

Sandhu, A. S. and H. H. Laude. 1958. Tests of drought and heat hardiness of winter wheat. Agron. J. 50:78-81.

Taylor, H. M. and B. Klepper. 1978. The role of rooting characteristics in the supply of water to plants. Advances in Agron. 30:99-128.

Townley-Smith, T. F. and E. A. Hurd. 1979. Testing and selecting for drought resistance in wheat. p. 448-464. In H. Mussell and R. C. Staples, (eds.). Stress physiology in crop plants. John Wiley and Sons, New York.

Turner, N. C. and J. E. Begg. 1978. Responses of pasture plants to water deficits. p. 50-66. In J. R. Wilson, (eds.). Plant relations in pastures. CSIRO, Melbourne.

Turner, N. C. 1979. Drought resistance and adaptation to water deficits in crop plants. p. 343-372. In H. Mussell and R. C. Staples, (eds.). Stress physiology in crop plants. John Wiley and Sons, New York.

Weaver, J. E. 1950. Effects of different intensities of grazing on depth and quantity of roots of grasses. J. Range Manag. 3:100-113.

Weaver, J. E. and R. W. Darland. 1947. A method of measuring vigor of range grasses. Ecol. 28:146-162.

Wong, S. C., I. R. Cowan and G. D. Farquhar. 1979. Stomatal conductance correlates with photosynthetic capacity. Nature (Lond.) 282:424-426.

ROTATION GRAZING OF SMALL GRAIN PASTURE

R.L. Dalrymple, Pasture & Crop Specialist
Agricultural Division, Noble Foundation
2510 Highway 70 East
Ardmore, Oklahoma 73402

Rotation grazing of small grain pasture can be defined as: **The art of a planned sequence of utilizations during which each pasture, among several to many pastures, is both grazed and deferred several times by one congregated herd during the same production year.** In unique cases more than one herd may be used.

Rotation grazing approaches are highly recommended for most, if not all, major forage types including typical "wheat pasture" and more intensively produced "winter pasture mixtures" used east and southeast of the usual wheat belt. These mixtures are predominately combinations of rye, wheat, and ryegrass with limited usage of oats, barley, or winter legumes.

The purpose of this writing is to explore the production responses of forage harvesting and pasture rotation and to present practical application information and recommendations therein.

LITERATURE REVIEW

The grazing of the herded beasts of Biblical times and the herds of roaming American bison constituted a form of rotational grazing, but these "rotations" were more by providence than man's plan. We might even want to believe that rotation grazing originated during recent times from some university or private institute work. The work is done; the origination is not. Rotation grazing, as it is basically conceived today, was actually reported on in 1760 (22)[1]. The concept likely evolved earlier in the 18th century on permanent forages. The French appear to be the "fathers" of rotation grazing . Pertinent bits from the 18th century, as cited and discussed in the aforementioned reference, are summarized in the next paragraphs. The basic principles apply to small grain pastures of today. You are also encouraged to partake of more delightful reading about the "old days" of rotation grazing in the book by Voisin (22).

---

[1] Numbers in parenthesis are references.

"Grass that is too mature becomes hard and loses much of feeding substances. Grass that is not mature does not possess enough of these substances. As beasts always go to the most tender herbage, **it is essential** when managing grassland, so that all the grass will be grazed at maturity and re-grow, **that the pastures be divided up into sections, the size of which is in proportion to the number of beasts they are to carry;** the aim being that each section contains sufficient keep for three or four days, after which the stock are put on to another section so that the first can bear fruit. Division is achieved by banking up the soil and planting trees on top, or by hedges and willow trees".

--Anonymous, 1760

"And if there were just so many parks as there are required days to make the grass of these fields advance to a proper length after being eat bare down, the first field would be ready to receive them by the time they had gone over all the others; **so that they might thus be carried round in a constant rotation.** --James Anderson, 1791

"Moreover, the number of paddocks required derives from **the principle that grass should only be grazed when it has made sufficient re-growth**--in general this is achieved only after three to seven weeks.

--Falke, 1907

We are saying much the same today. Why over 200 years of **"the dark ages of pasture rotation"** when producers have largely failed to use the practice? No doubt modern metallic fencing helps, but that too has been here for almost 120 years. The basic technology is available, the deficiency is in application of the information. We would probably do well for small grain pasture rotation grazing with what the guys said in the 18th century, however, there really are some refinements since then.

A review of small grain forage harvesting and grazing information was conducted for data from Oklahoma, all adjoining states, and several other southeastern United States locations.

Forage Harvesting Research

Much forage harvesting data is available on some general yield aspect. A limited amount of data is available on varying utilization treatments. Some of that available involves antique varieties and outmoded cultural practices, but the principles of utilization and plant responses are there so some of that data is used to illustrate forage management responses. Small grains generally have basic similarities in forage response so little attempt is made herein to separate responses between the different kinds. All references (1 to 23) offer in-depth data for greater study.

Hand harvested small grain forage studies probably do not exact the performance of this forage as if it were grazed. However, these data do illustrate the relative responses we might expect from different utilization heights and intervals. I believe we can loosely consider that short, close frequency harvests probably invoke a forage response similar to that expected from short, continuous grazing as is often typical in small grain regions. I am sure there are continuous grazing situations both worse and better than shown in the harvested data. We should also consider that harvest intervals of about 20 to 45 days, depending on growth, season, and other factors, at heights of two to four inches may be more typical of responses under "good" rotation grazing. There simply are not any harvested plot situations that are precisely the way I recommend rotation grazing.

Harvested Forage Yield and Actual Beef Yield Correlations

Small grain forage harvesting data are often used to estimate carrying capacity and potential beef yield per acre. If the harvests are made too infrequently, forage yields are high compared to harvesting more like a rotation grazing system. Harvesting twice per year resulted in 213% more forage than harvesting four times per season which is more like traditional rotation grazing (Table 1). One pound of beef was produced per eight pounds of forage when the forage was harvested four times per season. This is accepted as a reliable estimate for grazed small grain forage and beef production relationships (17, 18).

Personal experience has shown that forage yields from harvesting similar to rotation grazing correlates well for estimating carrying capacity and beef production on the basis of 3% of animal body weight per day for dry weight forage consumption for long term pasture and associated waste and with an ADG (average daily gain) of 1.5 to 1.8 pounds per day depending on usual stock quality and pasture management. Animal consumption is less than 3% with new stock grazed early in the season.

Table 1. Small Grain Total Forage Production and Beef Production Relationships [1]

Production Item	Two Harvests	Four Harvests
Forage Yield	4693	2200
Lbs Forage/Lbs Beef	15	8
Increase in Forage by Two Harvests	213%	--
Decrease in Forage by Four Harvests	--	53%

[1]Adapted from McMurphy and Tucker (17, 18), Okla. Agr. Exp. Sta. Composite of all varieties and two years data produced with 60-40-20 lbs of N-P_2O-K_2O fertilizer per acre.

Early Season Harvest Delay

One of the major characteristics of a small grains pasture is to allow it to accumulate forage volume before initial grazing begins. Let the pasture "get ahead" of the cattle! In general, pastures that accumulate forage, up to a point, before initial harvest begins will have more uniform forage distribution, greater yield throughout winter and for the total season than pastures that are grazed too soon or too late (Tables 2, 3, and 4) (21, 23). In practical experience in the intensive winter pasture areas we know that an accumulation of about one-third to approaching one ton, eight to 12 inches tall, of dry weight forage per acre before initial grazing will result in excellent long-season pasture production providing other inputs are acceptable. Dry weight yield varies tremendously within an eight- to 12-inch growth height due to moisture content which usually ranges 75% to over 90% and stand density variation. Moisture content largely dictates the time of forage lodging and under very high moisture forage conditions, the forage may reach only six free standing inches tall before beginning to lodge.

Too much delay and accumulation results in various wastes including chlorosis to necrosis and decomposition of lower shaded leaves. There probably must be some of this if production is to accumulate properly. This may be the case of treatments 1 and 2 compared to treatments 3 and 5 of Table 2. In this case two winter harvests yielded about 1,000 pounds per acre more dry forage than one winter harvest. In effect, early season harvest delay is a function of harvest deferment and deferment data would apply here.

Typical wheat belt pasture would have less fall forage accumulation with about one-fourth to one-half ton, four to eight inches tall, of dry weight forage per acre before initial grazing begins.

Table 2. Small Grain Total Forage Production as Influenced by Varying Harvest Dates.[1]

Harvest Treatment	Lbs/Acre Oven Dry Forage 10-9	12-1	3-15	4-15	5-22	Total	No. of Harvests	% of Most Continuous Harvest
1	----	----	4354	----	3546	7900	2	94
2	----	----	4269	415	2109	6793	3	81
3	----	3089	1931	----	4252	9272	3	110
4	----	3052	----	5415	1063	9530	3	113
5	----	2829	1972	580	2214	7595	4	90
6	2027	1186	2335	----	4207	9758	4	116
7	1810	1174	2327	690	2474	8394	5	100
					Average	8463		

[1]Adapted from Phillips and McMurphy (21). Okla. Agr. Exp. Sta. Composite of three small grains harvests produced with 180-80-0 pounds of $N-P_2O_5-K_2O$ fertilizer per acre.

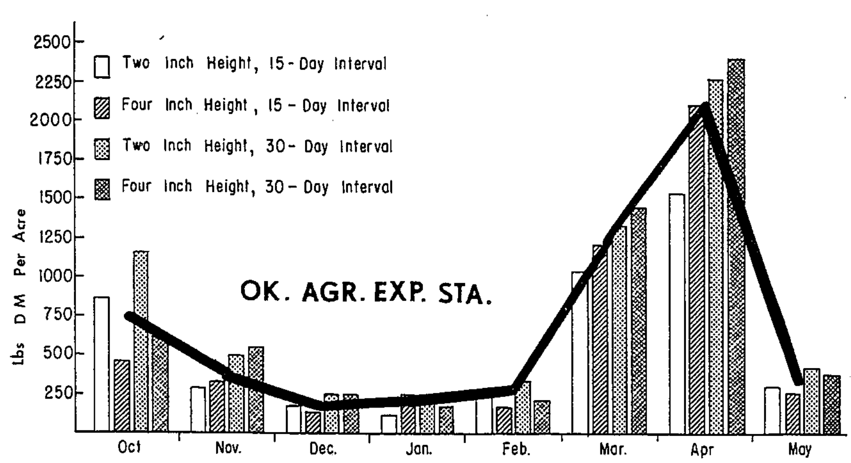


Figure 1. Monthly Production and Distribution of Winter Small Grain Forage Harvested at Two Different Heights at 15- and 30-day Intervals (9).

Table 3. Small Grain and Ryegrass Total Forage Production as Influenced by Plant Growth at Harvest and Stubble Height.[1]

Plant Ht. When Cut	Harvest Ht. After Cut	Lbs/Acre Dry Wt. Small Grain	Lbs/Acre Dry Wt. Rye-Grass	% of 7 & 2.5 In. Small Grain	% of 7 & 2.5 In. Rye-Grass
7 In.	1 In.	3636	3787	99	95
7 In.	2.5 In.	3656	3993	100	100
7 In.	4 In.	3463	3785	95	95
7 In.	Alternate 4&1 In.	3607	4121	99	103
12 In.	2.5 In.	3797	4240	103	106
Delay to Jan 1., then cut & recut at 7 In.	2.5 In.	3899	4133	107	104

[1]Adapted from Watson and Ward (23), Miss. Agr. Exp. Sta. Composite of small grains and ryegrass data from three Mississippi locations. Soil fertility unknown.

Table 4. Elbon Rye Total Forage Production as Influenced by Harvest Frequency.[1]

Treatment	Dry Weight Lbs/Acre	% of Continuous Use
Study I		
4 Harvests	1560	100
1 Harvest (Silage Cut)	3660	235
Study II		
Continual Harvest	2200	100
Continual Harvest to March, Then Cut in May (Silage Cut)	2970	135
May Only (Silage Cut)	6300	286

[1]Data from Noble Foundation, fertilization unknown.

Harvest Height

Shorter harvest heights of small grain forage usually result in less overall forage yield (Tables 5, 6, 7, and Figure 1). Shorter harvest heights sometimes yield more early during the season, but the forage yield is then less later in the season (2, 3, 9). Another exception is that during the very last of the grazing season in a grazeout situation, short grazing utilizes more forage and increases final yields. At the last, "take it all!" However, agronomically we should leave about one ton of root and forage mass for maintenance of soil tilth and other factors.

Based upon the data herein, short harvests of one to two inches usually result in decreases of 5 to over 25% forage production over harvests at two to four inches. Usual forage yield reduction due to short harvest seems to be about 20% in situations of three- to seven-week harvest intervals. There are some cases when short harvests relative to comparative taller harvests result in similar yields as taller harvests (Table 6) (17, 18), but this is the exception to usual pasture circumstances where short harvesting is usually very short (Table 5).

These data also show the tolerance to forage utilization that the small grains have. Even with very short harvesting, yields are still often good, but harvest height should be controlled to increase practical yields.

Acceptable harvest height may possibly be somewhat lower in cases where late planted, prostrate growing wheat is used, but data does not support that (Table 5).

Table 5. Small Grain Dry Weight Forage Total Production as Influenced by Harvest Heights.[1]

Kind	Lbs/Acre To Early March		Lbs/Acre Total		2 in % of 1 in	
	1 In.	2 In.	1 In.	2 In.	To Early March	Total
Arkwin Oat	653	342	3303	4031	52	122
Elbon Rye	1813	1924	3226	4062	106	126
Ponca Wheat	478	212	2580	3223	44	125
Average	981	826	3036	3772	84	124
Common Ryegrass	275	101	3902	4274	37	110
Overall Average	805	645	3253	3898	80	120

[1]Adapted from Bates (2, 3), Noble Foundation. Average forage yield of three studies on sand, silt loam, and clay soils produced with 53-59-0 pounds of $N\text{-}P_2O_5\text{-}K_2O$ fertilizer per acre.

Table 6. Small Grain Forage Production as Influenced by Harvest Frequency and Harvest Height.[1]

Frequency of Harvest	Ht. of Harvest (In.)	Lbs/Acre Oven Dry Forage Height	Lbs/Acre Oven Dry Forage Frequency	% of 30 Days	% of 45 Days
15 Days	2	3874	3824	75	65
15 Days	4	3775			
	Average	3824			
30 Days	2	5205	5128	100	88
30 Days	4	5050			
	Average	5128			
45 Days	2	5796	5852	114	100
45 Days	4	5908			
	Average	5852			
60 Days	2	6660	6509	127	111
60 Days	4	6358			
	Average	6509			
Overall Days	2	5384	5334	104	91
Overall Days	4	5273			
	Average	5334			

[1]Adapted from Elder (9), Okla. Agr. Exp. Sta. Average of four years data produced with 150-50-0 pounds of $N\text{-}P_2O_5\text{-}K_2O$ fertilizer per acre.

Harvest Frequency and Deferment

The more often small grain forage is harvested the lower will be the resulting forage yield and, therefore, carrying capacity (Tables 1, 2, 4, 6, 7, 8, & Figure 1). There are few exceptions (Table 2), but the close intervals of that study were within the guidelines for good harvest interval range. For analysis of this data, consider harvest frequencies of 20 to 45 days as being within usual ranges for a good rotation grazing approach. This varies with the season and other factors. Within that consideration harvesting at shortened intervals usually result in reduced forage yields of 10 to 35%, therefore, continuous harvest of small grain forage reduces forage yields and production (2, 3, 9, 10, 17, 18, 21).

This data also points out the great importance of harvest deferment. Allowing a 30-day deferment, versus a 15-day deferment increased forage yield 25% (Table 6). That is a tremendous relative difference in forage production! Giving the pasture a 45-day harvest deferment resulted in 35% greater forage yield compared to a 15-day deferment. Even greater differences occur with extended deferments (Tables 7, 8) but these situations are often impractical for usual pasture rotation grazing approaches.

In practice small grain harvest frequency and deferment are varied with the season and other factors. During lush forage periods of fall and spring, some harvests may vary at about two- to four-week intervals, but during slow growth periods of winter the harvest interval may shorten until the forage is gone. During lush pasture periods closer harvest intervals are acceptable because there can be too much forage waste if too much forage is accumulated. Data in Tables 2 and 3 illustrate some of these situations. An important factor is that the forage be well developed at harvest time. **These deferment periods greatly encourage cold weather growth since some shelter is provided by the plants themselves.** I believe this to be a very important factor.

Table 7. Small Grain Forage Production as Influenced by Frequency of Harvests.[1]

Relative Harvest Frequency	Lbs/Acre Oven Dry Weights Early Winter	Late Winter	Winter Tot.	Early Spr.	Late Spr.	Spr. Tot.	Season Tot.	% of High Freq.
Low Frequency[2]	NH[2]	1340	1340	NH	3321	3321	4661	208
High Frequency[2]	690	512	1202	660	384	1044	2246	**100**

[1]Adapted from McMurphy and Tucker (17, 18), Okla. Agr. Exp. Sta. Composite of 18 comparisons of all varieties produced with 60 to 100 pounds of actual nitrogen per acre.

[2]NH identifies treatments not harvested at this period. Low frequency and high frequency were harvested two and four times per year respectively.

Table 8. Small Grain Forage and Root Production as Influenced by Harvest Frequency.[1]

Harvest Frequency	Forage Dry Wt. Lbs/Acre	Forage % of 40 Days	Roots Dry Wt. Lbs/Acre	Roots % of 40 Days
10 Days	1223	56	445	71
20 Days	1905	88	530	84
40 Days	2170	100	625	100
At Maturity	2460	113	725	116

[1]Adapted from Holt (11) Tex. Agr. Exp. Sta. Average of two varieties. Soil fertility unknown.

Forage distribution must be considered in managing a small grain rotation grazing approach. The data herein shows that forage distribution is better with harvests at about 30- to 45-day intervals. Height of harvest, variety or mixture, planting date, soil fertility, and volume of forage present at harvest also influences forage distribution.

Root Development

The closer the harvest frequency, the less the root systems (Table 8) (11). Harvesting at 10-day frequency resulted in a 29% reduction in root system compared to harvesting at 40-day frequency. This reduction in root system in turn likely causes slower regrowth, less regrowth, more drought susceptibility, less nutrient uptake and slower growth during cold weather.

Kind and Variety

Small grain forage production is influenced by small grain kind and variety or mixtures thereof and rotation grazing helps capitalize on these differences. Several of the differences in kind and variety for southern Oklahoma are shown in Table 5: 1) rye often produces more during winter, 2) ryegrass, wheat, or oats often produce more during spring, 3) rye usually yields greater total forage than other small grain but that is not shown in this data. These differences are some of the reason for mixtures.

Ryegrass had much the same responses to height of harvest and interval of harvest as small grain (Tables 3 & 5) (2, 3, 15, 23) but there are times when ryegrass yield does not vary greatly with different harvest approaches (23).

Rotation Using Low Yielding Pastures

Rotation harvesting is beneficial even under low producing circumstances (Table 8) (11, 14). In this case where only about one ton of forage was produced, harvesting at 40-day intervals yielded 177% more forage than harvesting at 10-day intervals.

Summary of Small Grain Forage Harvesting Results

There are exceptions to all the usual responses discussed in the small grain forage harvested information. However, if a small grain forage is to yield near its practical potential the forage management must include:

1. Delayed harvest for forage accumulation before initial utilization.

2. Maintenance of a minimum harvest height of two to four inches, until the last harvests. Some wheat pastures may be different.

3. Harvest frequency or deferment of three to six weeks depending on the season and forage growth.

GRAZING COMPARISONS

Two studies report the advantages of rotational grazing compared to continuous grazing (9, 19). These studies were intensive winter pasture situations, but I would expect the general trends to be similar from typical wheat pasture.

Average Daily Gain

ADG of stocker cattle on good adequately available small grain pasture are essentially the same with continuous and rotational grazing (Table 1). This is realistic since small grain forage quality during winter to mid spring is considered adequate to surplus for good animal gains, therefore, if quantity is adequate to surplus ADG will be very similar regardless of grazing approach.

ADG is likely different under producer circumstances when the grazing approach creates a forage quality or quantity deficiency, either throughout the pasture, or in spots within the pasture, or the grazing approach allows a wasteful or over-maturity condition of forage. This sometimes happens under cases of severe lodging during fall to spring, spot grazing anytime due to inadequate rotation, etc., and/or maturing small grain pasture during spring to early summer.

Rotation grazing, with adequate stocking rates, can control much of these conditions and probably keep animal gains near the possible peak for that pasture.

Table 9. Comparison of Continuous versus Rotation Grazing of Small Grain Pastures.[1]

Study Area	Average Daily Gain/Head		Steer Grazing Days/Acre		Lbs Beef Gain/Acre	
	Cont.	Rot.	Cont.	Rot.	Cont.	Rot.
Stillwater[2]	1.54	1.54	224	257	345	397
Muskogee[3]	2.23	2.24	170	184	381	412
Average	1.89	1.89	197	221	363	404
Increase by Rotation		0%		12%		11%

[1]Adaptation and calculation from Elder (9) and McMurphy and Tucker (19).

[2]A four-pasture rotation.

[3]A three-pasture rotation.

Beef and Grazing Yield Per Acre

Pounds of beef per acre and grazing days per acre were increased 11% and 12% respectively with rotation grazing compared to continuous grazing (Table 9). That's as good as a Ralgro implant! This increase is due to increased carrying capacity of the rotation grazed pastures. There was a 15% increase in the Stillwater study and an 8% increase in the Muskogee study. There was indication that relative differences may be greater under dryland versus irrigated conditions. This is understandable when we consider the rotation pastures likely have better root systems (Table 8). These rotation grazed pastures also had better regrowth and less trample damage than continuously grazed pastures.

Based upon this data, and interpolation from other grasses, I believe that per acre beef and grazing yield are regularly 10% to 30% better under good rotation grazing versus continuous grazing.

Other generalized data of Table 10 supports the advantage of rotation grazing over continuous grazing and shows the general efficiency relationships of forage utilization methods from green chop to continuous grazing.

Table 10. Generalized Forage Use Efficiency Through Various Methods of Utilization (20).

Method of Utilization	Present Forage Use Efficiency
Conventional Grazing (continuous)	50
Rotational Grazing	65
Strip Grazing	70
Hay Harvest	82
Silage Harvest	87
Green Chop Harvest	92

Almost any number of small grain harvests, or grazings, reduces total forage yield over only one or two harvests. **Grazing becomes one of the necessary evils of a small grain pasture.** The trick is to have the pasture grazed as wisely as possible to get the best overall practical forage production, animal carrying capacity and animal product yield per acre. Rotation grazing must be a part of that management! Benefits of rotation grazing are obvious!

CONSIDERATIONS FOR ROTATION GRAZING APPROACHES

Information in this section is intended for the practical application of small grain rotation grazing. Our approach to rotation grazing of small grain pastures has evolved through a blend of applied forage research, known and expected plant physiological responses, and careful evaluation of the applied various practices in intensive small grain winter pasture operations. The responses and some guidelines will be different for the usual wheat belt area, but I believe the same basic principles apply. Most producer rotation grazing approaches have been developed through trial and error approaches within the resources of a particular farm. Small grain rotation grazing approaches are practically adaptable in some degree to almost all small grain pastures.

As a consultant, rotation grazing is easy to explain, but there is something mysterious about it that is often confusing, misunderstood and difficult to accept by the uninitiated producer. That should not be! Rotation grazing is not difficult! It is my hope that this information will help to dispel the negative feelings about rotation grazing of small grain pasture. Rotate graze properly and get that added 10% to 15% additional beef production!

Remember! Your forage management is no better than the best of your weakest management input. Think about it!

Most producers probably use adequate cultural practices to have the potential to produce good small grain pasture yields. However, as an example, let us suppose only a small amount of nitrogen were applied. This would limit production a far greater percentage than good continuous grazing. Nitrogen fertilization may then be the weakest management input. Rotation grazing would still improve product yield over continuous grazing, but a 10% to 15% increase of a small yield is not as great as 10% to 15% of a large yield. **In order to realize optimum benefit from good rotation grazing, good production practices must first be used throughout the pasture production period.** Rotation grazing is an aid to maximize grazing yield if all other good cultural practices are applied.

There is little question that a rotation grazing approach should be a part of the pasture-stock management of almost all small grain pastures. We rotation graze, in some manner, practically all pastures on Noble Foundation property.

Fencing and Water

Producers and researchers often get stymied on rotation grazing approaches due to fencing and watering needs. While this is a valid consideration, good high voltage, high joules, electric interior fencing is effective and relatively cheap. One mile of single strand electric fence can be constructed for about $250 plus charger. Stock water often can be organized so one water location provides stock water for many pastures. We have one situation where stock from five pastures can be watered from one water tank location (Figure 2). Just make some plans!

Rotation of stock from one pasture to another is extremely easy within approaches organized as those in Figures 2 and 3. Little or no force is needed. Stock like a fresh pasture. A little feed or hay bait from one pasture to the next works wonders.

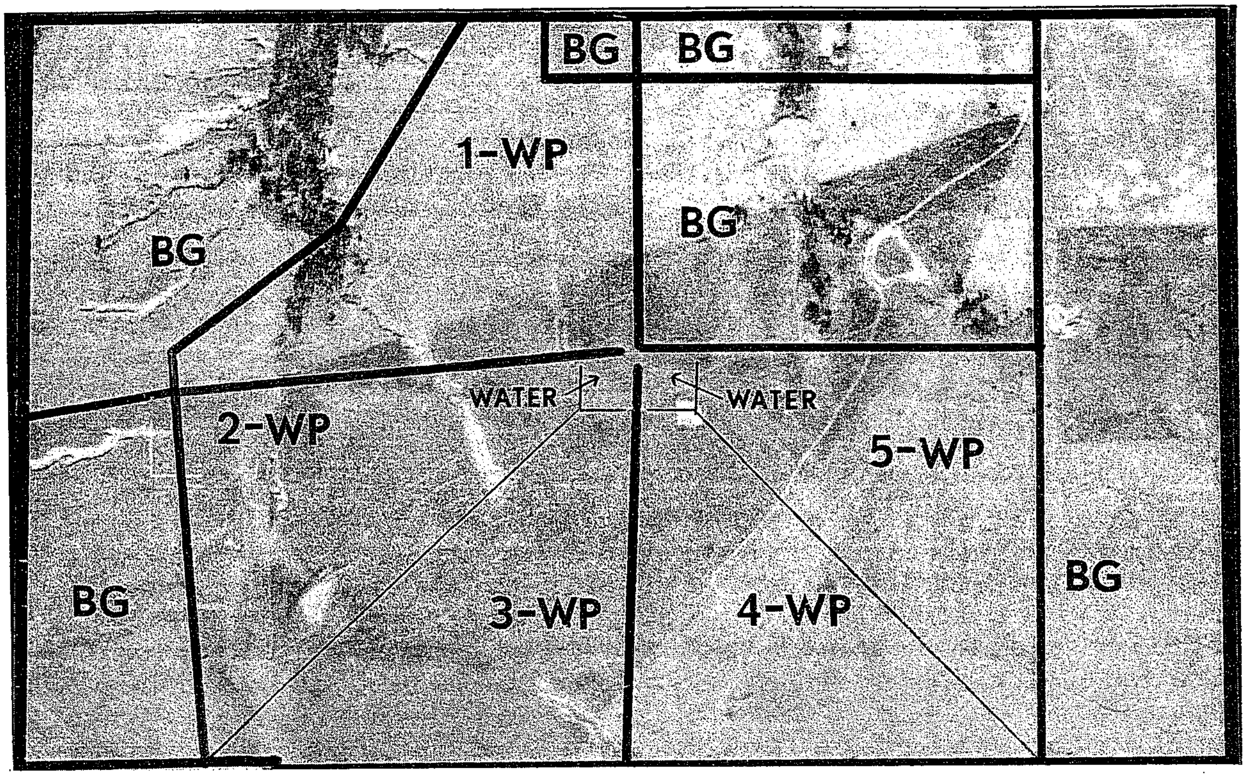


Figure 2. Example of Five Winter Pastures (WP) in a Rotation Grazing Approach Organized So Stock Can Water from One Tank. Bermudagrass (BG) Can Be Used For "Off" Areas.

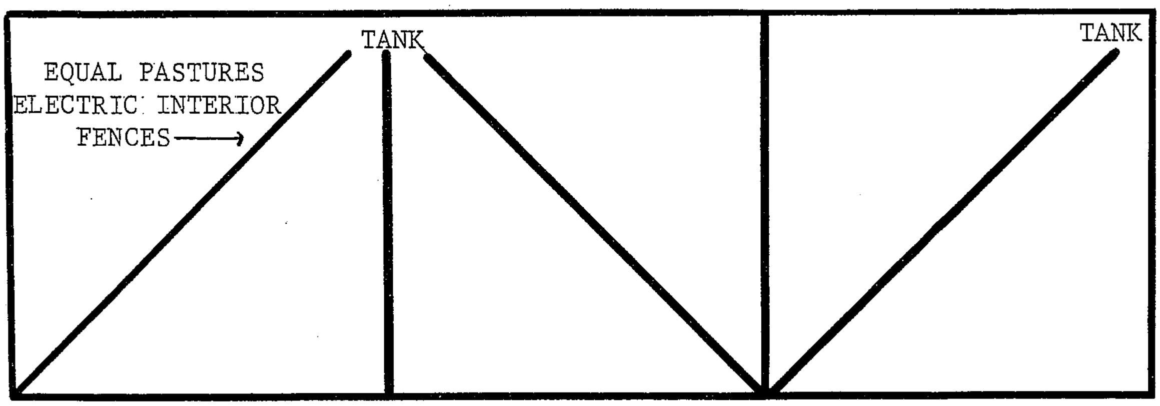


Figure 3. Actual Example of a Six-Pasture Winter Pasture Rotation Grazing Approach--A Pasture Man's Dream.

Number of Pastures

Based upon many years experience, I firmly believe any number of pastures in a small grain rotation grazing approach, up to a point, is better than one pasture continuously grazed. **Two pastures are better than one, three pastures are better than two, four pastures are better than three, five pastures are better than four, and six pastures are better than five.** I have had little opportunity to work with a rotation grazing approach on small grain that involved more than six pastures. There may be some improvement to adding more pastures, but I believe it would be little because there is a limit to the congregation of stock within an area and the associated trample damage and wasting effects.

The six-pasture small grain pasture rotation grazing approach was on the DeHart-Swindell Stocker Cattle Operation near Ardmore. It was a "pasture man's dream"--top notch cultural practices, good quality soil, soil well drained, and the approach was organized very well (Figure 3). The pasture was an intensive small grain-ryegrass mixture. The six-pasture had two water locations. Their usual fall-winter stocking rate was about 550 pounds of beef per acre. Spring stocking rates were increased to about 1000 pounds per acre for grazeout pastures. Think about this!--They had about 550 pounds of beef per acre during fall-winter on the overall area. This was about 3300 pounds of beef stocking rate per acre on a given pasture, one-sixth of the whole area, during the fall-winter rotation sequences. This figure would be about double, or about 6000 pounds per acre, during spring.

There are two very important points here: 1) The pasture tolerated that stock congregation very well, and 2) Based upon this, and other related experiences, I believe this pasture number is near the optimum need for most good small grain pasture rotation grazing.

We have a seven-pasture rotation on small grain pasture at the Noble Foundation Pasture Demonstration Farm during 1983-84. Stocking rates per acre far exceed that of the example in the aforementioned paragraph and there have not been any serious problems to date.

Stocking Rates

Part of making a rotation grazing approach successful is in having the pastures as properly stocked as possible. This is done through several approaches.

1. History of the usual stocking rates in the given region of the pasture.

2. Specific grazing records of the particular pastures managed in a specific consistent manner.

3. Calculations by formula. These formulas, presented on the following page, have worked well for me when calculating stocking rates of intensive winter pastures in situations where a history or records were not available (6). This method is an approximation and should be tempered with a grazing history and records whenever possible. These production figures also assume usual good upland soil, good timely production practices from site and variety selection to fertilization and rotation grazing and the usual initial weight of stock has been from about 350 to 475 pounds per head. Long-term Noble Foundation research data is used to determine forage production without nitrogen and per pound of nitrogen applied. Forage per pound of nitrogen may be different in other locations.

   The formulas are used primarily for rye base pastures and they may not be as accurate for typical wheat belt pasture but the method needs to be tried and developed in those situations in conjunction with other rotation grazing guides in this writing.

Note that the actual real stocking rate is in **pounds of stock per acre**, although finally we do arrive at a needed head count of given weights of animals. The figure arrived at above is very close to our usual winter pasture stocking rate per acre on Noble Foundation pasture from fall to early March. The formula works! Wheat belt pastures would generally be substantially less with about 250 pounds of animal per acre being close to usual rate for decent wheat pasture in a median wheat belt area where no feeding is involved. Also remember that this stocking is intended to go throughout the grazing period without depleting forage supply or feeding excessively. Nature provides that this is not always the case as itemized in the "Balance and Flexibility" information.

Stocking rates during spring grazeout will be greater than during fall to spring provided nitrogen is applied for that production and other management is acceptable. Spring, March 1 to grazeout, stocking rates will usually be 1.5 to 1.8 times the stocking rates during fall to spring. Occasionally, double stocking rates are possible during spring to grazeout. Nitrogen fertilization can drastically alter spring or fall stocking rates.

Step 1. Determine Expected Dry Weight Fall Forage Production Per Acre.

A. Forage/Acre =

$$\text{625 Lbs of Forage Without Nitrogen} + \text{13 Lbs of Forage /Lb of N Applied} \times \text{Lbs/Acre of Early Fall N Applied}$$

B. Example: Forage/Acre =

625 + (13 x 100) = 1925 Lbs/Acre (Fall to March 1)

Step 2. Determine Expected Production Per Calendar Day of Grazing (Fall to March 1).

A. Production/Day =

$$\frac{\text{Expected Dry Wt. Fall Forage Production/Acre (From Step 1)}}{\text{Expected Calendar Days of Grazing}}$$

B. Example: Production/Day =

$$\frac{\text{1925 Lbs/Acre}}{\text{120 Days (Nov 1-Mar 1)}} = \text{16 Lbs/Day}$$

Step 3. Determine Pounds of Needed Average Stock Weight/Acre.

A. Needed Stock Weight/Acre =

$$\frac{\text{Expected Production/Calendar Day of Grazing (Step 2)}}{\text{Expected Animal Consumption \& Waste (3\% of Body Wt.; 3\% = .03)}}$$

B. Needed Stock Weight/Acre =

$$\frac{\text{16 Lbs/Day}}{.03} = \text{533 Lbs Avg. Stock Weight/Acre}$$

Step 4. Determine Number of Stock of a Given Weight Needed.

A. First, determine the initial stock weight, assume an ADG of 1.5 lbs/day to March 1, and calculate mid season stock weight. Stock at 360 lbs/head on Nov. 1 would be 450 lbs/head at mid season Jan. 1.

B. No. of Stock Needed =

$$\frac{\text{Lbs Avg. Stock Weight/Acre (From Step 3)}}{\text{Avg. Lbs/Head At Mid Season (from A above)}}$$

C. Example: No. of Stock Needed =

$$\frac{\text{533 Lbs/Stock/Acre}}{\text{450 Lbs/Head at Mid Season}} = \text{1.18 Head/Acre Initial Stocking Rate for Calves Weighing 360 Lbs/Head on Nov. 1}$$

Stocking rates during spring can be calculated through Steps 1 to 4 listed previously, but there are some different figures to include:

1. Step 1: A. Lbs of forage without nitrogen = 1100 lbs/acre
   B. Lbs of forage per lb of N = 17
   Step 4: A. ADG should be 1.8 (or greater as per records)

2. Adjust calendar days of grazing, spring nitrogen applied, and any other factors that will be different.

3. Remember, all formula inputs can be changed, fall or spring, to fit your actual inputs.

Academically, these formulas could be combined into one large model and even computerized and each component could be refined by knowing small grain kind, specific fertilizer response for your rates and dates, variation in soils, variation in region, etc.

Stock Weight Per Pasture

Experience has shown the stock weight per acre on one pasture of a pasture rotation grazing approach can be about 3000 to over 8000 pounds or more per acre during fall without undue pasture damage. This assumes proper management as discussed in this writing. During spring the stock weight accumulation may be up to 15,000 pounds or more per acre. The tolerable stock weight per acre possible to obtain prior to excessive trampling, etc., is highly variable depending upon soil type, soil and forage moisture content, and pasture growth stage. "Fine" textured soils, wet soil condition and leafy high water content forage all add to potential pasture damage from trampling. Watch pastures closely! Use common sense judgement!

Balance and Flexibility

Rotation grazing management must contain elements of balance of forage production and stocking rate and flexibility factors to allow adjustment as needed due to innumerable changes that will occur. There is a "usual" goal to set; there must be balance, flexibility, and adjustments to reach that goal.

The scope of this writing does not permit full explanation of all the ways to enact these factors, but some major ways are listed as follows.

1. Reduce stocking rates in severe cases. See Step 1 in "How to Rotation Graze Small Grain Pastures".

2. Limit graze to prorate forage use.

3. Integrate grazeout and grain production. This allows easy increase in grazeout stocking rate during spring.

4. Sodseed permanent pasture to small grain for spring pasture.

5. Fluctuate nitrogen fertilization to reduce or increase forage production during certain periods.

6. Hay excess small grain during spring.

7. When pasture is grazed to the recommended minimum height, feed off pasture to allow pasture regrowth, then regraze later. An alternative to this is to remove some cattle to feed and leave some on to graze full time or to limit graze.

8. Buy and sell cattle at different periods.

9. Buy light weight cattle that will grow to approach needed spring stocking rates.

10. Feed on pasture to lighten grazing pressure.

Avoid OverGrazing and Trample Damage

One aspect of rotation grazing of small grain pasture is that it is easy to overgraze, or graze too short, a given pasture. The stock are congregated on one of several pastures, as the pastures reach minimum grazedown height, forage disappears fast. Extreme caution must prevail at this point to avoid excessive overgrazing and pasture production damage. Lost production cannot be completely recovered! If there is question about whether the pasture will feed the stock a bit longer, **don't hesitate, rotate the stock and regraze the pasture later.**

Overgrazing comes in many forms:

1. Grazing too often.

2. Grazing too short.

3. Continuous grazing, especially short-grazed pastures.

4. Spot grazing. **Spot grazing is in all pastures,** but it is most common in continuous grazed pastures or low pasture number rotations and it results in too frequent and too short grazing in spots and possible forage waste in ungrazed areas. The idea is to control spot grazing; there are only two ways to absolutely eliminate it: (1) don't graze, and (2) severely overgraze.

There will be trample damage in all grazed pastures. We must manage to control that waste. Some considerations and management guides for that are listed as follows.

1. Initiate grazing before forage accumulates to the point of severe lodging. This point is reached at below 1000 to near 2000 pounds per acre, depending on forage moisture content and other factors, in intensive winter pasture situations. Typical wheat belt pasture situations would not reach that point, but accumulated yields can be 500 to 1000 pounds per acre.

2. Provide an area, and preferably a grassy "off the pasture" area, for watering, salt-mineral, feeding, and loafing. This is extremely important! Have stock water and other of these items at pasture extremities if possible. This helps to distribute grazing and non-grazing use of the pasture.

3. Manage to remove stock from pastures during extremely wet periods. If the stock are bogging into the wet soil enough to destroy plants, they should be removed until the soil is dry enough to support them. This is very important on fine textured soils. If removal is not possible consider temporary limit grazing in this case or spread the stock over all pastures for a few days and recongregate them later.

4. Manage to defer grazing during periods of extreme cold, about 15°F or less. Trampling high yielding pastures during frozen forage conditions is one of the greatest trample losses in central and southern Oklahoma and this can be most severe under rotation grazing if stock are not removed as needed. Pastures thus damaged are extremely slow to recover. Much production is lost forever. Potential damage is reduced if the forage has been well hardened by previous cold.

HOW TO ROTATION GRAZE SMALL GRAIN PASTURES

It is difficult to summarize a small grain rotation grazing approach that will directly fit typical wheat pasture as well as intensive small grain pasture. Typical wheat pastures are lower yielding, more prostrate, and possibly a little more tolerant of short grazing, while intensive small grain pastures are higher yielding, erect growing, and less tolerant to short grazing. The information presented will be for the more productive small grain pastures, with some deviation to fit the more typical wheat belt pasture.

Step 1. Accumulate a growth of small grain forage.

Small grain pasture is characterized by being high quality throughout a wide range of growth stages and ages. This allows good stock gains on accumulated or stored forage during fall-winter grazing. Forage must be accumulated to manage for good long-term pasture because growth is minimal during cold winter periods. This accumulation, plus growth that will occur, is to be utilized in a prorated manner by early March. Before grazing is initiated, intensive small grain pastures should be all of the following:

1. Eight to 12 inches tall (use four to eight inches for typical wheat pasture), but not severely lodged.
2. At least four to six weeks from emergence.
3. Well tillered and well rooted.

There must be practical exceptions. There are some situations when pasture is very limited. There are cases when lodging occurs early. These guidelines must be altered some in these cases.

Step 2. Initiate fall-winter rotation grazing.

Use two to six pastures--the more the better. This is my favorite approach. Graze the first pasture to utilize up to 20% to 50% of it. **Just "top it off".** Leave lots of leaf! Don't worry about slight spot grazing! It won't be grazed even. Make a judgement. Continue this process throughout the sequence of pastures whether two pastures or up to six or more pastures. Continue this sequence over and over throughout the winter and **"seesaw" the pasture down** until deferment time for grain production, or until grazedown reaches the minimum recommended stubble height. If fall production is excessive rotate stock more often to keep all pastures lightly grazed to limit forage lodging and associated waste. Rotation time interval during fall-winter will usually vary from two to six weeks with a total of three to five rotations being done. If all goes as planned, the accumulated production of Step 1 will be utilized by March grain deferment time or the minimum recommended grazedown stubble height will be reached just as spring growth accelerates to accumulate forage for spring grazing. It does often work this way. **Ideally, there will be only one winter time that the pasture reaches the minimum grazedown height. When a pasture reaches the minimum stubble height, defer use, don't rotate grazing faster to try to keep grazing. Rotating faster merely causes overgrazing.**

An alternate to this approach is to simply rotate every week. This is easier for some operators, but I prefer to see and know the pastures and judge these rotations as above and preferably have the more productive pastures grazed first.

Remember! Small grain pasture should only be grazed down to the minimum stubble height, not any lower. Grazing should then be deferred and not restarted on that pasture until regrowth has occurred. An exception is: If the forage dies due to some calamity, such as freeze desiccation, utilize it!

This approach leaves an abundance of leaf for photosynthesis and regrowth and it allows better soil cover and insulation factors to extend well into the coldest part of winter.

Years ago we placed stock into a given pasture and left them until the minimum grazedown stubble height was reached. Only then would we rotate. This was a terrible shock to the small grain plant. There was little leaf remaining, sometimes only a naked white stem, trample damage was much greater and regrowth much slower. The above method is far superior!

Minimum grazedown stubble height for intensive pastures is considered to be about two to four inches with much basal leaf remaining in these rotation approaches. This is two to three joints of a finger! Minimum grazedown stubble for lower producing, prostrate wheat pasture may be about one inch, but with the soil well covered with basal leaf.

Step 3. Initiate spring-early summer rotation grazing.

Use exactly the same approach as during fall-winter. Forage production should accelerate during spring to create what may appear to be surplus accumulation by April. This accumulation is then grazed off through the sequence of rotations very much like the fall accumulation is grazed during fall-winter. If there is a true excess utilize it for hay or some other purpose. During the rapid spring growth period it is often best to rotate more rapidly to keep the plants vegetative, non-maturing, over a longer period of time. Rotation time interval during spring will often be two to four weeks with a total of four to six rotations being done.

Rotation grazing and nitrogen applied for ryegrass are crucial to making ryegrass perform well in a small grain-ryegrass mixture. During the later stage of major small grain production, in mid April to early May, graze a given pasture of the mixture to the recommended minimum stubble height, then rotate the stock to another pasture allowing the grazed down pasture to regrow predominately ryegrass for future grazing. A three-to four-week deferment is good. Continuous grazing is often disastrous for ryegrass because stock preferably graze it and prevent its accumulation.

Minimum stubble height should be maintained throughout the period until the last couple weeks of pasture at which time all available forage can be taken.

I consider these general approaches as close to the "state of the art" today. New experiences and research data will no doubt refine the approaches to small grains pasture rotation grazing.

A SUMMARY OF ADVANTAGES AND DISADVANTAGES

This section is a summary from research, demonstration and producer circumstances of small grain pastures in a good rotation grazing approach. The advantages far outnumber the disadvantages. Think about it!

Advantages to Rotation Grazing:

1. Increase forage production
2. Increase stocking rate
3. Increase beef production per acre
4. Increase root systems

5. Control forage distribution
6. Increase percent utilization
7. Control regrowth
8. Manage mixtures better
9. Quicker pasture recovery
10. Increase tolerance to drought and extreme cold
11. Control waste from freeze damage, trampling, animal waste, etc.
12. Control bloat
13. Less travel time
14. Less labor time to check stock
15. Less feed at some stocking rates
16. Better animal waste distribution
17. More uniform grazing
18. Increased income of the enterprise is profitable.

Disadvantages:

1. Possible added fence cost
2. Possible added water cost
3. More animal waste around consolidated water locations
4. Possible ease of overgrazing as pasture gets short
5. Possible increase surface soil compaction and less water infiltration
6. Increased time for initial organization
7. Potential for severe trample damage during extreme cold or wet period
8. Possible increased lose if the enterprise is losing money.

Bloat Control

The subject of bloat control bears added comment. Bloat control usually, but not always, tends to correlate to a period when short small grain pasture is making new "onion leaf" regrowth. This is especially true during late winter to spring after short winter grazing, but may be also the case during the rest of the season. The actual cause of bloat is surely a chemical factor, but this usually occurs at the growth stages above. In my experience, in a good rotation grazing approach, this risky stage of production, is seldom, and sometimes never encountered. Historically, bloat problems on Noble Foundation rotation grazed small grain pastures have been very trivial compared to the region experiences. We also probably fertilize with nitrogen at equal or higher levels than the average producers of the region, so that, per si, is probably not a direct cause.

RESEARCH NEEDS

I believe there is sufficient research and practical use data available to illustrate the general forage growth and production aspects of different harvest regimes and rotation grazing versus continuous grazing. However, there is no doubt that much more research could be done to refine and improve what we know.

New research is needed to study forage production responses of modern varieties and mixtures, managed with varying soil fertility including modern rates and dates of application. Results should include effects of earliness of harvest, harvest frequency and the effect of deferment, harvest height, and growth before harvest. This data is greatly needed for the more prostrate growing typical wheat pasture of the wheat belt. These studies should be conducted with the aid of livestock where possible, i.e., the yields would have to be taken mechanically, but the areas should be grazed off to remove forage and set up the next growth period. Root response studies are needed.

New and much expanded research is much more seriously needed to study the effects of rotation grazing approaches of small grain pasture under: 1) Typical wheat pasture in the various wheat belt areas, and 2) Well managed, very intensive small grain-ryegrass-legume pasture of the southern and eastern winter pasture area. These studies need to be set up to consider forage growth characteristics as well as long term livestock needs. This research should include studies involving six or more pastures per unit of rotation as well as other practical considerations discussed elsewhere in this writing. A method of more accurately estimating stocking rates in the wheat belt is sorely needed.

REFERENCES

1. Altom, Wadell, C.A. Griffith, and J.E. Pumphrey. N.D. Winter pasture and stocker cattle. Agr. Div. Noble Fdtn. Bulletin.

2. Bates, R.P. 1957. Forage yields of small grains as influenced by clipping frequency, soil type, and variety. Paper presented for Annual Rep. 1957-58. Agr. Div. Noble Fdtn.

3. Bates, R.P., and R.C. Chessmore. 1959. Small grain forage production--Effects of soil types, varieties, planting dates, clipping intensities, and varietal mixtures. Paper presented to the Crop Sci. Soc. of Am. Nov. 19, 1959.

4. Craigmiles, J.P., and R.M. Weihling. 1971. Temporary winter pasture studies in the Gulf Coast Rice Belt. Tex. Agr. Exp. Sta. Pub. MP-990.

5. Crowder, L.V. 1954. The effect of date of planting and clipping on oat forage and grain yields. Agron. J. 46:154-157.

6. Dalrymple, R.L. 1979. Estimating carrying capacity of intensified high level production irrigated winter pastures. Agr. Div. Noble Ftdn. Photocopy Rep. WP-79.

7. Dalrymple, R.L. 1972. Small grain winter pasture systems and their management. In: Proc. of Sym. on Intensified Winter Pastures and Stocker Calves. Agr. Div. Noble Fdtn.

8. Dalrymple, R.L. 1982. Winter pasture management summary. Agr. Div. Noble Fdtn. Photocopy Publication.

9. Elder, W.C. 1960. Grazing characteristics and clipping responses of small grains. Okla. Agr. Exp. Sta. Bull. 567.

10. Fuehring, H.D. 1981. Effect of date of planting and clipping of irrigated Centurk winter wheat on forage and grain yield. New Mex. Agr. Exp. Sta. Res. Rep. 453.

11. Holt, E.C. 1959. Small grains for forage. Texas Agr. Exp. Sta. Bull. 944.

12. Holt, E.C. 1961. Growth behavior and management of small grains and ryegrass for forage--1959-60. Agron. Dept. Tex A&M Univ. Photocopy Report of Project Hatch 721.

13. Holt, E.C. 1963. Management of Gulf ryegrass. Agron. Dept. Tex A&M Univ. Photocopy Report of Exp. No. 3950-01.

14. Holt, E.C. 1969. Production and management of small grains for forage. Texas Agr. Exp. Sta. Bull. 1082.

15. Hubbard, V.C., and H.J. Harper. 1949. Effect of clipping small grain on composition and yield of forage and grain. Agron. J. 41:85-92.

16. Justis, Norman, and R.L. Thurman. 1955. The effect of clipping and grazing on the subsequent growth of winter oats. Agron. J. 47:82-83.

17. McMurphy, W.E., and B.B. Tucker. 1970. Forage fertilization and clipping studies. In: Research Progress Report--1970. Eastern Okla. Pasture Sta. Okla. Agr. Exp. Sta. Prog. Rep. P-637.

18. McMurphy, W.E., and B.B. Tucker. 1972. Small grain grazing and clipping comparisons. In: Eastern Pasture Research Station Progress Report. Okla. Agr. Exp. Sta. Res. Rep. P-672.

19. McMurphy, W.E., and B.B. Tucker. 1974. Small grain and ryegrass pasture research. In: Eastern Pasture Research Station--1974 Field Day Report. Okla. Agr. Exp. Sta. Res. Rep. P-705.

20. Moline, W.J. 1977. Agronomic aspects of forages in the U.S. U.S.-U.S.S.R. Trade Center. Moscow, USSR. Seminar. (Agron. Dept. Univ. of Ark.)

21. Phillips, L.J., and W.E. McMurphy. 1974. Small grain forage production: Effect of clipping frequency. In: Research Progress Report. Agron. Res. Station. Okla. Agr. Exp. Sta. Res. Rep. P-695.

22. Voisin, Andre. 1959. Grass productivity. Philosophical Library, Inc. 15 East 40th St. New York, NY. pp 89-93.

23. Watson, Vance, and Ward. 1963. The forage yield of rye, wheat, barley, oats, and ryegrass as influenced by height and frequency of cutting--1961-62. Agron. Dept. Miss State Univ. Photocopies of Annual Reports Data.

GRAZING MANAGEMENT CONSIDERATIONS
DISCUSSANT COMMENTS

M. M. Kothmann[1]

Texas A&M University, College Station 77843-2126

The speakers in this session have considered aspects of both plants and animals and their interactions in relation to grazing. Christiansen and Svejcar reviewed physiological responses of grass to grazing and the role of carbohydrates during different stages of plant development. Klepper presented the phyllochron concept for systematically evaluating environmental stress on wheat plants. Integration of the phyllochron technique for describing plant development with physiology and morphology studies should prove fruitful. The use of degree days and moisture availability for predicting maturity of wheat in the Great Plains region could lead to the development of better management recommendations for timing of grazing and pull-out dates in the spring. Additional basic research in this area should strengthen the information base for management.

Forbes reviewed concepts for ingestive behavior. This is a highly important area of research that has received essentially no attention in the Great Plains wheat-belt. Several important questions are readily apparent: 1) What limitations does sward structure place on nutrient intake? 2) What are the critical sward heights and levels of forage availability? (3) How do prostrate and erect varieties differ with respect to their response to grazing, and in the animal's ability to harvest nutrients from them? Animal performance during the fall and winter is perhaps limited more by low forage density than by other factors. This has not been adequately considered in most research.

Ellis and Telford discussed intake and digestion of annual ryegrass. They suggested, based on constant fecal output, that intake was limited by physical characteristics of the forage. This observation was not adequately explained by the research that had been conducted, and further investigation of forage characteristics that may limit intake seems warranted. They also reported that digestibility of grazed diets was most closely related to grazing pressure. Since intake was highly correlated with digestibility, this focused additional attention on the importance of investigating ingestive behavior.

Dalrymple discussed management programs for grazing wheat pastures. There seemed to be a large gap between research and management. The amounts of basic and developmental research available are inadequate to support management practices such as rotational and limit grazing. Management systems are being developed as an "art" by trial and error; however, reports indicate some success. Controlled experiments should be conducted to compare different management systems with respect to plant, animal, and economic responses. More basic research is needed

---

[1] Department of Range Science.

to provide a "knowledge bank" from which more efficient and effective practices can be developed.

One major concern I have is that there does not appear to be any data and little concern for determining the relationship between stocking rate or herbage allowance and animal performance. Dalrymple presents formulas in his written paper for calculating stocking rate based on expected forage production. These are useful tools and appear generally sound. However, the factor for herbage allowance (he uses 3% of body weight) may have a strong influence on animal performance, and this relation needs to be quantified by research. Only when this information is available can there be meaningful comparison of different experiments and economic analyses.

Based on several questions during the discussion I got the impression that there is considerable "fuzzy thinking" regarding grazing management principles. Questions were asked regarding stocking rate, and answers were given in terms of stocking density. Herbage allowance (or grazing pressure) was generally ignored. Progress in grazing management will require development of specific concepts and terms to describe them. Basic concepts describe the interrelationships among the components of the grazed system: 1) land, 2) forage, 3) animals, and 4) time. Stocking density refers only to animals/land, and stocking rate to animals X time/land. The term grazing pressure is similar to stocking density in that it does not consider time (animal/forage), and the term grazing pressure index has been proposed to parallel stocking rate [animal X time/forage]. Stocking density and grazing pressure represent rates of forage demand, the first per unit of land and the second per unit of forage available. Stocking rate and grazing pressure represent quantities of forage demand (intake) per unit area and per unit forage, respectively. More attention should be given to development of these concepts and others with a more precise vocabulary to describe them.

IV. LIMIT-GRAZING COWS AND STOCKER CATTLE ON SMALL GRAINS FORAGES

LIMIT GRAZING OF SMALL GRAIN PASTURES

Wadell Altom, Soils & Fertility Specialist
T. Fred Schmedt, Agricultural Economist
Agricultural Division, Noble Foundation
P.O. Box 2180
Ardmore, Oklahoma 73402

Summary and Conclusions

Daily allowances of small grain forages for cows or stocker cattle can be regulated by restricting grazing times. Stocker cattle grazing small grain forages at three head per acre for two hours per day for 118 days had an average daily gain of .8 pound per head per day. The cattle were allowed free access to small grain forage for an additional 83 days and gained 2.5 pounds per head per day. During the entire 201-day season the cattle gained 1.45 pounds per head per day. Although limit grazing may offer better labor utilization and more profit potential during favorable markets there is also the potential for greater losses during falling markets.

A cow can consume almost 12 pounds (dry matter basis) of small grain forage containing up to three pounds of crude protein in two hours. Thus, small grain forages provide a "cheap" source of protein supplementation for cows only if intake is restricted. By limit grazing, one acre of small grain forage has the potential to supply the protein for two to 19 cows depending on calving date and hay or dry grass quality.

Introduction

The term "limit grazing" comes from the use of some technique to restrict (limit) the amount of standing forage an animal consumes. In comparison, "full-time grazing" denotes a grazing system where animals have access to a particular forage any time they desire it. Animals may eat more of a high quality forage than is necessary for optimum growth or maintenance requirements when given the opportunity (1, 5, 8, 10, 11, & 12). These feed intake excesses could influence profits (1, 8, 9, & 10).

Small grain forages, in most growth stages, are excellent quality feeds. In some instances quality has been rated high enough that methods were devised to restrict the intake of small grain forages (1, 2, 3, 4, 5, 6, 7, 8, & 9). Although considerable work has been done with dairy cows (2 & 6), and some with beef cows (4, 5, & 12) there is little in the literature concerning limiting the intake of small grains for stockers or replacement heifers (1, 5, 7, 8, & 9). In fact a literature review of the forage intake of grazing livestock compiled in 1978 (3) did not list any stocker cattle grazing small grains.

The remainder of this paper will be used to present data, discussion, and economics of limit grazing small grains with stocker cattle and beef cows.

Steer Data and Discussion

Small grains, especially wheat and oats, grown for forage tend to produce more forage during the February to June period than during the September to February period. When these forages are grazed with stocker cattle an adjustment in stocking rates may be needed during the season. Limit grazing experiments were conducted to maintain a constant stocking rate all season, to measure animal performance, to evaluate forage utilization, and to analyze profit potential.

Evaluation of Different Daily Allowances

During the 1967-68 grazing season the Noble Foundation initiated a four-year project to evaluate cattle performance at different small grain grazing time periods. The cattle were purchased as one group, held on feed and hay until pastures were ready and then randomly divided into four groups. Each group consisted of 10 steers classified as #1 Okies.

Pastures were rye and ryegrass planted about mid September. Cattle groups were rotated among the four pastures to eliminate pasture differences and to obtain better forage utilization. The total small grain acreage was stocked at 1.2 steers per acre. Free choice grass hay (lovegrass or bermuda with a crude protein content ranging from 6% to 9%) was available to the cattle when they were not grazing small grain forages. Tables 1 and 2 show animal gain summaries.

Table 1. Average Daily Gains of Stocker Cattle Grazing Small Grain Pastures for 4 Different Daily Time Periods at Ardmore, Okla.

Year & Calendar Grazing Period	Daily Grazing Period (Hrs.)	Avg. Start Wt. (Lbs.)	Avg. Gain Limit Period (Lbs/Day)	Avg. Gain Full-Time Period (Lbs/Day)	Avg. Gain Entire Period (Lbs/Day)
1968	1	394	.41	2.75	1.16
Limit—	2	382	.82	1.94	1.18
Jan. 5 to April 18	4	401	1.15	.61	1.00
Full-Time—	FT[1]	373	1.64	NA[2]	NA[2]
April 18 to June 5					
1969	1	464	1.14	3.77	2.38
Limit—	2	463	2.19	1.84	2.09
Feb. 19 to Mar. 26	4	451	1.92	1.75	1.90
Full-Time—	FT	476	2.61	2.07	2.44
Mar. 26 to April 22					
1970	1	463	.61	2.03	1.26
Limit—	2	460	1.12	1.71	1.39
Jan. 20 to April 7	4	463	1.26	1.86	1.54
Full-Time—	FT	464	1.90	1.95	1.92
April 7 to June 11					
1971	1	431	1.12	2.30	1.71
Limit—	2	427	1.43	2.17	1.80
Jan. 4 to Mar. 10	4	451	1.10	2.38	1.70
Full-Time—	FT	413	2.63	2.11	2.37
Mar. 10 to May 14					
Avg. 1968-1971	1	438	.82	2.71	1.63
	2	433	1.39	1.91	1.61
	4	441	1.36[3]	1.65[3]	1.53[3]
	FT	431	2.20[3]	2.04[3]	2.24[3]

[1]Full-time. Cattle had free access to small grain pastures. Gains reported are for same time periods as limit grazed cattle.

[2]Data not obtained. Comparable cattle weighing 438 pounds gained 1.69 pounds per day from February 12 until June 5.

[3]Average of 3 years only.

Table 2. Four-Year Average Daily Gains and Total Gains of Stocker Cattle Grazing Small Grain Pastures for 4 Different Daily Time Periods. Ardmore, Okla. 1968-71.

Daily Grazing Period	Avg. Lbs Gain During Entire Grazing Period (Lbs/Day & Total Lbs)									
	1968		1969		1970		1971		Avg.	
	Day	Total	Day	Total	Day	Total	Day	Total	Day	Total
1 hour	1.16	175	2.38	145	1.26	179	1.71	224	1.63	181
2 hours	1.18	178	2.09	127	1.39	197	1.80	236	1.61	185
4 hours	1.00	151	1.90	116	1.54	219	1.70	223	1.53	177
Full-time	---[1]	---[1]	2.44	149	1.92	273	2.37	310	2.24[2]	244[2]

[1] Data not obtained. Cattle gained 1.64 pounds per day during the first 2/3 of the grazing period (see Table 1).

[2] Average of 3 years. If 1.64 pounds per day is assumed for all of 1968, the average total gain is only increased to 245 pounds.

Our normal grazing season for stockers usually begins in early November and continues until early June. During the four years of this study the grazing seasons were short (usually starting in early January) resulting in lower total gains than normal for a grazing season (Table 2). We found that cattle grazing small grains only one hour per day averaged gaining less than a pound per day while those grazing two hours or more exceeded 1.3 pounds per day. They usually compensated if given enough full-time days at the end of the grazing season. Although an average daily gain of 1.5 or 1.6 pounds per day for the grazing season is acceptable the full-time grazing cattle had gains greater than two pounds per day.

After cattle had adjusted to the routine we observed that one-hour cattle ran onto the pasture and grazed intently for the entire hour. This is similar to the observations of Jameison (7). The two-hour cattle could just "fill-up" in the two hours. Cattle grazing four hours filled, loafed around a little, and were just beginning to graze again when the four hours were over. Forage intake was measured by weighing cattle before and after grazing (see Table 3).

Table 3. Average Forage Intake of Steers Grazing Small Grain Pastures Average of 4 Days Between March 1 and April 19. Ardmore, Okla., 1968.

Daily Grazing Period	Avg. Weight (Lbs) Mar 1	Avg. Weight (Lbs) Apr.19	Avg. Forage Intake (Lbs)	Avg. Forage Moisture (%)	Avg. Forage Intake Dry (Lbs)	Intake % of Body Weight
1 hour	387	437	12.7	76.6	3.0	0.7
2 hours	414	469	18.6	79.0	3.9	0.9
4 hours	459	522	22.6	77.5	5.1	1.0

These cattle were consuming 0.7% to 1.0% (dry weight) of their body weight. Hay consumption was not measured for the separate groups but was later found to be about 4.5 pounds per day (1.3% of average body weight) for cattle grazing small grains two hours per day.

Limit-Grazing in a Normal Pasture System

The information derived from the above studies led to the development of a two-hour limit grazing program utilizing 300-pound #1 Okie cattle stocked at about three head per acre. Cattle were limit grazed from early November or December until mid-March. Grass hay was fed free choice.

Pastures were a mixture of rye, wheat, and ryegrass planted in early September each year. Nitrogen rates were 120 to 175 pounds per acre.

In 1971 limit grazing cattle started grazing October 28 and a comparable group of cattle started grazing full-time November 15. The full-time cattle were stocked on the small grain at two head per acre. Grass hay was also available to the full-time cattle. Extremely dry conditions created a pasture shortage in March and both groups were fed. Gain comparisons are shown in Table 4.

Table 4. Average Daily Gains of Limit Grazing and Full-time Grazing Steers. Ardmore, Okla., 1971-72.

Grazing System	Start Date	Avg. Start Wt. (Lbs)	Full-Time Date	Avg. Gain (Lbs/Day) Limit Period	Full-time Period	Entire Period
Limit (2 hrs)	10/28/71	313	3/15/72[1]	.56	2.63[1]	1.32
Full-time	11/15/71	321	11/15/71[2]	---	1.71[2]	1.71

[1]Cattle were fed 5 pounds of a 14% protein grain cube from March 15 to April 28.

[2]Cattle were limit-grazed for 4 hours per day from December 15 until March 15 due to drought. These cattle also had 5 pounds of cubes per day March 15 to April 28.

The results of three years grazing two hours per day during the fall and winter with 80 to 90 days of full-time grazing in the spring are shown in Table 9. During those years most stocker operators strived for about 300 pounds of gain per steer during a normal grazing season. We were close to that goal all three years although extra feed was required one year.

Table 5. Grazing Days and Average Daily Gains of Stocker Cattle Limit-Grazing Small Grain Pastures. Stocking Rate 3 Steers Per Acre. Ardmore, Okla., 1971-73.

	Starting Dates 1971-72 Oct. 28	1972-73 Dec. 13	1973-74 Nov. 12
Starting Weight (Lbs)	313	341	305
Daily Grazing Periods (Hrs.)	2	2	2
Days Limited	138	89	126
Days Full-time	80	90	78
Limit-grazing Gain (Lbs/Day	.56	1.15	.69
Full-time Grazing Gain (Lbs/Day)	2.63[1]	2.28	2.60
Avg. Gain for Season (Lbs/Day)	1.32[1]	1.73	1.42
Total Gain (Lbs/Steer)	288[1]	310	290

[1]Cattle were fed 5 pounds of 14% protein grain cubes per head per day from March 15 until April 28.

A slightly different limit grazing system was used during the 1976-77 season. Cattle weighing an average of 312 pounds were purchased in October. They were allowed to graze the small grain pastures four hours per day during the week and full-time on weekends beginning November 12. This limit system continued until February 23. Results in Table 6 show that gains were lower than expected during the limit period but gains were excellent (2.49 lbs/day) during the four-month full-time period giving a good gain for the entire season. These cattle were only stocked at two per acre so some forage was utilized with other cattle and a portion of the area was harvested as hay.

Table 6. Average Daily Gains of Stocker Cattle Grazing Rye, Oats, Ryegrass, & Clover Forage. Grazing Frequency = 4 Hours Per Day During Week and Free-choice on Weekends. Ardmore, Okla., 1976-77.

Avg. Start Weight	Limit Period	Gain Limit Period (Lb/Day)	Full-Time Period	Gain Full-time Period (Lb/Day)	Gain For Season (207 Days) (Lb/Day)
308	11/12/76 to 2/23/77	.88	2/23/77 to 6/7/77	2.49	1.69

Economics of Limit Grazing in a Stocker Calf Enterprise

This discussion of the "economics" or profitability of limit grazing stocker cattle should be prefaced with a review of the conditions and relationships that prevailed in the cattle industry and agriculture in the mid 1960's. Cattle prices were in a general uptrend and numbers were increasing. There were a multitude, by today's standards, of small to very small cow-calf operations in Eastern Oklahoma and throughout the Southeastern United States. These were almost universally spring calving herds that sold all their calves at the local livestock auction at or near the time of the first killing frost. Nitrogen fertilizers were abundant and relatively cheap. Feed grain supplies were also abundant and relatively cheap. Money or credit was available and by today's standards was very cheap. In essence, conditions were ideal for buying light weight calves in the fall when the big "runs" were on, wintering them on small grain pastures and selling them in the spring to the rapidly expanding feedlot industry. This type of program was so profitable that it took very little pencil pushing (there were no hand held calculators or microcomputers then!) to figure out that the "more calves you ran the more money you made". Initially this hypothesis held true but eventually, as is almost universally the case in agriculture, the relationships changed somewhat and, as illustrated in Budgets 1 and 2, owning more calves was not necessarily more profitable.

A close interpretation, however, of the returns in Budgets 1 and 2 will reveal that the producer who had available family labor could still earn a greater total return to his resources with a limit grazing program. If he happened to be involved in feeding cattle in a custom feedlot then he also had the potential for additional feedlot profits due to greater numbers of cattle "backgrounded" through his winter pasture program. Analysis of Budgets 1 and 2 should also point out the added risk, both market and weather, inherent to an intensified limit grazing program. Anyone contemplating limit grazing today (see Budgets 3 & 4) should make certain that ample hay and/or feed is available or attainable in case of adverse weather. Also, before initiating a limit grazing program, one should arrange for financing to maintain ownership of the cattle in a custom feedlot. Finishing the cattle in a custom feedlot becomes almost mandatory in the event that a dry spring eliminates the compensatory gain that is necessary to offset the low gains during the limit grazing period.

In summary, even though "creating" compensatory gain is undesirable there have been and will be occasions when market conditions and/or relative costs combine to make limit grazing stocker cattle a profitable program.

Stocker Summary

The results of grazing trials and observations on cooperators' farms encompassing a 10-year period clearly indicate that limit grazing can be used to: increase stocking rates, lengthen the pasture season by allowing earlier grazing, and intensify small acreages. Many Noble Foundation cooperators have used limit grazing to get by temporary pasture shortages or as a planned program to increase stocking rates. Jay Dyer of Purcell, Oklahoma, almost doubled beef production from his farm by limit grazing from November to February using a five- or six-hour grazing period each day (8). Limit grazing allowed him to more fully utilize his available labor and served as a profitable "outlet" for unmerchantable alfalfa hay.

Limit grazing stocker cattle is not for everyone, however, there are situations where it may be a sound management tool. Some of the advantages are:

1. Increase stocking rate.
2. Intensify small acreages and/or more fully utilize available labor.
3. Continue grazing during temporary forage shortages.
4. Stock pastures in the fall with numbers needed for total utilization of spring grazeout.

Budget 1. Noble Foundation Limit Graze Cattle. Summary of 1972-73 Costs & Returns.

Item	Unit	Quantity	Price/ Unit	Value
EXPENSES:				
319-Lb Crossbred Bulls @ $59.68	Head	121	$190.38	$23,036.38
Cattle Operating Expense	Head	121	28.76	3,480.33
Pasture Expense	Head	121	20.65	2,498.87
Total Cash Expense	Head	121	$239.80	$29,015.58
RECEIPTS:				
631-Lb Crossbred Bulls @ $49.00[1]	Head	119	$309.42	$36,821.49
RETURNS TO LAND-LABOR-CAPITAL OVERHEAD-MANAGEMENT-RISK	Head Acre	119 50[4]	$ 65.60 $156.12	$ 7,805.91
ANALYSIS OF RETURN				
Land Charge[2]	Acre	50[4]	$ 15.00	$ 750.00
Labor & Overhead Charge—				
Receiving & Limit Period	Cattle Days[3]	13,794	$ .075	$ 1,034.55
Full-Time Period	Cattle Days[3]	10,829	$ .05	$ 541.45
Capital Charge—				
Cattle (205 Days)	Dollars	$23,036.38	$ .08	$ 1,035.06
Pasture & Operating (180 Days)	Dollars	$ 5,979.20	$ .08	$ 235.89
Total Allocated Returns				$ 3,596.95
NET RETURN TO OVERHEAD MANAGEMENT-RISK	Head Acre	119 50	$ 35.37 $ 84.18	$ 4,208.96

[1]651 pounds off-pasture weight less 3% shrink.

[2]Calculated as a 6% return to land valued at $250 per acre.

[3]Cattle days are equal to the number of cattle times the days owned. The receiving and limit graze period covered 114 days and the full-time period covered 91 days.

[4]Approximately 50 acres of clean-tilled and sodseeded small grain pastures were utilized by the limit graze cattle. In addition, approximately 9 acres of bermudagrass were used for late spring grazing. A land charge is not made against the 9 acres of bermudagrass, but a fertilizer expense on this land is included in the pasture expense.

Budget 2. Noble Foundation Full-Time Cattle. Summary of 1972-73 Costs & Returns.

Item	Unit	Quantity	Price/ Unit	Value
EXPENSES:				
331-Lb Bulls & Steers @ $62.68	Head	70	$207.47	$14,522.94
Cattle Operating Expense	Head	70	8.73	610.78
Pasture Expense	Head	70	17.41	1,218.52
Haying Expense	Acre	10	31.50	315.00
Total Cash Expense	Head	70	$238.10	$16,667.24
RECEIPTS:				
Hay	Bales	700	$ .85	$ 595.00
612-Lb Bulls & Steers @ $52	Head	67	318.40	21,308.56
500-Lb Bulls @ $52	Head	2	260.00	520.00
Total Receipts	Head	69	$324.98	$22,423.56
RETURNS TO LAND-LABOR-CAPITAL	Head	69	$ 83.42	$ 5,756.32
OVERHEAD-MANAGEMENT-RISK	Acre	40[1]	$143.91	
ANALYSIS OF RETURNS				
Land Charge[2]	Acre	40[1]	$ 15.00	$ 600.00
Labor & Overhead Charge	Cattle Days[3]	9,940	$ .05	$ 497.00
Capital Charge—				
Cattle (142 days)	Dollars	$14,522.94	$ .08	$ 452.00
Pasture & Operating (180 days)	Dollars	$ 1,218.52	$ .08	$ 48.07
Total Allocated Returns				$ 1,597.07
NET RETURN TO OVERHEAD	Head	69	$ 60.28	$ 4,159.25
MANAGEMENT-RISK	Acre	40	$103.98	

[1]33.5 acres of non-tilled small grain pasture were utilized by the stockers. The cattle also had access to a native grass area of approximately 6.5 acres. Therefore, the analysis is based on 40 acres of land.

[2]Land charge calculated as a 6% return to land valued at $250 per acre.

[3]Cattle days are equal to the number of cattle times the days owned. In this case the cattle were owned 142 days.

Budget 3. 300-Lb Stocker Steer (Limit Grazed 2 Hours/Day) on Rye-Wheat-Ryegrass for Graze-Out. 1983-84. .8 Lb Gain/Day November 1 to March 1 and 2.5 Lb Gain/Day from March 1 to June 1. Stocked at 2.5 Head/Acre.

Item	$/Head	$/Acre
EXPENSE:		
300-Lb Calf @ $74/cwt	$222.00	$ 555.00
Vet-Medicine	7.00	17.50
Salt, Feed, Hay (100 lbs feed, 750 lbs hay)	27.75	69.38
Miscellaneous	3.00	7.50
Hauling & Marketing	12.00	30.00
Pasture	41.20	103.00
Operating Interest ($158 @ 14%)	22.10	55.25
Labor	20.00	50.00
Total Cash Expense	$355.05	$ 887.63
RECEIPTS:		
610-Lb Feeder @ $68/cwt[1]	$414.80	$1037.00
POTENTIAL RETURNS TO LAND, OVERHEAD, MANAGEMENT, & RISK	$ 59.75	$ 149.37

Cost/lb gain = 43c (land & overhead not included)

Break-even = $58.20/cwt (to land, overhead, management, & risk)

$1/cwt change in sell price changes returns/acre by $15.25

$1/cwt change in buy price changes returns/acre by $9.00

2.5% change in interest rate changes returns/acre by $9.88

.1 lb change in average daily gain changes returns/acre by $35.70

[1]624 pounds gross weight less 2% for death loss.

Budget 4. 350-Lb Stocker Steer on Rye-Wheat-Ryegrass for Graze-Out. 1983-84. 1.6 Lb Gain/Day, November 15 to March 1 and 2.2 Lb Gain/Day from March 1 to June 1. Stocked at 1.75 Head/Acre.

Item	$/Head	$/Acre
EXPENSE:		
350-Lb Calf @ $72/cwt	$252.00	$441.00
Vet-Medicine	7.00	12.25
Salt, Feed, Hay (100 lbs feed, 4 bales hay)	17.00	29.75
Miscellaneous	3.00	5.25
Hauling & Marketing	12.00	21.00
Pasture	58.86	103.00
Operating Interest ($152 @ 14%)	21.34	37.35
Labor	15.00	26.25
Total Cash Expense	$386.20	$675.85
RECEIPTS:		
700-Lb Feeder @ $67.50/cwt[1]	$472.50	$826.88
POTENTIAL RETURNS TO LAND, OVERHEAD, MANAGEMENT, & RISK	$ 86.30	$151.03

Cost/lb gain = 38.34c (land & overhead not included)

Break-even = $55.17/cwt (to land, overhead, management, & risk)

$1/cwt change in sell price changes returns/acre by $12.25

$1/cwt change in buy price changes returns/acre by $6.13

2.5% change in interest rate changes returns/acre by $6.65

.1 lb change in average daily gain changes returns/acre by $23.00

[1]716 pounds gross weight less 2% for death loss

5. Background large numbers of cattle for the feedlot.
6. Increase profit potential from a fixed land resource during a rising cattle market.

Some of the disadvantages are:

1. Increased labor requirement.
2. Increased hay requirement.
3. Risk of over stocking and low gains if spring moisture is deficient.
4. Increased loss potential during periods of declining cattle prices.
5. Good fences are needed.
6. Potential for additional cattle health problems due to a greater concentration of animals.

The importance of hay quality, spring moisture, and parasite control has been observed by Rouquette, et al (9).

Cow Data and Discussion

Supplying winter protein to beef cows can be a major cost item. Since small grain forages are known to contain good levels of protein (5, 9, 10, and 11), often exceeding 20% crude, they appear to be an economical protein source. However, when one considers the cost of producing small grain forages it is not economical to just open the gate and let the cows have all they can eat. That would be analogous to putting your total winter supply of 20% cubes in the barn and then opening the door so the cows could eat anytime. In order to realize any cost savings the producer must design and implement some system to regulate the cow's intake of high quality small grain forges.

Elder (5) looked at a system where cows grazed small grains one day and dry grass three to five days depending on calving date, etc. He reported that a cow would eat about 25 pounds of small grain forage (D.M. basis) per day and calculated the protein supplied. Table 7 shows the results of a two-year study and Table 8 shows the suggested grazing plan for spring calving cows.

Table 7. Wintering Dry Cows on Small Grain and Weeping Lovegrass Pastures (5).

	1964-1965	1965-1966	Avg.
Total Days Grazed	136	140	138
Days on Lovegrass	98	110	104
Days on Small Grains	38	30	34
Avg. Weight of Cows, Nov.	1030	1068	1049
Avg. Weight of Cows, April 1[1]	975	976	976
Avg. Weight Loss (Lbs)	55	92	74

[1]All calves dropped in March.

Table 8. A Winter Program for Grazing Dry Beef Cows on Small Grain and Dry Summer Grasses (5).

November December	1 day grazing small grains 5 days grazing dry grass
January February	1 day grazing small grains 4 days grazing dry grass
March	1 day grazing small grains 3 days grazing dry grass
150-day grazing period	32 days on small grains 118 days on dry grass

Dalrymple (4) measured the forage intake of cows limit grazing small grains. Table 9 indicates that the cows ate more after they became trained to the system. By the third day they were eating enough in one "fill-up" to more than meet their daily protein requirement. This would suggest that the cows would not even need one "fill-up" every day. Actual needs will depend on calving date.

Table 9. Cow Rye Forage Intake Per 1 Fill-up in a Limited Grazing System. Noble Foundation Pasture Demonstration Farm. Ardmore, Oklahoma. 1973 (4).

Day After Starting Limited Grazing	Lbs Cow Wt. Before Rye Intake	% DM Of Rye Pasture	Lbs Total Intake/ Fillup[1]	% Intake On Body Wt. Basis	Lbs DM Intake/ Fillup	Est. Protein Intake/ Fillup[2]
1st Day	882	14.3	35	4.0	5.0	1.25
3rd Day	863	14.3	50	5.8	7.2	1.80
23rd Day	871	15.4	68	7.8	11.9	2.98
Avg.	871	15.4	51	5.9	8.0	2.01

[1]DM = Dry matter content.

[2]Based on estimated 25% crude protein content of rye.

Various calculations can be done to estimate stocking rates. In addition to calving date, hay or dry grass quality will also influence small grain forage needs. Some suggested stocking rates are shown in Table 10.

Table 10. Projected Cow Stocking Rates Limit-Grazing Small Grains.

Forage	Calving Time	Grazing Frequency	Cows/Ac (Nov-Mar)
Rye	Spring	1 Day Per 4 or 5	2+[1]
Wheat	Fall	1 Day Per 2 or 3	--[2]
Wheat	Spring	1 Day Per 4 or 5	--[2]
Rye-Wheat-Ryegrass	Spring	1 Day Per 6 or 7	19[3]
Rye-Wheat-Ryegrass	Fall	1 Day Per 4	3[3]
Wheat	Spring	1 Day Per 6 or 7	11[3]
Wheat	Fall	1 Day Per 4	2+[3]

[1]Elder, W.C., OSU (5).

[2]Wagner, Don, OSU (12).

[3]Schmedt, T.F., Noble Foundation (10).

Economics of Limit Grazing in a Cow-Calf Enterprise

If an adequate supply of roughage is available, protein is usually the most limiting factor in wintering rations for beef cows. Winter protein supplement is one of the major cash expense items in the annual cow maintenance budget. Excess consumption of protein is used by the cow as an additional source of energy but protein is almost always too expensive to be used as an energy source. When forage or roughage is adequate, protein supplements should always be evaluated on the basis of cost per pound of digestible protein.

With this in mind, the costs of providing protein for cows from the forages produced from a rye-wheat-ryegrass mixture (Budget 5) and from wheat for pasture and grain (Budget 6) are compared with cottonseed meal in Table 11. With cottonseed meal currently costing $280 per ton there is a rather dramatic savings from limit grazing small grain pastures for cow protein supplementation.

In terms of break-even calf prices the savings are currently from $6 per cwt for spring calving cows to $12 per cwt on fall calving cows. Obviously, shifts in input prices will alter these relationships from year to year. Also, one should always consider the weather risk associated with small grain pasture when comparing costs of various sources of protein.

Table 11. Cost of Protein Supplementation for Wintering Beef Cows (1000 Lb) With Limit Grazing on Small Grain Pastures Versus Cottonseed Meal.

Protein Source	$/Cow Fall Calving[1]	$/Cow Spring Calving[1]
Rye-Wheat-Ryegrass @ $98.75/Acre	$19.75	$ 7.90
Wheat Pasture @ $23.30/Acre[2]	27.94[3]	20.73[4]
Cottonseed Meal @ $280/Ton	63.00	27.58

[1]Stocking rates on limit grazed small grains. Schmedt, T.F., Noble Foundation (10).

[2]$23.30/acre additional cost over cost of wheat for grain only.

[3]$18.62 for CSM plus $9.32 for wheat pasture; CSM balances protein, not energy, during the time period when wheat pasture is not available (March and April).

[4]$18.62 for CSM plus $2.11 for wheat pasture; CSM balances protein during the time period when wheat pasture is not available (March and April.)

Budget 5. Rye-Wheat-Ryegrass on Clean Seedbed. 2300 Lbs Forage from November 1 to March 1 and 2700 Lbs Forage from March 1 to June 1.

Item	$/Acre
Land Preparation & Sowing	$30.00
Seed (60 lbs rye & 40 lbs wheat + 15 lbs ryegrass)	15.00
Insecticide	8.00
Anhydrous Ammonia (100 lbs @ $190/ton)	9.50
18-46-0 (100 lbs @ $225/ton)	11.25
0-0-60 (66 lbs @ $140/ton)	4.25
Ammonium Nitrate (150 lbs @ $170/ton)	12.75
Interest on Operating Capital ($53.40 @ 14%)	7.50
Total "Out-of-Pocket" Expense	$98.75

The forage produced by this enterprise is assumed to have 17.5% digestible protein and 65% TDN on a dry matter basis.

Cost/Lb of D.P. = 11.29¢

One acre provides enough protein for 19 spring calving cows from November 1 to March 1. From March 1 to May 1 one acre will provide protein for 9 spring calving cows and their calves. Fall calving cows can be stocked (limit grazing) at the rate of 3 cows per acre from November 1 to January 1 and 6 cows per acre from January 1 to May 1.

Budget 6. Wheat on Clean Seedbed for Pasture and Grain. 1400 Lbs Forage from November 1 to March 1.

Item	$/Acre
Land Preparation & Sowing	$ 30.00
Seed (80 lbs @ $6/bu)	8.00
Insecticide	8.00
Anhydrous Ammonia (100 lbs @ $190/ton)	9.50
18-46-0 (100 lbs @ $225/ton)	11.25
0-0-60 (60 lbs @ $144/ton)	4.75
Ammonium Nitrate (150 lbs @ $170/ton)	12.75
Interest on Operating Capital ($46.40 @ 14%)	6.50
Production Subtotal	$ 90.75
Combine & Hauling	20.00
Total "Out-of-Pocket" Expense	$110.75

The forage produced by this enterprise is assumed to be 17.5% digestible protein and 65% TDN on a dry matter basis.

Cost/Lb D.P. = 9.5¢[1]

One acre provides enough protein for 11 spring calving cows from November 1 to March 1. One acre provides protein for 2 or 3 fall calving cows from November 1 to March 1.

[1] Cost of producing forage is $23.30 per acre for additional seed, fertilizer, and insecticide that would not be recommended for grain production alone.

Cow Summary

Many factors will influence the producer's decision about using small grains for cow protein supplementation. Land availability, alternative uses for the forage, fencing systems, management and/or labor availability, cost of "conventional" sources of protein, and hay or grass supplies are just a few. Some cows train easily while others may never adjust. Many ranchers have encountered few problems and others give up. One ranch had 200 cows in three separate herds well trained in less than one week to limit graze on one pasture. On the other hand, on one of the Noble Foundation demonstration farms a group of cows repeatedly tore up the fences and were a problem all winter.

The magnitude of the cost savings available through limit grazing cool season pastures for protein fluctuates from year to year with the price of traditional protein supplements and fertilizer costs. However, if the manager can succeed in devising an operable limit grazing system then it is apparent, especially for fall calving cows, that utilizing small grain pastures for winter protein offers great potential for profit minded cow-calf producers.

Areas of Needed Research

1. Research is needed to determine how precise we can be with cow grazing allocations and stocking rates. Can we allow a dry pregnant cow to graze small grains one or two hours every six or seven days and thus provide protein for 15 or more cows per acre? What are the pasture and/or cattle management problems associated with these systems?

2. Research is needed to determine the optimum protein content and quantity of hay for both stockers and cows limit grazing small grains. Is there a hay-winter pasture scheme that is more profitable than 4.5 pounds of 8% protein hay and two hours per day grazing winter pasture?

3. Increased gains during the limit grazing period are needed as cattle are actually losing money on a daily basis due to high "fixed" costs (interest, land, overhead, etc.). Therefore, additional study is needed to determine if a grain-supplemented limit grazing system might produce economical gains.

Literature Cited

1. Altom, W. 1978. Limit-grazing of small grain pastures. Noble Foundation Agricultural Division Bulletin. Noble Foundation, Inc., Ardmore, Okla.

2. Combellas, J., and J. Hodgson. 1979. Herbage intake and milk production by grazing dairy cows. 1. The effects of variation in herbage mass and daily herbage allowance in a short-term trial. Grass and Forage Science 34(3):209-214.

3. Cordova, F.J., J.D. Wallace, and R.D. Pieper. 1978. Forage intake by grazing livestock: A review. J. of Range Mgt. 31(6):430-438.

4. Dalrymple, R.L., and W. Dobbs. 1976. Cow intake of rye pasture in a limited grazing system. Noble Foundation Headquarters and Pasture Demonstration Farm Field Day Report. Noble Foundation, Inc., Ardmore, Okla. pp 44-45.

5. Elder, W.C. 1967. Winter Grazing Small Grains in Oklahoma. Okla. State Univ. Agr. Exp. Sta. Bulletin B-654. pp 11-14.

6. Glassey, C. 1979. Pasture availability and dairy cow productivity. Dairyfarming Annual. Massey Univ., Palmerston North, New Zealand. pp 75-76.

7. Jamieson, W.S., and J. Hodgson. 1979. The effect of daily herbage allowance and sward characteristics upon the ingestive behavior and herbage intake of calves under strip-grazing management. Grass and Forage Science 34(4):261-271.

8. McGill, S. 1971. He doubled winter grazing gains. The Furrow (May-June). pp 26-27.

9. Rouquette, F.M., Jr., R.D. Randel, and J.V. Davis. 1981. Forage systems for wintering replacement heifers. Forage Research in Texas. Tex. A&M Departmental Technical Report No. 81-12. pp 3-8.

10. Schmedt, T.F. 1976. Alternatives for wintering beef cows --reduce cost with cool season pastures. Noble Foundation Agricultural Division Typed Report.

11. Utley, Philip R., R.S. Lowery, and W.C. McCormick. 1973. Corn silage and corn silage plus small grain pasture for finishing steers. J. of Animal Sci. 36(3):423-427.

12. Wagner, Don. 1975. The wheat plant for cows. Beef Cattle Research at Fort Reno. Okla. State Univ. Agr. Exp. Sta. Research Report P-725. pp 38-39.

LIMIT-GRAZING COWS AND STOCKER CATTLE ON SMALL GRAINS FORAGES

RANCHER'S PERSPECTIVE AND DATA NEEDS

John L. Merrill

Texas Christian University, Fort Worth, Texas 76129

Summary

There is a series of biologic and economic decisions related to management of small grain pastures, including who will farm, what crop and variety will be grown, how the crop will be fertilized, whether to graze or not and if so, at what rate, frequency, duration, by what class of animals, full time or limit-grazed and with what kinds and amounts of supplementation and non-nutrient products. Each of these decisions, although often interrelated, has its own set of parameters, opportunities, and data needs.

Introduction

In order to bring our use of limit-grazing into the perspective requested, I shall need to move somewhat beyond the specific subject to place our use of small grains in context of the total ranch operation.

The home unit of XXX Ranches consists of 5,700 acres in Tarrant and Johnson Counties near Fort Worth, Texas. Of this unit 1,544 acres are in cropland with most of the balance rangeland, a tall-grass true prairie. No outside income is available to the ranch operation, making it imperative that we apply whatever technology is available in an integrated management plan for maximum productive efficiency. Biology and economics must guide every management decision.

The cattle operation consists of a base herd of approximately 300 to 400 mother cows with provision and flexibility to carry over the entire calf crop as yearlings or sell part or all at weaning and take in other cattle according to market projections. Stocking rate is adjusted one or more times per year according to forage available for proper use.

An intensive short duration grazing system with one herd on eight to twelve native pastures is used during the growing season, with the one herd slowed down during the dormant season or broken into smaller groups to target supplementation to specific needs. One or more native pastures may be deleted from the intensive rotation during the growing season and deferred July through September for use by stockers the following nine months. Each of these range grazing methods allows good integration of grazing from small grain fields and aftermath.

Soils on both rangeland and cropland are dark, calcareous, inherently fertile clay and clay loam soils of the Sanger-Purves-Slidell and Aledo-Bolar-Sanger associations that range in depth from deep to shallow and rocky. Growing season averages 249 days from March 16 to November 21.

Average rainfall is 32.1 inches with April and May being the highest and July and August being the lowest average rainfall months. Under these conditions, the longterm average yield of wheat is 27 bushels per acre and of oats, 50 bushels per acre. Yields of 40 bushels and 70 bushels respectively are not uncommon with adequate and timely seedbed preparation, fertilization and favorable climatic conditions.

Discussion

There is a series of decisions related to small grain establishment, production, and use with economics and risk management becoming an all-prevailing concern. For many years, we could plow, plant, and fertilize a crop of small grain for $25.00 per acre exclusive of land cost. The figure now is near $75.00 per acre. Loss of one $25.00 crop could be overcome with net profit from several other good ones. It is difficult to make enough good crops to overcome one $75.00 per acre loss, which makes crop insurance look better all the time.

One area of decision is who shall do the farming - myself, have it custom-farmed for me, or leased out to another with the grazing leased back for my use. Over time, we have done all three. In recent years, we have opted for the latter two in that order, because we lacked adequate labor available and because of the capital required to upgrade equipment capacity. We still maintain a line of paid-for, depreciated-out farm equipment so as not to be totally dependent on others.

Now, we deduct the acres we wish to graze out according to the annual grazing and marketing plan, have it custom-farmed for us, and lease the rest out, both to a farmer who farms twice as much land with new, large capacity equipment that spreads his overhead and reduces his overall cost per acre. On the cropland that is leased out on a prepaid cash basis, we lease back, at a favorable rate, any grazing available up to March 1.

Thus, we pay on a per-head per-day basis only for grazing available with no risk, while the farmer benefits from the income of custom farming and grazing. On or about March 1, he may elect to cease grazing to combine in June or to offer it for grazeout at a mutually satisfactory price. We have the option to graze it or not.

Another kind of decision is what crop will be grown. Oats and wheat are best adapted to our area and afford the most alternative uses. At one time, we had developed a unique market providing prairie hay and oats to several horse operations in our area. The disadvantages of no custom swather in the area to prevent lodging and shattering near harvest, greater susceptibility to cold damage, more labor required in storage and delivery, and a longer wait for income put us out of the oat business several years ago, and we have grown only wheat since. That option deserves consideration each year.

A related decision is what variety to plant. For grazeout in our area, a beardless soft wheat produces more forage and can be grazed longer without interference from awns than bearded hard varieties. When harvest is a major objective, recent market discounts on soft wheat indicate selecting a hard wheat variety with superior, or at least adequate, forage production. With volatile markets and narrow margins, being able to graze and harvest with more flexibility and diversification of income is especially significant.

Another group of decisions to be considered is the timing, analysis, placement, and rate of fertilizer application related to yield and duration of forage production, grain yield and quality, and cost/return. When the optimum timing, analysis and mode of application are determined, the input/output data should be reported in chart curve form in order that producers may use current cost of fertilizer with projected value of forage and grain yield to determine the optimum rate of application for maximum net return for each crop cycle.

The decision of whether to graze or not is partially answered by the need to maximize and diversify income and by data which indicates no harm to grain yield by proper grazing use. Proper grazing that allows plants to be well rooted with sufficient leaf area before grazing is commenced and then maintains sufficient leaf area for continued leaf and root growth by proper stocking, rotation grazing, and stockpiling growth during rapid growth periods to carry through slow or no growth periods will protect both forage and livestock performance.

In our area, long term averages indicate 3 acres per animal required from November to March 1 and 1 acre per animal from March 1 to grazeout due to difference in growth rate related to day length and temperature. This ratio allows grazing out 1/3 of the acreage with the original number of animals, while harvesting the other 2/3 as grain or hay or adding twice as many more animals during the rapid growth period.

Careful attention to frequency and height of grazing may have a salutary effect on both forage and grain yield by maintaining the vegetative state, reducing freeze damage, and encouraging additional tillering. On the other hand, overgrazing can reduce leaf and root growth, plant vigor, resistance to stress, insects and disease, and subsequent grain yields. Several years observation at the McGregor Station indicated no difference in grain yields dependent on whether or not cattle were removed form clay loam soils in wet weather.

The decision of whether to grazeout or terminate to harvest involves a relatively easy budget calculation and comparison of each alternative-grazing, hay silage, or seed production. The main problem lies in accurately forecasting yields and product values. Previous production records together with constant market observation, published economic forecasts, commodities futures markets and forward sale contracts will assist, and the latter two may be used to guarantee prices.

The related decision is when to cease grazing if the choice is to harvest. There is good data that grazing even a few days too long will reduce subsequent grain yield substantially. On the other hand, terminating grazing too soon wastes animal gain that already is paid for. Unfortunately, a calendar date often is used to cease grazing, even though no two years are alike in growth pattern, and the correct time easily can vary by plus or minus two weeks.

The termination time should be determined by emergence from the crown of the apical meristem, which can be detected by close observation of the crowns of several plants each day, beginning about two weeks before the average termination date. A helpful addition is that microscopic examination of the primordial inflorescence as it emerges will allow counting the number of spikelets, each of which will bear two seed. That number of seed cannot vary due to subsequent moisture conditions, but fill and quality certainly may.

Combined with experience passed on from my father that counting the number of seed in an average head will approximate the yield in bushels per acre, the foregoing process would allow alert producers to determine which day to cease grazing for maximum animal gain and seed production, estimate the probable grain yield, check cattle and grain price forecasts, compare probable returns, and more accurately determine whether continued grazing or termination for harvest would be more profitable.

A major grazing decision is the class of animals to make best use of the forage quality and cost of small grain grazing according to economic priorities. A special use may be to favor first-calf two-year old heifer after calving during the most critical period of their lives, as they must have sufficient nutrition simultaneously to maintain themselves, nurse their calves, grow, and only then and in that order to cycle and conceive. By handling our crossbred, high milking, two-year old heifers in this way, we have achieved a 97.73% conception rate (on 88 heifers for those seeking statistical significance) while maintaining their growth and then weaning a heavy calf at 6 months of age.

The second priority for us usually is weaned steer calves in which every pound of gain is sold. In fall calving cow herds, a third priority might be green creep feed for calves by placing creep gates in field fences so that calves may have constant access when cows are limit-grazed or have none at all. If small grain pasture is even more limited, cows with steer and heifer calves might be separated in order to favor steer calves whose gain is worth more.

A fourth priority for full-time grazing might be for cows in inadequate condition due to poor grazing conditions or late weaning in order to restore adequate condition before calving for adequate lactation and early rebreeding. Care must be taken to avoid excess fat and extra large fetuses that would contribute to calving difficulty and losses. The lowest priority for full-time grazing would be yearling replacement heifers which easily can get too fat and whose development cost is not offset by salable product.

Not ranked in priority but definitely worth considering is finishing animals for slaughter on small grain pastures with or without energy supplementation. We have produced home-raised crossbred steers that received only native grass and small grain pasture to reach a weight of 978 pounds at 14 to 16 months old. This one trial did not include the more productive cattle cross we now use, nor grazeout wheat, nor reimplanting.

Where small grain grazing is not unlimited, as is the usual case, strong consideration should be given to limit-grazing cattle as a protein supplement to dormant native grass or other roughage. Possible advantages over prepared feeds include conditioning qualities and Vitamin A content, with usually lower cost and less labor.

All classes of cattle will prosper when grazing small grain pasture for two hours per day and numbers of animals may be 3 times or more that of full-time grazing due to less grazing, trampling, and fouling. Equal results may be obtained with less labor by grazing yearlings or dry cows 2 to 3 consecutive days per week according to condition of cattle and forage, while nursing cows need 3 days per week. There certainly is no problem in letting animals into the field, so that the only labor involved is removing them once each week.

Handling replacement yearling heifers in this manner in conjunction with native grass and charging small grain establishment cost to the harvested grain crop has allowed us to keep heifers from weaning to a year later as bred heifers for a total cost of $50.00.

Where fields are located adjacent to 2 or 3 pastures, it is possible to supplement cattle from at least 2 and sometimes 3 pastures by alternate use of one field. Priority for limit-grazing would be the same as that indicated for full-time, or the top priority categories may be given fulltime use with any remainder devoted to limit grazing.

The final set of decisions relates to kind and amount of mineral and amendments such as ionophores and anabolic agents with measured responses to fulfill needs and opportunities under varying economic conditions on small grain pastures.

You and I know well that most producers and researchers are not conscious of the many decisions and data needs related to small grain grazing. We may be equally sure that the many opportunities that small grains afford will not be fulfilled until we know more and use what we know to the best advantage in a flexible integrated management plan.

It is easy to envision some future time, perhaps not too far away, in which parameters of plant variety, soil moisture and temperature, photoperiod, fertility available, and amendments may be input to a computer model which accurately can predict forage production and nutrient value and when combined with precise description of livestock can project average daily gain.

Small grains already are an important part of my own and many other ranching oeprations. With advances in research later and applications that are possible, small grains will become even more significant in improving ranching efficiency and profitability.

Areas Of Needed Research

Data needs related to establishment include economic analysis of field efficiency of power, tillage, and planting equipment including labor, fuel, and maintenance cost per acre; timing, rate, depth, and method of planting, degree and method of desirable compaction in various location and soil types; most efficient combinations of tillage, herbicide and insecticide related to cost, yield, soil, water, and plant protection.

Palatability and forage quality seem to be high and uniform enough not to merit a high research priority. Through new techniques in plant breeding, it may be possible to develop new perennial varieties with adequate forage and grain production, greater reliability, and no annual re-establishment cost.

Data needs related to the forage/livestock interface in grazing small grains include defining physiological and/or morphological keys usable by producers to determine more precisely the commencement of grazing, carrying capacity, duration of grazing and rest periods for optimum forage and livestock production, optimum time to cease grazing for grain or hay harvest, and opportunities to finesse management with growth modifiers such as mefluidide.

Data needs related to livestock include defining needs and responses of various crosses, ages, weights, and classes of animals to various amounts and durations of small grain grazing, kinds and amounts of supplementation and non-nutrient products.

V. SUPPLEMENTATION PROGRAMS FOR WHEAT PASTURE STOCKER CATTLE

SUPPLEMENTAL FEEDING OF GRAIN AND PROTEIN FOR STOCKER CATTLE ON SMALL GRAINS PASTURES

Don Wagner, Oklahoma State University
Robert Lowrey, University of Georgia
Mark Grigsby, New Mexico State University

Winter annuals are very high in protein and moisture, especially when growing rapidly. Moreover, they are expensive to grow and subject to adverse weather conditions. In recent years, some studies have focused on supplementing winter annuals with energy feeds and in two studies (New Mexico) with a protein supplement.

Supplementation of cattle on small grains might be considered as a management practice for a wide variety of reasons. These, among others, could include:

- Increase daily gain
- Increase carrying capacity or stocking rate
- Extend grass during short months or adverse weather
- Increase carcass grade if attempting to finish cattle on pasture
- Enhance cattle management
  - -- Teach calves to eat in preconditioning programs
  - -- Taming wild cattle
  - -- Ease daily counting and checking
  - -- Control movement
  - -- Reduce grazing pressure?
- Supply additives, reduce health or disease problems
  - -- Poloxalene (bloat)
  - -- Mg
  - -- Monensin
  - -- Reduce excess wheat pasture intake following winter storms
- Increase energy or protein intake or to better balance protein and energy since small grains are often very high in protein (20-30% CP) if young and growing rapidly
- Increase profits?
  - -- Work cattle up in average price (calves usually sell higher in the Spring than Fall)
  - -- Sell more beef if profitable
  - -- Increase net returns/head or acre.

Winter annuals (wheat, rye, oats, ryegrass or mixtures of these have been used to stocker (grow) and to some extent finish beef cattle in the South and Southwest for many years (Burton et al., 1949; McCormick et al., 1958; Godbey et al., 1959; Harris et al., 1971).

A variety of energy sources have been used as a supplement to the cool season pasture. Representative studies for most of these are included in this paper. Results of a 4-year Oklahoma study are shown in Table 1. In these studies grain was fed at approximately one percent of body weight.

Table 1. Effect of feeding supplemental grain to stocker cattle on small grain pastures (rye-wheat) - (Elder, 1967, Oklahoma)

	Grain /day	Steer grazing days/acre	Daily grain	Lb beef per acre	Feed efficiency[a]
Year 1					
Pasture	--	213	1.30	276	8.2
Pasture + grain	5.4	253	1.75	442	
Year 2					
Pasture	--	150	1.35	202	13.5
Pasture + grain	6.0	175	1.60	280	
Year 3					
Pasture	--	196	1.49	292	8.2
Pasture + grain	5.0	248	1.79	443	
Year 4					
Pasture	--	154	1.50	231	9.0
Pasture + grain	6.0	200	1.82	364	
Average (4 years)					
Pasture	--	178	1.41	250	9.2
Pasture + grain	5.54	219	1.74	382	

[a]Pounds of feed required/lb of increased gain.

An example calculation showing the supplemental feed required per pound of additional gain in this four year study is:

219 grazing days per acre X 5.54 lb
Grain/day = 1213 lb grain fed per acre
382 - 250 = 132 lb extra beef acre by feeding grain

$\therefore \frac{1213}{132}$ = 9.2 lb grain for each pound of extra beef

The results of this study can be further summarized as follows:

	Average Advantage From Grain Feeding
Carrying capacity (steer grazing days/acre)	+ 25%
Daily gain	+ .33 lb/day
Beef/acre	+ 53%
Feed efficiency (lb grain/lb gain)	9.2
Feed efficiency if no advantage were taken of the increased carrying capacity	$\frac{5.54}{.33} = 16.6$

The 9.2 lb of grain required to achieve an extra pound of gain could be viewed in the economic context of marginal cost vs. marginal revenue to assess the liklihood of this being an economically viable practice. In this sense, the time such a practice is most likely to be profitable is when grain is cheap relative to the sale price of extra weight, when little or no discount is paid for extra fleshing or condition scores on feeder cattle and when cattle might be contracted for a certain price regardless of weight or condition. It is believed by some that greater efficiencies (lb grain/lb extra gain) might be observed at lower levels of supplemental grain intake than the 1% of body weight levels used in this study. However, it is difficult, if not impossible, to assess the level of substitution effect (if cattle eat more grain and thus eat less grass) or extra carrying capacity which might have been noted in such studies. Further studies are needed to better quantify and assess response parameters (including intake and utilization of the wheat forage and utilization of grain) observed over a range of supplemental grain levels between 0 and 1% of body weight (as well as possibly higher levels).

Two Oklahoma studies in which higher levels of grain were fed (ad lib in a self feeder) are shown in Tables 2 and 3. In these studies, any increased carrying capacity was not measured, and thus, the apparent efficiencies were very poor (17.5 and 29.2 lb of grain required to produce an extra pound of beef). Yet, such figures illustrate the unliklihood of such a practice being profitable when no advantage is taken of potentially greater carrying capacity.

Corn or sorghum silage works well with winter annual grazing programs. Animals can be switched from pastures to silage without digestive problems. When a combination of winter grazing and silage is used, silage should provide for more complete utilization of winter annuals and increase the carrying capacity of the winter annuals by supplying additional energy. In the case of silage feeding, the high protein content of winter annuals will eliminate the need for supplemental protein. The winter annual grazing crop and the silage crop can be grown on the same land area (double-cropping). An example of the utilization of silage and winter grazing is presented in Table 4.

Table 2. Supplemental grain on wheat pasture[ac] (Oklahoma).

	Grain/ day	Daily gain	Feed efficiency[b]
Pasture (114 days) 11/21 - 3/14	------	1.37	17.5
Pasture + grain	10.66	1.98	

[a]Grain self fed.

[b]F/E = $\frac{10.66}{.61}$ = 17.5/1

[c]Renbarger et al. (1968).

Table 3. Supplemental grain on wheat pasture[ac] (Oklahoma).

	Grain/ day	Daily gain	Feed Conversion[b]
Pasture (88 days)	------	2.22	29.2
Pasture + grain	9.34	2.54	

[a]Grain mixture (77% ground milo, 8% molasses, 15% chopped alfalfa hay) self fed.

[b]F/E $\frac{9.34}{.32}$ = 29.2/1

[c]Ewing et al. (1967).

Table 4. Corn silage or corn silage plus small grain pasture (rye) for finishing yearling steers.

	Grazing	Silage & Grazing	Silage
Steers	28	28	28
Initial wt, lb	834	839	838
Final wt, lb	1052	1045	1041
ADG, lb	1.93	1.83	1.79
Acres/steer	1.00	.67	--
Carcass data			
Quality grade	10.5	11.0	11.0
Color	2.6[a]	2.5[a]	1.2[b]

[a,b](P<.05).
Quality grade 11.0 = high good; 10.0 = med good.
Color 1 = white; 2 = slightly yellow; 3 = yellow.
Utley et al. (1973).

In the above study cattle receiving corn silage free choice while grazing consumed 6-8 lb silage dry matter per day.

Many Georgia producers are using the silage grazing system to stocker weanling calves. The grazing and silage are produced on the same land area. A stocking rate of two 400-500 lb calves per acre is common with a total gain of 300-400 lb per animal for the stockering period.

Corn grain has also been used to provide supplemental energy on winter annual grazing. Table 5 presents data from a 3-year Georgia study comparing performance of weanling cattle on either winter annual grazing (mixture of rye, oats, wheat) or winter annual grazing plus free-choice ground corn.

Table 5. Performance of weanling steers on winter annuals with or without ground corn (208 days) (Univ. of Georgia).

	Grazing	Grazing & Corn
Steers	44	34
Initial wt, lb	413	420
Final wt, lb	803	840
ADG, lb	1.88[a]	2.01[b]
Daily grain, lb	--	9.5
Acres/steer	1.00	0.5
Beef/acre	390	840
Grain/steer	--	1977
lb Corn/lb extra Gain, lb[c]	--	8.8

[a,b] (P<.05).

[c] 840-390 = 450# extra gain from 3954# feed (1977 X 2).
Worrell (1977).

In the above study ground corn was provided in a self-feeder on the winter annual pasture.

Utley and McCormick (1975) compared the full-feeding of either dry corn or high moisture corn to yearling steers (Avg. wt, 850 lb) grazing oat pasture. Steers fed high-moisture corn gained about 12% faster (P<.10) and were about 8% more efficient than steers fed dry corn.

Utley and McCormick (1976) studied the full feeding of whole-shelled corn or rolled grain sorghum as energy supplements to annual rye pasture (Table 6).

Table 6. Performance of yearling steers fed whole-shelled corn or rolled grain sorghum on rye pasture (103 days).

	Grazing	Grazing and sorghum	Grazing and corn
Steers	18	18	18
Initial wt, lb	708	705	705
Final wt, lb	948	1008	1013
ADG, lb	2.33[a]	2.96[b]	2.99[b]
Daily feed:			
Sorghum	--	13.01	--
Corn	--	--	12.9
Acres/steer	1.3	.67	.67
Gain/acre, lb	185	452	460
Grain/lb extra gain, lb	--	7.31	7.23
Carcass grade[c]	9.6	9.7	9.5
Ribfat, inches	.34	.36	.34

[a,b](P<.05).

[c]9 = low good; 10 = med good.

Utley and McCormick (1976).

In the above study daily gain was increased about 28% with supplemental energy with whole shelled corn and rolled grain sorghum giving the same response.

Research at Auburn (Anthony et al., 1971) indicated that the feeding of corn on winter annual pasture (rye-ryegrass-yuchi arrowleaf clover) increased average daily gain, decreased stockering rate and increased the percentage of cattle grading choice (Table 7).

Table 7. Performance of yearling cattle on rye-ryegrass-yuchi arrowleaf clover pasture and drylot feed (Auburn).

Item	Drylot corn silage	Drylot whole corn	Grazing + corn	Grazing only
Days on test,				
November 12 - June 7	208	176	208	208
Number of steers	20	20	32	28
Initial wt, lb	578	568	559	576
Final wt, lb	920	962	1006	971
ADG, lb	1.64	2.27	2.16	1.90
Feed day/head				
Corn silage, lb	38.8	7.1	--	--
Whole corn, lb	4.0	16.3	11.5	--
Auburn-65, lb	1.0	1.0	--	--
Total corn/head, lb	832	2869	2404	0
Carcass Grades				
Choice, %	20	75	56	13
Good, %	75	25	44	87
Standard, %	5	0	0	0
Dressing %	57.7	61.7	61.9	60.6

Anthony et al. (1971).

Edwards et al. (1968) compared limit feeding of grain (5 lb/head/day) to full feeding of grain (avg intake of 9.61 lb/head/day) on ryegrass-clover pasture. The initial weight of the cattle averaged 489 lb and the length of the grazing period was 197 days. The cattle receiving the full feeding of grain gained about 5% faster than those on limited grain (2.01-vs-1.90 lb). There was a trend for the carcasses of cattle from the full feeding of grain treatment to grade higher.

By-product feeds have been used successfully as supplemental energy sources on winter annuals as indicated in Table 8.

Table 8. Influence of different energy sources on performance of steers grazing winter annuals (Georgia).

	Grazing	Grazing & citrus pulp	Grazing & corn	Grazing & corn & peanut skins
Initial wt, lb	744	729	751	722
Final wt, lb	1208	1234	1236	1245
Daily feed, lb	--	8.5	5.0	8.7
ADG, lb	2.56	2.79	2.68	2.89
Acre/steer	1.4	.7	.7	.7
Grade[c]	11.6[ab]	11.1[b]	11.9[ab]	12.8[a]
Fat color[d]	2.6	2.7	2.8	2.4

[a,b] (P<.05).
[c] 11 = high good; 12 = low choice.
[d] 1 = yellow; 3 = slightly yellow; 5 = white.
Mills (1981).

Oklahoma studies by Horn et at. (1981) investigated the effects of supplemental monensin upon intake and digestibility of winter wheat pasture and performance by stocker heifers (Table 9). Intake and digestibility were not altered by monensin. In line with other studies, rumen propionate levels were elavated by monensin and methane production decreased. The addition of 200 mg of monensin per day increased daily gain by an average of +0.19 lb per day (P<.01) in the two trials above cattle receiving 2.0 lb grain (no monensin). Cattle fed 2.0 lb of grain (no monensin) gained 0.10 lb more/day than those receiving only wheat forage (1.21 vs. 1.31 lb/day). No assessment of potential increased carrying capacity could be made.

Table 9. Effect of monensin on intake and digestibility of wheat forage and performance (Horn et al., 1981).

Effect of monensin on wheat forage intake and digestibility in steers.

	Trial 1[b]		Trial 2[c]	
	Control	Monensin[a]	Control	Monensin[a]
Forage intake,				
Forage organic matter, % body wt	3.16	3.28	2.79	2.12
Forage digestibility,				
Dry matter, %	86.5	85.8	82.2	82.4
Organic matter, %	82.2	82.5	80.0	78.3

[a]200 mg/day.

[b]Eight steers avg. 493 lb.

[c]Eight steers avg. 609 lb.

Stocker heifer trials on winter wheat pasture.

	Trial 1[b] (112 days)			Trial 2[b] (113 days)		
	Control	-Monensin	+Monensin	Control	-Monensin	+Monensin
No. of heifers	37	39	40	43	45	43
Monensin intake, mg	--	--	85	--	--	95
ADG, lb	1.21[e]	1.41[d]	1.61[e]	1.21[e]	1.23[c]	1.39[d]
Two trials (ADG)						
Control	1.21					
2 lb grain	1.31					
+ Monensin	1.50					

[b]2.0 supp/day; 85 mg monensin/day in Trial 1, 95 mg/day in Trial 2.

[cde](P<.01).

Since wheat forage is high in crude protein (CP), often exceeding 25% CP, it is commonly assumed that stockers consume excess protein when grazing winter wheat pastures. Mader and Horn (1980) have shown, however, that wheat forage protein is highly soluble, with up to 40% of the total N being soluble. Due to this high protein solubility, possibly stockers grazing winter wheat might respond to supplemental protein, provided it is a natural protein source and not non-protein nitrogen.

Since no data were available comparing supplements of different protein contents for stockers grazing small grain pasture, two studies were conducted by Grigsby at New Mexico to evaluate the response of stocker cattle grazing irrigated winter wheat pasture to additional protein. Moreover, additional energy and/or monensin was investigated in the studies. Composition of the supplements is shown in Table 10 and results of the two studies in Tables 11 and 12. In the first study (Table 11), protein levels of 11, 26 and 38% were compared. In study 2, 11% CP, with or without monensin, and a 23% CP treatment were compared.

Table 10. Composition of supplements fed in trials 1 and 2 (DM basis).

Ingredient	IFN	11% CP	26% CP	38% CP
Trial 1[a]				
			%	
Steam flaked corn	4-02-931	80.8	45.0	10.8
Soybean meal	5-04-6004	-	36.4	71.0
Molasses	4-04-696	9.0	8.8	8.5
Fat	4-00-409	4.8	4.7	4.6
Limestone, ground	6-02-632	3.0	2.9	2.8
Dicalcium phosphate	6-01-080	1.8	1.8	1.7
Hominy feed[b]	4-02-887	0.6	0.6	0.6
Trial 2[c]				
Steam flaked milo	4-04-444	88.7	88.7	57.4
Soybean meal	5-04-6004	-	-	31.6
Molasses	4-04-696	6.3	6.3	6.2
Hominy feed	4-02-887	4.9	4.9	4.8
Monensin (mg/kg)		0	174.0	174.0

[a]Fed 3X/week to give 3.0 lb/head/day.

[b]Carrier for monensin to provide 27 mg/head/day.

[c]Fed 3X/week to give 2.0 lb/head/day.

Table 11. Effect of supplemental grain or protein on performance of heifers grazing winter wheat (Trial 1, 134 days) (Grigsby, New Mexico, 1982).[c]

	Control	11% CP	26% CP	38% CP
Initial wt, lb	403	396	408	413
Supp/day, lb	--	3.0	3.0	3.0
ADG, lb	1.47[a]	1.76[b]	1.78[b]	1.58[ab]
Total gain, lb	198	235	239	212
F/G, lb	--	10.9	9.7	29.9

[a,b](P<.05).

[c]Trial ran from Nov. 17, 1981 - March 31, 1982; 20 heifers/treatment.

Table 12. Effect of supplementation upon performance of steers grazing winter wheat (Trial 2, 123 days) (Grigsby, New Mexico; unpubl).[e]

	Control	11% CP	11% CP + M[d]	23% CP
Initial wt, lb	406	297	405	407
Supp/day, lb	--	2.0	2.0	2.0
ADG, lb	1.45[a]	1.76[bc]	1.91[c]	1.72[b]
Total gain, lb	184	215	236	212
F/G,lb	--	9.3	5.6	10.5

[a,b,c](P<.01).

[d]160 mg/day of monensin

[e]Trial run from Nov. 12, 1982 to Mar. 15, 1983; 24 steers/treatment.

Results of trial 1 indicate that heifers grazing winter wheat pasture responded to a grain supplement with increased ADG; however, no additional response was obtained by increasing the protein content of the supplements. Replacing corn with SBM in the supplement resulted in lower ADG, although the difference was not statistically significant. Even though there was no difference in ADG between the heifers receiving the 11% or 26% CP supplements, when the cost of the additional protein is considered, the economical returns would undoubtedly favor the 11% CP supplement.

In trial 2, steers fed any of the 3 supplements gained significantly more than unsupplemented controls (P<.01). Increased ADG above controls was .27, .31 and .46 lb for steers receiving the 23% CP, 11% CP and 11% CP+M supplements, respectively, and the feed required per unit gain above the unsupplemented controls was 10.5, 9.3 and 5.6 lb, respectively.

Including monensin in an 11% CP supplement increased ADG .15 lb (8.8%) over steers fed the same supplement without monensin, which is in agreement with data by Horn et al. (1981). Replacement of steam flaked grain with SBM to increase the CP content of supplements was not beneficial. Heifers fed 26% CP or 38% CP supplements (trial 1) had ADG similar to those fed the 11% CP supplement while steers fed a 23% CP supplement with monensin (trial 2) gained significantly less than those fed an 11% CP supplement with monensin. It is obvious from these results that additional protein, at least in the form of SBM, is not beneficial to stockers grazing irrigated wheat pasture.

In conclusion, it appears that optimum performance of stockers grazing winter wheat pasture can be obtained by feeding low levels (less than 1 kg/head/day) of a grain-based supplement containing monensin. Such supplemental programs provide significant increases in ADG over unsupplemented controls while requiring low levels of supplement for each additional unit of grain. Omitting monensin from a grain supplement reduced ADG in steers while increasing protein levels either had no effect or reduced ADG, relative to the 11% CP supplement, while increasing cost of the supplement.

In studies involving limit-feeding, the feedstuff was usually provided daily or every other day on a hand-fed basis. This requires labor and sufficient feeder space to permit adequate intake by each animal. Animal fat and salt (Table 13) have been used successfully at a level of 10% in the grain mix to limit intake of grain fed free-choice on winter perennial pasture (Wise et al., 1967) to about 1.0-1.25% of body weight.

Table 13. Use of salt of animal fat to limit free-choice grain intake on ladino clover-grass pasture (Wise et al., 1967).

Intake limiters	Av. daily gain, lb	Av. daily conc. intake, lb	Conc: gain
Handfed	2.15	5.08	2.23
Salt - 10%	2.27	6.33	2.79
Fat - 10%	2.54	7.72	3.04

Moreover, field observations in Oklahoma have shown that a mixture of about 40% ground wheat straw and 60% grain, fed free choice, will usually provide a total intake of about 1% of body weight (straw + grain) without the use of salt, fat or other intake regulators.

Summary

1. Silage (sorghum or corn) is an excellent feed to use for stockering cattle with winter annuals. Free-choice feeding of silage permits the doubling of the stocking rate, but daily gains may be reduced 10-15% particularly with young cattle. The same land area can be used for both grazing and the silage crop.
2. Free-choice grain feeding is more commonly used where finishing cattle on winter annuals is the objective. The stocking rate can be doubled, daily gain increased 10-15%, and the carcass quality

improved. The cattle will consume about 1.5% or more of their body weight in grain on winter annuals. No health problems have been reported feeding free-choice grain.

3. Limit feeding of grain (1% body weight or less) is being used to stocker cattle in the southeast. Animal fat or plain salt mixed with grain has the possibility of acting as intake limitors.

4. The profitability of using energy supplements on winter annual pastures depends primarily upon the relative prices of grains and the value of additional weight.

5. Most studies show that it takes nearly 9.0 lb of grain to produce an extra pound of gain on small grain pastures. Lower levels of grain (less 1% of body weight) may be more advantageous, although this needs further study.

6. Feeding a low protein supplement as a carrier for monensin resulted in significant improvements ($P<.01$) in daily gain in 3 studies.

7. Providing additional protein in the form of soybean meal resulted in no improvement in performance beyond that of a grain supplement.

Areas of Needed Research

1. Although in past studies optimum supplementation responses of stockers grazing winter wheat pastures has occurred with grain-based supplements with no additional benefit being observed with higher levels of CP supplied by soybean meal, it still is not known whether the response is due to the additional energy or to additional microbial protein synthesis which may occur with grain supplements. Due to the highly soluble nature of wheat forage protein, rumen ammonia levels are high. Addition of starch to the rumen should increase microbial protein production. Therefore, research is also needed on the effect of supplements on post-ruminal protein (microbial vs feed protein) and the effect of supplemental starch on rumen ammonia levels and VFA production in steers grazing wheat pasture. Since SBM protein is, itself, quite soluble, studies involving the use of high by-pass protein sources such as corn gluten meal, may provide some useful information. High by-pass protein supplements have proven beneficial in dairy cows in England grazing lush, early spring pastures. But, the protein needs of good lactating dairy cows in early lactation are also much higher than that for growing stocker steers or heifers grazing wheat pasture, and therefore, the liklihood of obtaining a beneficial response from supplementation of high by-pass protein on wheat pasture may be quite remote. Nevertheless, it should be tested.

2. Research is needed on response parameters (animal, ruminal, forage intake and utilization) to varying levels of grain supplementation ranging from very low levels (e.g. 1.0 lb/day) to higher levels

(e.g. 1.5% of body weight) in the same experiment. However, most of the time supplemental feeding of grain has not been economical or has been a breakeven situation at best, if used. Results of different trials suggest that the improved gain (lb/day or %) response (other parameters generally not measured) from grain supplementation tends to be somewhat similar across a range of supplementation levels. However, no single experiment has compared different feeding rates of the same supplement. Data is needed in such studies to quantify the intake and utilization of wheat (or other such pastures) forage with changing supplement levels to assess or quantify changes in carrying capacity, etc. As more grain is fed, cattle gain more up to a point, but forage intake likely decreases in a stepwise manner as grain is substituted for forage. Moreover, utilization may be altered as well. Utilization of both the forage and supplemental grain component needs to be assessed. Data of this type needs to be generated. Numerous studies, reported previously herein, indicate that when low levels of grain are fed, it usually takes about 8 to 9 lb of grain to produce an extra pound of weight gain in stocker calves. While such figures may imply a relatively low level of efficiency for supplemental grain feeding (lb feed/unit gain) compared to that normally expected in a feedlot environment (perhaps 6-7 lb feed/unit gain or less), it must be recognized that the cattle on pasture fed some supplemental grain are gaining at much lower rates <u>with much less dilution of maintenance</u> occurring. If cattle were fed grain in a feedlot situation at the level of daily gain obtained in pasture studies (often 1.0-2.0 lb/day, probably closer to 1.2-1.5 in most research studies), the apparent efficiencies (lb feed/lb gain) would rise above the 6-7 figure, and may indeed approach or be similar to the figures often observed on wheat or pasture programs (because of dilution of maintenance factor). Nevertheless, actual efficiencies need to be assessed. Future New Mexico studies will be looking at the importance of method of grain processing as another factor due to the anticipated high rate of passage on wheat forages. Possibly the type of grain or grain by-product (e.g. wheat middlings) should also be investigated.

3. Utilization parameters for both forage and supplements should be investigated for daily vs less frequent supplementation strategies. For reasons of labor, travel, etc., most producers are interested in less frequent feeding. Methods for self feeding might bear further investigation, and especially as vehicles for incorporating additives such as monensin, poloxalene and the like.

4. As indicated for supplemental grain in item 2, intake, utilization, performance and ruminal response parameters should be measured for different levels of supplemental silage fed to calves on small grain pastures. Different types of silages should also be evaluated.

Literature Cited

Anthony, W.B., C.S. Hoveland, E.L. Mayton and H.E. Burgess. 1971. Rye-ryegrass-yuchi arrowleaf clover for production of slaughter cattle. Auburn University (Ala.) Agr. Exp. Sta. Cir. 182.

Burton, G.W., S.A. Parham, B.L. Southwell and J.L. Stephens. 1949. Winter grazing in Georgia Coastal Plain. G. Agr. Exp. Sta. Bull. 47.

Edwards, R.L., G.C. Skelly, Jr., D.W. Eddy, W.C. Godley, R.F. Wheeler, J.W. Hubbard and H.C. Gilliam, Jr. 1968. A comparison of drylot and supplemented pasture systems for finishing beef cattle. S.C. Agr. Exp. Sta. Bull. 537.

Elder, W.C. 1967. Winter grazing small grains in Oklahoma. Okla. Agr. Exp. Sta. Bull. B-654. pp 10.

Ewing, S.A., Gayle Thompson and Robert Renbarger. 1967. The influence of stilbesterol implants on the performance of calves on wheat pasture or sorghum silage. Okla. Agr. Exp. Sta. MP 79:76.

Godbey, E.G., R.F. Wheeler, D.H. Kropt, W.C. Godley and L.V. Starkey. 1959. Winter forage for fattening steers. S.C. Agr. Exp. Sta. Bull. 469.

Grigsby, M.E. 1982. Supplements for stockers on winter wheat pasture. Clayton Livestock Research Center Field Day Rpt. pp 17.

Harris, R.R., W.B. Anthony, V.L. Brown, J.K. Boseck, H.F. Yates, W.B. Webster and J.E. Barrett, Jr. 1971. Cool-season annual grazing crops for stocker calves. Auburn University (Ala.) Agr. Exp. Sta. Bull. 461.

Horn, G.W., T.L. Mader, S.L. Armbruster and R.R. Frahm. 1981. Effect of monensin on ruminal fermentation, forage intake and weight gains on wheat pasture stocker cattle. J. Anim. Sci. 52:447.

Mader, T.L. and G.W. Horn. 1980. Wheat forage intake and utilization of wheat pasture stockers fed low-quality roughages. Oklahoma Agr. Exp. Sta. Res. Rep. p. 80.

McCormick, W.C., O.M. Hale and B.L. Southwell. 1958. Fattening steers on small grain pastures. Ga. Agr. Exp. Sta. Bull. N.S. 49.

Mills, Rebecca A. 1981. Effect of pasture type, energy supplementation, supplemental protein source, and monensin on stockering and finishing weanling and yearling steers. Master's Thesis. Univ. Ga.

Renbarger, Robert, S.A. Ewing and Dwight Stephens. 1968. Effect of supplemental feed and stilbesterol implants on the performance of heifer calves grazing winter wheat pasture. Okla. Agr. Exp. Sta. MP-80:61.

Utley, Philip R., Robert S. Lowrey and William C. McCormick. 1973. Corn silage and corn silage plus small grain pasture for finishing steers. J. Anim. Sci. 36:423-427.

Utley, P.R. and W.C. McCormick. 1975. Dry and high-moisture corn for finishing steers in drylot or on oat pasture. J. Anim. Sci. 41:495.

Utley, P.R. and W.C. McCormick. 1976. Corn and grain sorghum for finishing steers in drylot or on rye pastures. J. Anim. Sci. 43:1141-1144.

Wise, M.B., E.R. Barrick and T.N. Blamer. 1967. Finishing steers with grain on pasture. N.C. Exp. Sta. Bull. 425.

Worrell, David E. 1977. Performance, carcass traits and consumer acceptance of beef from cattle finished on temporary winter annuals with or without grain. Master's Thesis. Univ. Ga.

Effects of ionophores on grazed forage utilization and their economic value for cattle on wheat pastures.

W.C. Ellis[1], G.W. Horn[2], D. Delaney[3] and K.R. Pond[4]

SUMMARY AND CONCLUSIONS

Results of a number of grazing trials are summarized and indicate the ionophore monensin has significant and major effects on the dynamics of digestion of grazed forages. The direction and magnitude of these effects appear related to 1) the digestibility (OMD) of the forage, 2) the physical capacity of the ruminant to harbor undigested residues and 3) the productive capacity (energy requirement) of the animal. In grazing animals monensin generally reduces the turnover rate of undigested forage residues and thereby increases the digestibility of fiber. Monensin increases intake of medium quality forages (45-65% OMD) apparently by increasing fill of undigested dry matter in the gastrointestinal tract more than it reduces the turnover of such dry matter. Intake of poor quality forages (<45% OMD) is depressed by monensin's effect on reducing turnover of these residues combined with the animals' inability to accomodate further increases in fill of undigested dry matter from such low quality forages. Intake of higher quality forages (>65% OMD) appears to be depressed by monensin. This is suggested to be due to effects of monensin in increasing metabolic efficiency thereby reducing the quantity of forage intake required to meet the animals energy requirement; a requirement which regulates intake of such highly digestible forages. Thus the expected gain response to monensin decreases as the quality of forage consumed increases and as the realized gain approaches the genetic potential for gain by the animal.

Based on the above effects, the economic value of using monensin in wheat pasture stocker programs was evaluated as its effect on dollars returned per head for two situations as follows: (I) Adequate to excess quantities of available forage (OMD $\geq$ 65%) where effects of monensin were to decrease forage intake and have no effect on daily gains of cattle; (II) Inadequate quantities of available forage where effects of monensin were to increase efficiency of forage utilization and increase daily gains of cattle. In situation I the economic advantage of using monensin would result from increasing stocking rate. Use of monensin, at a cost of $.06/head/day, in situation I increased returns by about $3 to $4/head. In situation II, breakeven costs of feeding monensin were about .14, .08 and $.08/head/day where base rates of gain (i.e., rates of gain of cattle not fed monensin) of 1.00, 1.50 and

----

[1,3,4] Professor, graduate assistant and former graduate assistant, respectively. Department of Animal Science, Texas A&M University, College Station, TX 77843.

[2] Professor, Department of Animal Science, Oklahoma State University, Stillwater, OK 74078.

2.00 lb/day, respectively, were increased by .2 lb. Cost of the carrier feed in which monensin is fed and its effect on weight gains is a key consideration in evaluating the economics of feeding monensin to stocker cattle. Feeding monensin with 2 lb of corn ($3.75/bushel) increased profits by about $8 to $10/head. The data base for separation of the effects of monensin as per the above two situations is limited. Additional studies are needed relative to effects of ionophores on forage intake and utilization and daily gains of stocker cattle as influenced by the quantity of available small grains forage.

INTRODUCTION

When added to highly digestible mixed rations in the feedlot, ionophores such as monensin and lasalocid appear to have their major effect by increasing feed efficiency with negligible or small positive effects upon daily gains of cattle. In contrast, monensin substantially increases daily gains by stocker cattle grazing the less digestible warm season pastures which otherwise are capable of promoting daily liveweight gains of 0.4 to 0.7 kg/day (Oliver, 1975 and Rouquette et al., 1980). Effects of ionophores on stocker cattle grazing the more digestible winter wheat/small grain pastures have received less extensive study. This report summarizes a number of grazing studies which suggests a mode of action for ionophores in stocker cattle on wheat pasture and indicate further areas of research needed to more confidently project responses to ionophores and the economics of their use.

REVIEW OF LITERATURE

Digestive Effects: Thirteen grazing trials have been conducted by the Texas Agricultural Experiment Station (Ellis et al., 1981) to study effects of monensin upon intake and digestive utilization of bermudagrass or temperate grass pastures (ryegrass, oats or rescuegrass) by cattle. Monensin (100-300 mg/head/day) was fed in a daily supplement of .45 or .91 kg of grain with the same supplement exclusive of monensin serving as the control.

In these trials, the mean response due to monensin in the supplement appeared to be related to the digestibility (OMD) of the forage. These responses are summarized in figure 1. Results of these studies are interpreted to indicate:

A. Monensin increased OMD an average of 4% in all trials combined. There was a tendency for monensin to have less of an effect or no effect in more highly digestible forages (Fig. 1A).

B. The increased OMD was due to an increased digestibility of fiber (NDF) whose digestibility was inversely related to the turnover of forage residues (Kp) through the animals' gastro-intestinal tract (Fig. 1B).

C. Monensin increased fecal output (FO) by animals grazing forages of 45 to 65% OMD and depressed fecal output from animals grazing forages of greater than 65% OMD or less than 45% OMD (Fig. 1C).

D. Monensin increased fill of undigested dry matter in the gastrointestinal tract (FO/(Kp x 24)) of cattle grazing forages of 45 to 65% OMD and decreased this fill in cattle grazing forages of less than 45% OMD or greater than 65% OMD (Fig. 1D).

E. The increased fecal output from cattle grazing forages of 45-65% OMD appeared to be the result of monensin having a greater effect on increasing fill of undigested organic matter than upon reducing Kp. The decreased fecal output from cattle grazing forages of less than 45% OMD appeared to be the consequence of an inability to increase undigested dry matter fill as OMD further decreased below 45% (Fig. 1E).

F. Intake of forages of 45-65% OMD was increased by monensin apparently as the result of increased undigested matter fill. Intake of forages of less than 45% OMD was decreased by monensin apparently due to effects of monensin reducing Kp without compensating effects on increasing undigested dry matter fill.

The above interpretations are heavily influenced by the predominant warm season forages involved in these trials. With the exceptions of the four temperate forages (trials 4, 9B, 11 and 11B), the OMD of the other forages are all lower than that of the vegetative wheat plant. However projections that monensin would decrease forage intake of wheat pasture having >70% OMD are consistent with results by Horn et al. (1981) and with concepts concerning regulation of meal size and voluntary intake (Forbes, 1981). Intake of highly digestible forages (greater than 65% OMD, Conrad, et al. 1964) is regulated by metabolic rates which at some maximum level constitute the productive capacity or energy requirement of the animal.

When the physical bulk of undigested residues from forages does not limit forage intake, the intake of these forages will be regulated by metabolic rates (energy requirements). Supplementation of such highly digestible forages with monensin would then expectedly reduce forage intake by an amount proportional to the increased metabolic efficiency elicited by monensin. The expected response to monensin then would be analagous to the feedlot situation of reduced feed intake, increased feed efficiency and similar rates of gain.

According to these concepts, monensin would elicit an increased rate of gain whenever energy intake was restricted by any condition such that energy intake was less than that required by the animal. Under such conditions the improved metabolic efficiency of digestible energy utilization due to monensin would then cause an increased gain from this limited forage energy intake. It is generally recognized that intake of forages of less than 65% OMD is limited by the capacity of the gastrointestinal tract to harbor and dispose of undigested residues (Conrad et al., 1964). It appears that monensin may increase this capacity by cattle to harbor and dispose of undigestible residues (fecal output) largely by increasing their ability to harbor undigested residues (UDMF, figure 1D). The effects of monensin in increasing undigested dry matter fill are partially offset by an increased extent of fiber digestion associated with its reduced fractional turnover (Kp, figure 1B).

Others have reported monensin to have no significant effect on fiber digestion (Dinius et al., 1976 and Lemenager et al., 1978; Poos et al., 1979) or a negative effect on fiber digestion (Poos et al., 1979) of forages of less than 55% DMD. Results of a recent study indicate that monensin and lasalocid increase digestibility of fiber of wheat/ryegrass grazed by cattle (Tanner et al., 1984a) and further support the results in figure 1. The results in figure 1B indicate that monensin does not always reduce Kp and on those occasions digestibility of fiber is not decreased. De Jong and Berschauer (1983) recently demonstrated an adaptation response by rumen microorganisms in which the initial depressing effect by monensin on rate of cellulose digestion in vitro was overcome after 28 days. Thus a number of factors could contribute to the different responses in fiber digestion in vivo that have been reported for monensin.

Performance Effects: A number of experiments have been reported comparing liveweight gain responses by cattle to ionophores in a supplement as compared to a similar supplement devoid of ionophores. Results of a number of these studies for cattle grazing ryegrass or small grain pastures are summarized in table 1. At their optimum levels, the two ionophores result in an approximately 15% increase in daily livewight gain when the control animal had liveweight gains for the trial in the range of .54 to .86 kg/hd/d. As earlier discussed, the expected liveweight gain response should decrease as the productive potential (energy requirement) of the animal is approached. This appears to be the case as the response was reduced to an order of 6 to 10% when the trial gain was higher (1.04 kg/hd/d). No response to monensin was observed in one trial (3) when a trial gain of 1.15 kg/hd/d was obtained over 201 d. In this particular trial, there was also no significant difference in the trial carcass gain due to monensin (not included in table 1). Tanner et al. (1984b) reported the ionophores monensin and lasalocid had no significant effect on empty body weight gain of growing heifers grazing ryegrass/wheat pasture.

Results in figure 1 suggest an increased fill of undigested dry matter in the gastrointestinal tract of cattle grazing forages of 45 - 65% OMD. This estimated undigested dry matter fill is less than the total dry matter fill in the gastrointestinal tract and does not include liquid fill. More direct estimates of fill in the reticulorumen (Delaney, 1980) are summarized in table 2. Monensin increased the dry matter in the reticulorumen of cattle in all three trials although this was statistically significant only for the trial involving the less digestible bermuda forage. The trend for monensin to reduce the liquid content of the reticulorumen was not statistically significant (P>.7). Tanner et al. (1984a) have reported that lasalocid, but not monensin, significantly reduced the content of total gastrointestinal water in cattle grazing ryegrass/wheat pastures.

Collectively these results indicate that ionophores have effects on fill which could contribute to the liveweight responses observed.

Economic Value of Feeding Monesin: The budget shown in table 3 served as the "baseline" budget in evaluating the economic value of feeding monensin to wheat pasture stocker cattle. The price structure of the cattle at sale weights is a 5-year average (1977-1981) of the Oklahoma City Market and has been seasonally adjusted. Cattle were purchased in October and sold in March or May. The economic value of feeding monensin to wheat pasture cattle was evaluated as its effect on returns ($) per head for the following two situations as discussed under digestive effects.

Situation		Amount of available forage[a]	Effects of Monensin	
I.	Energy intake of cattle not restricted	Adequate to excess	Decreased forage intake	No effect on daily gain
II.	Energy intake of cattle restricted	Inadequate	Increased efficiency of forage utilization	Increased daily gain

[a] Organic matter digestibility of forage $\geq$65%.

In situation I the economic advantage of feeding monensin would be due to increased stocking rate. Where wheat pasture is rented (e.g., $2.00/cwt/month as used in the "baseline" budget in table 3), variations in stocking rate do not change pasture cost expressed as $/head as shown below.

Pasture cost ($/cwt/month)	Acres of wheat	Stocking rate (acres/head)	Number of 400 lb steers per 160 acres	Pasture cost ($/head)
2.00	160	2	80	32
2.00	160	1.8	88.89	32

Effects of feeding monensin to cattle on wheat pasture (situation I) on returns ($/head) are shown in table 4. Cost of pasture was decreased 10% for both a rental situation and where pasture cost was placed at $40/head to allow for a 10% increase in stocking rate by feeding monensin. Breakeven cost of feeding monensin versus not feeding monensin were about 6¢/head/day in evaluating its economic value in situation I. In the rental situation, total dollars due the leasor would be the same. Feeding monensin in situation I increased returns by about $3 to $4/head (table 4).

Effects of feeding monensin to cattle on wheat pasture (situation II) on returns ($/head) are shown in table 5. Monensin itself is inexpensive. However, cost of the carrier in which monensin is fed and its effect on weight gains must be considered in evaluating the economics of feeding monensin to stocker cattle. Where the carrier feed did not increase daily gains beyond the .2 lb expected in response to monensin alone (i.e., first 5 lines in body of table 5), breakeven costs of feeding monensin versus not feeding monensin were about 14, 8 and 8¢/head/day at base rates of gain of 1.00, 1.50 and 2.00 lb/day, respectively. Feeding monensin with 2 lb of corn and assuming that daily gains would be increased by .09 lb/lb of corn fed (Elder, 1967 and Gulbransen, 1976) increased profits by about $8 to $10/head. Use of a mineral supplement containing some corn as the carrier feed, which could be self-fed at a target intake level of .50 lb/head/day in whirl-wind type mineral feeders, increased profits by about $5 to $12/head depending on base rates of gain of the cattle.

AREAS OF NEEDED RESEARCH

1. Additional studies are needed relative to effects of ionophores on forage intake and utilization and daily gains of stocker cattle as influenced by the quantity of available forage.

2. Effects of ionophores upon the quantity of digesta within the gastrointestinal tract needs clarification, especially as it relates to empty body weight gain. Such research should consider possible interactions with forage quality and quantity and the productive potential of the animal.

LITERATURE CITED

Byers, F.M., J.W. Tanner, R. May, L.M. Schake, W.C. Ellis and C.R. Long. 1982. Ionophore effects on growth rates of grazing stocker cattle. Beef Cattle Research in Texas, 87-89.

Conrad, H.R., A.D. Pratt and J.W. Hibbs. 1964. Regulation of feed intake in dairy cows. 1. Changes in importance of physical factors with increasing digestibility. J. Dairy Sci. 47:54-61.

De Jong, A. and F. Berschauer. 1983. Adaptation effects of ionophores on rumen fermentation. S. Afr. J. Anim. Sci. 13(1):67-70.

Delaney, David Scott. 1980. Effects of monensin on intake, digestibility and turnover of organic matter and bacterial protein in grazing cattle. M.S. Thesis, Texas A&M University.

Dinius, D.A., M.E. Simpson and P.B. Marsh. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. J. Anim. Sci. 42:229-234.

Elder, W.C. 1967. Winter grazing small grains in Oklahoma. Oklahoma Agr. Esp. Sta. Bull. 13-654.

Ellis, W.C., G.T. Schelling, K.R. Pond and D.S. Delaney. 1981. Effects of monensin upon intake and utilization of grazed forages and interaction with forage digestibility. Proc. 16 Conf. on Rumen Function.

Forbes, J.M. 1981. A model of the short term control of feeding in the ruminant: Effect of changing animal or feed characteristics. Appetite 1:21-41.

Gulbransen, B. 1976. Response to supplementary sorghum grain by cattle grazing oats. Aust. J. Exp. Agr. and Anim. Husb. 16:646.

Horn, G.W. 1983. Personnal Communication.

Horn, G.W., T.L. Mader, S.L. Armbruster and R.R. Frahm. 1981. Effect of monensin on ruminal fermentation, forage intake and weight gains of wheat pasture stocker cattle. J. Anim. Sci. 52:447

Lemenager, R.P., F.N. Owens, B.J. Shockey, K.S. Lusby and R. Totusek. 1978. Monensin effects on rumen turnover rate, twenty-four hour VFA pattern, nitrogen components and cellulose disappearance. J. Anim. Sci. 47:255.

Mills, Rebecca A., R.S. Lowrey, H.C. McCampbell and Grady V. Calvert. 1982. Forage type, energy level and monensin for stocker and/or finishing steers. J. Anim. Sci. 55:72 (Supplement 1).

Oliver, W.M. 1975. Effect of monensin on gains of steers grazed on Coastal bermudagrass. J. Anim. Sci. 41:999-1001.

Poos, M.I., T.L. Hanson and T.J. Klopfenstein. 1979. Monensin effects on diet digestibility, ruminal protein, bypass and microbial protein synthesis. J. Anim. Sci. 48:1516

Rouquette, F.M., Jr., J.L. Griffin, R.B. Randel and L.H. Carroll. 1980. Effect of monensin on gain and forage utilization by calves grazing bermudagrass. J. Anim. Sci. 51:521-525.

Tanner, J.W., F.M. Byers, W.C. Ellis, G.T. Schelling and L.W. Greene. 1984a. Effect of two ionophores on digestibility, gastrointestinal fill and utilization of winter pasture by grazing heifers. J. Anim. Sci. (Supplement 1, in press).

Tanner, J.W., F.M. Byers, W.C. Ellis, G.T. Schelling and L.W. Greene. 1984b. Influence of two ionophores on rate and composition of gain of heifers grazing small grain winter pastures. J. Anim. Sci. (Supplement 1, In Press).

Table 1. AVERAGE DAILY GAIN RESPONSES (%) TO VARIED LEVELS OF TWO IONOPHORES IN 1 KG OR LESS OF SUPPLEMENT ON SMALL GRAIN PASTURES

Study		Control ADG,	Response, % Over Supplemented Control							
			Monensin mg/hd/d			Lasalocid mg/hd/d				
No.	D.	kg	50	100	200	50	100	200	300	400
1	112	.54	-	15**	-	-	-	-	-	-
1	113	.54	-	12**	-	-	-	-	-	-
2	64	1.04	-	7.8	6.1	-	-	10.4	-	6.0
2	84	.86	-	-	-	20.2*	13.3	13.3	16.0	-
3	201	1.15	-	7.8	-	-	-	-	-	-
4	97	.79	-	-	-	-	-1.1	13.7	-	-

*=P<.05
**=P<.01

Study 1. Horn et al., 1981.
Study 2. Byers et al., 1982.
Study 3. Mills et al., 1982.
Study 4. Horn et al., 1983.

TABLE 2. EFFECTS OF MONENSIN ON CONTENTS OF RETICULORUMEN (DELANEY ET AL., 1980)

Trial	Forage	OMD of	Dry Matter		Liquid	
		Con.[a]	Con.[a]	Mon.[b]	Con.[a]	Mon.[b]
			----- kg/100 kg body wt. -------			
9B	Rescue	63	1.54	1.69	2.38	2.33
10B	Bermuda	48	2.18	2.50*	3.71	3.53
11B	Oats	66	2.62	2.92	-	-

*P<.05
[a] Control
[b] Monensin

Table 3. Baseline budget for evaluating the economic value of monensin for wheat pasture stocker cattle.

PASTURE GAIN ANALYSIS;
WITH PROFIT OR LOSS

	(INPUTS)		
CATTLE COST $ PER CWT.	73	CATTLE SELLING PRICE ---->>>>>	
PURCHASE WEIGHT LBS.	400		
DAYS PASTURED	120		
	(INPUTS)	TOTAL COST	COST /DAY
EQUITY IN $ PER HEAD	0.00		
CATTLE INTEREST (RATE) %	13.50	13.14	0.11
PASTURE COST $ / CWT / MO.	2.00	32.00	0.27
MEDICAL COST / HEAD ($)	7.00	7.00	0.06
DEATH LOSS (%)	1.00	2.99	0.02
LABOR COST ($) PER HEAD DAY	0.05	6.00	0.05
MARKETING COST PER HEAD ($)	0.00	0.00	0.00
FIXED FEED COST ($) HEAD	0.00	0.00	0.00
*IMPLANT (S), COST ($)	0.00*	0.00	0.00
*IMPLANTS 0=NONE, 1=IMPLANT	0*		
*RUMENSIN 0=NO, 1= RUMENSIN	0*		
*FEED 0=ENERGY, 1=PROTEIN	0*		
*POUNDS PER HEAD PER DAY	0.00*		
*FEED COST PER 100 LBS.	0.00*	0.00	0.00
OPERATING CAPITAL INTEREST	13.50	1.08	0.01
	TOTAL $	62.21	0.52

PRICE STRUCTURE AT SALE WTS

WEIGHT	$ PER CWT
300	75.00
350	74.00
400	73.00
450	71.00
500	70.00
550	69.00
600	68.00
650	67.00
700	65.00
750	64.00
800	63.00
850	62.00
900	61.00

COST OF GAIN DEPENDING ON RATE OF GAIN

DAILY GAIN #		COST OF GAIN		SALE WEIGHT		BREAK EVEN $		PRICE OF CATTLE		PROFIT OR LOSS	
BASE	*EST.	BASE	*EST.	BASE	*EST.	BASE	*EST.	BASE	*EST	BASE	*EST
0.50	0.50	1.04	1.04	460.00	460.00	77.00	77.00	71.00	71.00	-27.61	-27.61
0.75	0.75	0.69	0.69	490.00	490.00	72.29	72.29	71.00	71.00	-6.31	-6.31
1.00	1.00	0.52	0.52	520.00	520.00	68.12	68.12	70.00	70.00	9.79	9.79
1.25	1.25	0.41	0.41	550.00	550.00	64.40	64.40	69.00	69.00	25.29	25.29
1.50	1.50	0.35	0.35	580.00	580.00	61.07	61.07	69.00	69.00	45.99	45.99
1.75	1.75	0.30	0.30	610.00	610.00	58.07	58.07	68.00	68.00	60.59	60.59
2.00	2.00	0.26	0.26	640.00	640.00	55.35	55.35	68.00	68.00	80.99	80.99
2.25	2.25	0.23	0.23	670.00	670.00	52.87	52.87	67.00	67.00	94.69	94.69

Table 4. ECONOMIC VALUE OF MONENSIN[a] IN SITUATION I[b].

Pasture Cost		Daily Gains (lb) of Cattle		
$/cwt/month	$/head	1.00	1.50	2.00
		-- Increased Return ($/head) --		
2.00	32.00[c]			
1.80	28.80[c]	$3.27	$3.27	$3.27
	40.00			
	36.00	$4.09	$4.09	$4.09

[a] Monensin cost = 6¢/head/day.

[b] Adequate to excess available forage. Monensin (1) decreasing forage intake (and therefore stocking rate increased 10%) and (2) having no effect on daily gains of stockers.

[c] 120 days.

Table 5. Economic value[a] of monensin in a wheat pasture stocker program (situation II)[b].

Monensin cost (¢/head/day)	Base ADG (lb)[c]		
	1.00	1.50	2.00
	----ADG (lb) of cattle fed monensin----		
	1.20	1.70	2.20
3	$13.12	$6.84	$6.00
6	9.44	3.16	2.32
9	5.76	- .52	-1.36
12	2.08	-4.20	-5.04
15	- 1.60	-7.88	-8.72
	----ADG (lb) of cattle fed monensin----		
	1.38	1.88	2.38
13.4[d]	$ 9.82	$8.77	$7.71
	----ADG (lb) of cattle fed monensin----		
	1.25	1.75	2.25
7[e]	$11.99	$5.60	$4.71

[a] Increased profit or loss ($/head) as compared with returns of cattle not fed monensin.

[b] Inadequate amounts of available forage. Monensin increased "base ADG's" by .2 lb.

[c] Average daily gains of cattle not fed monensin.

[d] Carrier feed = 2 lb corn ($3.75/bushel). Corn and monensin increased "base ADG's" by .18 (i.e., .09 lb/lb of corn fed) and .20 lb, respectively.

[e] Carrier feed = .50 lb supplement ($280/ton). Supplement and monensin increased "base ADG's" by .05 (i.e., .09 lb/lb of supplement fed) and .20 lb, respectively.

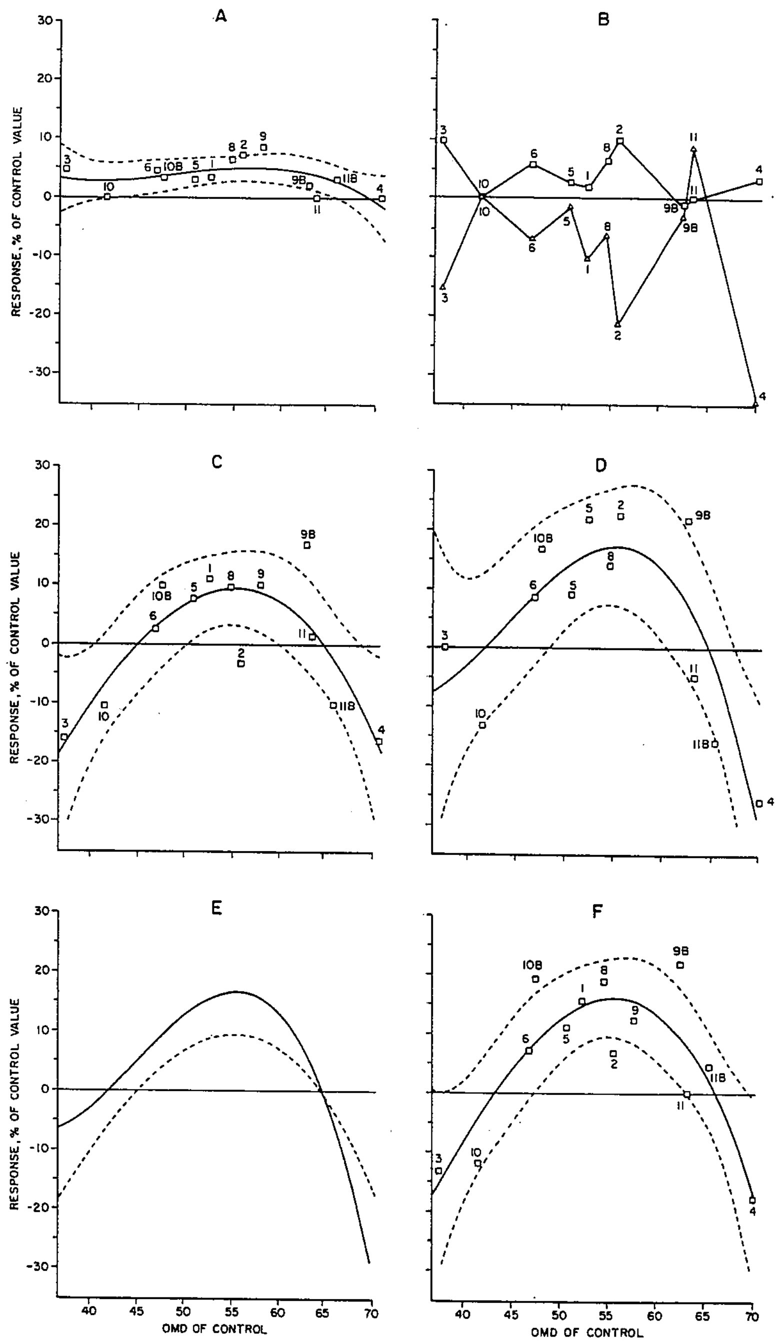


Figure 1. Response to monensin as a function of digestibility of organic matter (OMD) of control forage. A. Digestibility of organic matter (OMD). B. Digestibility of NDF (□) and Kp (Δ). C. Fecal output. D. Undigested dry matter fill (UDMF). E. Undigested dry matter fill (——) and fecal output (----). F. Forage intake. Confidence limits =95%.

USE OF IMPLANTS OF ANABOLIC COMPOUNDS FOR GROWING CATTLE ON SMALL GRAIN PASTURES

S. B. Laudert, G. W. Horn and J. W. McNeill

Animal Sciences and Industry, Kansas State University;
Animal Science Department, Oklahoma State University; and
Texas A&M University Research and Extension Center, Amarillo, Texas

Summary and Conclusions

Use of implants containing anabolic compounds dramatically increases rate of weight gain of stocker cattle grazing small grain pastures. Daily gains of steers were increased 19%, .13 kg/day in 10 trials involving 1150 cattle. Gains of heifers were increased 13.6%, .09 kg/day in 7 trials conducted with 645 cattle.

The number of trials that have evaluated the effectiveness of reimplanting stocker cattle grazing small grain pastures is limited. Daily gains of reimplanted steers were 16.5% greater than nonimplanted cattle. The percentage improvement in gains of reimplanted steers compared with steers that received a single implant ranged from 0 to 4.4%. Data relative to reimplanting heifers on small grain pastures were not found. Factors that affect the response of stocker cattle on small grain pastures to reimplanting need to be identified.

Improvements in daily gains of stocker cattle of 15 to 20% by use of growth promoting implants increased profits of cattle that received one implant (120-day grazing period) or two implants (180-day grazing period) by $9 to $23/head and $11 to $29/head, respectively, depending on base rates of gains of nonimplanted cattle. Potential effects of anabolic compounds on composition of carcass weight gains and fleshiness of cattle coming off small grain grazing programs need further study with regard to sale prices and subsequent performance of the cattle.

Introduction

Weight gain is a key factor affecting the profitability of stocker cattle programs. Gains of cattle grazing wheat or other small grain pastures can be affected by cattle type, health, management, weather conditions, and availability of forage. Implants of anabolic compounds have been used to improve cattle performance for over 25 years. Consistent positive responses have been reported for all phases of beef cattle production in hundreds of research reports. However, somewhat limited data are available on the use of implants in stocker cattle grazing wheat or other small grain pastures. Effects of implants on rate of gain of stocker cattle on wheat or other small grain pastures and the economic value of implants are discussed in this paper. Five implant products (table 1) are currently approved for use in growing beef cattle. However, it was not an objective of this paper to compare implant products per se with regard to their effects on performance of stocker cattle on wheat pasture.

Review of Literature and Economic Value of Implants

Most of the trials reported to date relative to effects of implants on weight gains of stocker cattle on wheat pasture have used Ralgro and/or Synovex. Weight gains of steers and heifers that were not implanted or received a single implant are shown in table 2. A total of 1150 cattle were used in the 10 trials with steers; average days on pasture was 147. Average daily gain of nonimplanted, control steers was .69 kg (table 2) and daily gain of implanted steers was increased by 19%. Results of 7 trials that involved 645 heifers during an average grazing period of 129 days are shown in the bottom portion of table 2. Average daily gain of nonimplanted heifers was .67 kg; gains of implanted heifers were increased 13.6%.

Data from trials that evaluated reimplanting steers grazing wheat or other small grain pastures are shown in table 3. Because the response of steers to Ralgro and Synovex-S implants (table 2) was similar, the response to these implants was averaged for comparison of single and reimplant treatments in table 3. The reimplant trials averaged 185 days in length with about 85 days of grazing following reimplanting. Daily gains of reimplanted steers were 16.5% greater than nonimplanted cattle. The improvement in gains of reimplanted cattle compared with cattle that received a single implant ranged from 0 to 4.4% and was smaller than expected. The magnitude of weight gains of stocker cattle prior to reimplanting and timing to ensure reimplanting occurs close to onset of rapid spring growth of wheat forage may be critical factors that affect the response of stocker cattle to reimplants. Data relative to reimplanting heifers on small grain pastures were not found.

The budget shown in table 4 served as the "baseline" budget for evaluating the economic value of implants. The price structure of cattle at sale weights is a seasonally adjusted, 5-year (1978-82) average of the Oklahoma City Market. Cattle were purchased in October and sold in March or May. Additional inputs into the "baseline" budget were made as follows in evaluating the value of implanting wheat pasture stocker cattle:

Daily gains were increased 15 and 20% for 120 and 180 days.

Costs of implanting were $1.50 (single implant) and $3.00/head if cattle were reimplanted.

Work of Byers (1981 and 1982) and Lemieux et al. (1983) has shown that the anabolic compounds, diethylstilbestrol, estradiol 17B plus progesterone and zeranol, modify partitioning of energy from fat to protein deposition in growing-finishing cattle. Lemieux et al. (1983) fed cattle to final empty body weights of about 463 kg on 3 diets that contained sorghum grain silage and reconstituted grain sorghum in proportions (dry basis) of 85:0, 40:50 and 5:89. Empty body protein content was increased from 16.6 to 17.2% by implanting the cattle with anabolic compounds. Empty body fat content of the cattle was decreased from 26.1 to 23.2% by anabolic compounds.

Potential effects of anabolic compounds on increasing sale prices by decreasing fleshiness of stocker cattle coming off small grain grazing programs appear great. However, because of absence of data relative to sale prices of implanted versus nonimplanted wheat pasture stocker cattle, the price structure of cattle at sale weights in the baseline budget (table 4) was not changed in evaluating the economic value of implants.

Estimates of the value of implants in a wheat pasture stocker program, expressed as increased profit ($/head) as compared with nonimplanted cattle, are shown in table 5. Profits of cattle that received a single implant for a 120-day grazing period were increased by about $9 to $23 per head depending on base rates of gain (i.e., daily gains of nonimplanted cattle). Reimplanting increased profits of cattle grazing wheat pasture for 180 days by about $11 to $29 per head. These values reaffirm the large net return of the practice of implanting stocker cattle.

Areas of Needed Research

1. Evaluate further the effectiveness of the practice of reimplanting stocker cattle on small grain pastures.

2. Identify factors that affect weight gains of stocker cattle on small grain pastures in response to reimplanting.

3. Evaluate the effect of anabolic compounds on composition of growth of stocker cattle on small grain pastures and their potential effects on (A) sale prices of the cattle and (B) subsequent performance of the cattle.

Literature Cited

1. Apple, Ken. 1983. Oklahoma State University. Unpublished data.

2. Byers, Floyd M. 1981. Potentiating protein growth in cattle. Fed. Proc. 40(Part II):876 (Abstr.).

3. Byers, Floyd M. 1982. Nutritional factors affecting growth of muscle and adipose tissue in ruminants. Fed. Proc. 41:2562.

4. Crider, M. C. 1983. University of Georgia. Unpublished data.

5. Croix, Alfred. 1978. Denton County Agricultural Demonstration handbook. Texas A&M University.

6. Herd, D., R. Pinner, T. Lockany, J. Spitzer and R. Leps. 1978. Implant demonstration with stocker steers. Falls County Agricultural Demonstration Handbook. Texas A&M University.

7. Horn, G. W., S. L. Armbruster, M. L. Scott and V. L. Stevens. 1978. Effect of monensin on forage intake and weight gains of wheat pasture stockers. Anim. Sci. Res. Rep. MP-103. Okla. Agr. Exp. Sta. p. 11.

8. Koers, W. C., C. Parrott, R. H. Klett and L. B. Sherrod. 1974. Implant systems for growing-finishing steers. Texas Beef Conference Proc.

9. Laudert, S. and R. Nelson. 1983. Effect of Synovex-H and Ralgro implants on weight gain of heifers grazing wheat pasture. Kansas State University Cattlemen's Day '83, Agric. Exp. Sta. Rep.of Prog. 427. p. 103.

10. Lemieux, P. G., F. M. Byers, G. T. Schelling, G. C. Smith, L. M. Schake and T. R. Dutson. 1983. Anabolic effects on rate of protein and fat deposition and energy retention in cattle fed forage and grain diets. Proceedings American Society of Animal Science. Western Section. 33:312.

11. Leps, R. E., J. A. Jones and L. Boleman. 1983. Texas A&M University. Unpublished Data.

12. McNeill, J. W. 1977. Effect of implants on gain of heifers on graze-out wheat. Randall County Agricultural Demonstration Handbook. Texas A&M University.

13. McNeill, J. W. 1983. Effect of implants on performance of steers grazing winter pasture. Hansford County Agricultural Demonstration Handbook. Texas A&M University.

14. Scott, Melford. 1982. Oklahoma State University. Unpublished Data.

15. Smithson,L. J., E. G. Morrison, N. C. Edwards, Jr. and H. W. Essig. 1977. Growth stimulants for steers and heifers grazing winter pasture. Miss. Agri. and For. Exp. Sta. Res. Rep. Vol. 3. No. 6.

16. Smithson, L. J., E. G. Morrison, N. C. Edwards, Jr. and H. W. Essig. 1982. Growth stimulants for steers grazing winter pasture. Miss. Agr. and For. Exp. Sta. Res. Rep. Vol. 7. No. 15.

Table 1. Implants currently approved for use in beef cattle.

Implants	Active compound(s)	Approved usage
Compudose[a]	Estradiol-17B	Steers from birth to slaughter
Ralgro[b]	Zeranol	Steers and heifers from birth to slaughter
STEER-oid[c]	Estradiol and Progesterone	Steers from 182 kg to slaughter
Synovex-H[d]	Estradiol and Testosterone	Heifers from 182 kg to slaughter
Synovex-S[d]	Estradiol and Progesterone	Steers from 182 kg to slaughter

[a]Elanco Products Company.
[b]International Minerals and Chemical Corporation.
[c]Anchor Laboratories, Inc.
[d]Syntex Agribusiness, Inc.

Table 2. Summary of implant trials with steers and heifers receiving single implants while grazing small grain pasture.

Source	Trial Length	Initial weight, kg	Head/ treat	Average daily gain, kg			
				Control	Ralgro	Synovex	Compudose
Steers							
4	98	241	20	0.71	0.86	0.80	0.85
11	161	195	50	0.95	1.03	1.10	1.06
13	135	205	29	0.35	0.44	0.49	0.46
16	179	198	30	0.66	0.77	0.78	----
14	90	179	12	0.67	0.81	0.83	----
5	111	203	50	0.86	0.95	0.92	----
6	177	164	40	0.82	0.89	0.90	----
15	198	145	44	0.74	0.77	0.79	----
15	198	250	38	0.59	0.93	0.95	----
8	124	181	37	0.59	0.87	0.65	----
Heifers							
9	138	189	45	0.50	0.56	0.59	
14	128	179	33	0.68	0.70	0.76	
14	128	174	25	0.81	0.85	0.87	
14	128	175	10	0.85	0.91	0.90	
15	198	147	36	0.66	0.70	0.72	
12	61	222	36	0.92	1.38	1.05	
7	120	163	30	0.26	0.30	0.34	

Table 3. Summary of implant trials with steers receiving single or multiple implants of Ralgro or Synovex or a single Compudose implant while grazing small grain pasture.

Source	Trial length	Reimplant day	Initial wt., kg	Average daily gain, kg			
				Control	Single[a]	Reimplant[a]	Compudose
11	161	90	195	0.95	1.06	1.09	1.06
13	207	135	205	0.59	----	0.69	0.65
1	199	93	211	----	0.66	0.66	0.67
16	179	85	198	0.66	0.78	0.79	----
6	177	97	164	0.82	0.90	0.94	----

[a]Average of Ralgro and Synovex treatment groups.

Table 5. Economic value[a] of implants in wheat pasture stocker programs.

Number of implants	Response to implant(s)[b]	Days on pasture[c]	Base[d] ADG, kg(lb)		
			.45 (1.00)	.68 (1.50)	.91 (2.00)
			-Increased profit, $/head-		
One	15%	120	8.80	13.01	16.78
One	20%	120	12.15	17.81	22.78
Two	15%	180	11.41	15.18	21.53
Two	20%	180	16.21	23.38	29.25

[a]Increased profit ($/head) as compared with non-implanted cattle.
[b]Percentage increase in daily gains due to implanting.
[c]November 15 to March 15 (120 days); November 15 to May 15 (180 days).
[d]Average daily gains of non-implanted cattle.

Table 4. "Baseline" budget for evaluating the economic value of implants.

PASTURE GAIN ANALYSIS;
WITH PROFIT OR LOSS

	(INPUTS)		
CATTLE COST $ PER CWT.	73	CATTLE SELLING PRICE ---->>>>>	
PURCHASE WEIGHT LBS.	400		
DAYS PASTURED	120		
	(INPUTS)	TOTAL COST	COST /DAY
EQUITY IN $ PER HEAD	0.00		
CATTLE INTEREST (RATE) %	13.50	13.14	0.11
PASTURE COST $ / CWT / MO.	2.00	32.00	0.27
MEDICAL COST / HEAD ($)	7.00	7.00	0.06
DEATH LOSS (%)	1.00	2.99	0.02
LABOR COST ($) PER HEAD DAY	0.05	6.00	0.05
MARKETING COST PER HEAD ($)	0.00	0.00	0.00
FIXED FEED COST ($) HEAD	0.00	0.00	0.00
*IMPLANT (S), COST ($)	0.00*	0.00	0.00
*IMPLANTS 0=NONE, 1=IMPLANT	0*		
*RUMENSIN 0=NO, 1= RUMENSIN	0*		
*FEED 0=ENERGY, 1=PROTEIN	0*		
*POUNDS PER HEAD PER DAY	0.00*		
*FEED COST PER 100 LBS.	0.00*	0.00	0.00
OPERATING CAPITAL INTEREST	13.50	1.08	0.01
	TOTAL $	62.21	0.52

PRICE STRUCTURE AT SALE WTS

WEIGHT	$ PER CWT
300	75.00
350	74.00
400	73.00
450	71.00
500	70.00
550	69.00
600	68.00
650	67.00
700	65.00
750	64.00
800	63.00
850	62.00
900	61.00

COST OF GAIN DEPENDING ON RATE OF GAIN

DAILY GAIN #		COST OF GAIN		SALE WEIGHT		BREAK EVEN $		PRICE OF CATTLE		PROFIT OR LOSS	
BASE	*EST.	BASE	*EST.	BASE	*EST.	BASE	*EST.	BASE	*EST	BASE	*EST
0.50	0.50	1.04	1.04	460.00	460.00	77.00	77.00	71.00	71.00	-27.61	-27.61
0.75	0.75	0.69	0.69	490.00	490.00	72.29	72.29	71.00	71.00	-6.31	-6.31
1.00	1.00	0.52	0.52	520.00	520.00	68.12	68.12	70.00	70.00	9.79	9.79
1.25	1.25	0.41	0.41	550.00	550.00	64.40	64.40	69.00	69.00	25.29	25.29
1.50	1.50	0.35	0.35	580.00	580.00	61.07	61.07	69.00	69.00	45.99	45.99
1.75	1.75	0.30	0.30	610.00	610.00	58.07	58.07	68.00	68.00	60.59	60.59
2.00	2.00	0.26	0.26	640.00	640.00	55.35	55.35	68.00	68.00	80.99	80.99
2.25	2.25	0.23	0.23	670.00	670.00	52.87	52.87	67.00	67.00	94.69	94.69

FEEDING LOW-QUALITY ROUGHAGES TO STOCKER CATTLE ON WHEAT PASTURE

G. W. Horn[1], T. L. Mader[2], W. A. Phillips[3] and A. B. Johnson[4]

Introduction

Wheat pasture stocker cattle are frequently given ad libitum access to low quality roughages (LQR) in the form of (1) grazing adjacent stalk fields or pastures of dormant grass or (2) feeding large bales of wheat straw (WS), sorghum-sudan hay (SS) or other LQR on wheat pasture. Producers frequently voice the opinion that cattle consume .9 to 1.4 kg LQR daily and that the LQR (1) slows the rate of passage of "washy" wheat forage and, thereby, improves its utilization and (2) reduces the incidence of bloat. A very important question relative to the feeding of LQR to wheat pasture stockers is what effect LQR have on wheat forage intake and stocker weight gains. Intakes of .9 to 1.4 kg of straw dry matter per day, if substituted for wheat forage, could decrease stocker gains by as much as .21 kg/day as indicated in the table 1.

Table 1. Effect of wheat straw consumption on calculated[a] daily weight gains of wheat pasture stockers.

	All wheat forage	Wheat forage + .9 kg straw	Wheat forage + 1.4 kg straw
Daily gains, kg	.96	.82	.75
Change from "all wheat forage", kg	---	.14	.21

[a]Calculated for 200 kg steer with a total dry matter intake (wheat forage alone or wheat forage plus straw) of 3% of body weight.

The following net energy (NE) densities (Mcal/kg DM) were used:

	$NE_{maintenance}$	NE_{gain}
Wheat forage	1.51	0.92
Wheat straw	1.03	0.19

[1]Animal Science Department, Oklahoma State University, Stillwater.

[2]University of Nebraska, Northeast Station, Concord.

[3]USDA/ARS, El Reno, OK.

[4]Moormans, 1828 Koster, Garden City, KS.

Effects of feeding LQR to stocker cattle on wheat pasture on cattle performance, the incidence and severity of bloat, and wheat forage intake and utilization are discussed in this paper. The concept of using grass hays to stretch available wheat forage supplies in a "limit grazing" situation is discussed by Altom and Schmedt in the paper, "Limit Grazing of Small Grain Pastures", of this proceedings.

Review of Literature

Grazing Wheat Pasture Stocker Cattle on Stalk Fields

Daily gains of steer calves grazed on wheat pasture and an adjacent milo stalk field were decreased by .13 kg in studies conducted by Davis et al. (1973). However, stocking density on wheat pasture was increased from 1 steer/4.09 acres to 1 steer/3.18 acres of wheat pasture for steers having access to the milo stalk field. Johnson et al. (1983) reported results of a study in which steers and heifers grazed wheat pasture with and without access to milo stubble at stocking densities (acres wheat:acres stubble per head) of 3:0, 3:1 and 2:1. Daily gains of cattle of the 3:0 and 3:1 stocking densities were similar (i.e., .89 and .98 kg). Gains of cattle that had access to 2:1 acres of wheat:milo per head were decreased to .72 kg/day. Total gain per acre of wheat and milo decreased as stocking density on wheat increased and cattle were given access to 1 acre of milo stubble, whereas total gain per acre of wheat increased as stocking density on wheat increased. These studies indicate that giving wheat pasture stocker cattle access to some milo stubble does not increase cattle performance, and that daily gains of cattle are rapidly decreased as one attempts to stretch wheat pasture by giving cattle access to grazing on milo stalks.

Feeding Low-Quality Roughages (LQR) on Wheat Pasture

Effects on Cattle Performance and Bloat. Mader et al. (1983) conducted a 3 year study to evaluate effects of feeding LQR on live and carcass weight gains and the incidence and severity of bloat of stocker cattle grazed on wheat pasture. One hundred eighty-five (185) steer calves grazed clean-tilled wheat pasture and were either fed no LQR or had ad libitum access to wheat straw (WS) or sorghum-sudan hay (SS). Weigh dates for the steers were set subjectively to coincide with major changes in forage growing conditions and wheat forage quality and(or) maturity. Mean weight gains were calculated for the following four periods and corresponding dates (averaged across years):

Period I: Fall grazing period (November 23 to January 11)
Period II: Winter grazing period (January 12 to February 20)
Period III: Period of lush spring growth of wheat forage (February 21 to March 24)
Period IV: Period of advancing forage maturity and declining quality (March 25 to April 27)

Data were obtained for Period IV only in the second and third years of the study. The third year of the study was limited to Period IV because of very droughty summer and fall conditions, which resulted in a lack of wheat forage during the usual wheat pasture grazing season. Carcass weight gains were measured in 1978 to 1979 and 1979 to 1980, and were calculated from the mean dressing percentages of initial slaughter groups of four steers and final slaughter groups of three steers randomly selected from each treatment group. Intakes of WS and SS were measured every 2 wk by weighing portable feeders and unconsumed LQR to the nearest .45 kg on platform scales.

Samples of available wheat forage were collected by hand-clipping at 2- to 4-wk intervals throughout the study. Mean dry matter (DM), crude protein and acid-detergent fiber (ADF) content (percentage of DM) of available wheat forage averaged across years ranged, respectively, from 23.8 to 33.0, 19.8 to 26.4 and 21.5 to 27.7. Consumption of LQR by steers is shown graphically with DM content and IVDMD of available wheat forage of the first and second years of the study in figures 1 and 2. Because of snow and(or) ice cover of wheat forage, alfalfa hay was fed to all groups of steers for 8 and 22 days, respectivley, during Periods I and II of the first year of the study. The sharp increase in intake of WS and SS at the beginning of Period II of the first year was due to the snow and(or) ice cover of wheat forage. Consumption of WS tended to decline over the usual wheat pasture grazing season (i.e., Periods I through III) but increased slightly in Period IV. This increase was due to the greater than average intake of WS (i.e, .142 vs .088 kg) by steers that grazed wheat pasture during Period IV only of the third year of the study. Consumption of SS peaked in Periods II and III and declined in Period IV. Mean intakes of WS and SS during Periods I through III were .100 and .247 kg DM$\cdot$head$^{-1}\cdot$d^{-1}, respectively. McMillen and Langham (1942) reported that steers given free choice access to sumac cane fodder (Sorghum bicolor) on wheat pasture consumed .41 kg (as-fed) $\cdot$head$^{-1}\cdot$d^{-1}. However, there were only five steers per treatment and the stocking density on wheat pasture of 6.2 steers/ha was much greater than that of the present study, and the procedure of feeding and measuring fodder intake was not stated. Live and carcass weight gains of steers during periods I through III (i.e., November 23 to March 24) were not influenced (P>.05) by treatments.

Bloat was observed only during the last 2 wk of Period III of the first year. The incidence (steer days of bloat) and severity (bloat score) of control, WS- and SS-fed steers were 9.5 and 1.2, .5 and .5 and 2.0 and 1.0, and were not different (P>.05) among treatments. Meyer et al. (1956) and Hull et al. (1957) reported that feeding 1.4 to 2.3 kg$\cdot$head$^{-1}\cdot$d^{-1} of either oat hay or sudangrass hay "effectively controlled" bloat of steers grazing the young, lush regrowth of alfalfa. No data relative to the incidence and severity of bloat were reported by these workers. Similarly, Colvin et al. (1958a) found that an overnight feeding of 5.5 kg of oat hay reduced the incidence and severity of acute legume bloat of cows. However, Cole and Kleiber (1945) reported that 3.2 kg of sudan hay fed 2 h before pasturing alfalfa was ineffective in preventing bloat of cows, but that 7.7 kg of hay completely prevented bloat. Results of other studies suggest that LQR may reduce the incidence of bloat of cattle by (1) maintaining or strengthening ruminal motility (Colvin et al., 1958c; Colvin and Daniels, 1965; Colvin et al., 1978) and(or) (2) increasing eructation efficiency (Colvin et al., 1958b). Oat hay was fed to cows at levels of 3.1 kg and .75 kg/100 kg of body weight, respectively, in the studies of Colvin et al. (1978) and Colvin et al. (1958b). Clark and Quin (1945), in attempting to explain the results of Cole et al. (1943), suggested that roughages reduce bloat by mechanically preventing the formation of a frothy glutinous mass within the rumen.

The mean intake of LQR in the above studies, excluding that of Cole and Kleiber (1945), was about 3.2 $kg \cdot head^{-1} \cdot d^{-1}$ or 37.5 g/kg of metabolic body weight ($BW^{.75}_{kg}$), and is about 21- and 8-fold greater than the mean intake of WS (1.8 g/$BW^{.75}_{kg}$) and SS (4.5 g/$BW^{.75}_{kg}$) by steers grazing wheat pasture during Periods I through III in the study of Mader et al. (1983). While studies to determine minimal amounts of LQR required to reduce the incidence and severity of bloat have not been conducted, it seems unlikely that LQR consumed in amounts similar to those observed by Mader et al. (1983) would effectively control bloat of wheat pasture stocker cattle. Also, daily DM consumption of alfalfa tops of about 1.1%[5] of body weight of cows in the studies of Colvin et al. (1958b, 1978) was much lower than wheat forage organic matter intakes of about 3.0% reported by Horn et al. (1981) for stocker cattle grazed on wheat pasture. Production of ruminal fermentation gases would increase with increased intakes of bloat provocative forages, and the amount of LQR required to prevent bloat would be expected to increase.

Effects on Forage Intake and Utilization. Mader (1981) and Mader and Horn (1980 and 1981) reported results of feeding LQR on wheat forage intake, DM digestibility and passage rate of steers (1) fed harvested wheat forage in stalls and (2) grazing wheat pasture. Amounts of LQR (g/$WT^{.75}_{kg}$) that were fed were twice as great as those consumed by steers grazing wheat pasture in the work of Mader et al. (1983). Steers were pulse-dosed by feeding ytterbium-labeled wheat forage. Estimates of daily fecal DM output, ruminal turnover rates, time delay and total mean retention time of ingested wheat forage in the gastrointestinal tract were obtained by use of the time-dependent time-independent model of Ellis et al. (1979). Intake of wheat forage by steers fed harvested wheat forage in stalls and grazing wheat pasture was not affected ($P>.05$) by feeding LQR. Therefore, the data do not support the concern that LQR may be substituted for wheat forage by stocker cattle with adequate available forage. Ruminal turnover rate of wheat forage was not slowed ($P>.05$), total mean retention time of wheat forage in the gastrointestinal tract was not increased, and DM digestibility of wheat forage was not altered by feeding LQR. These data do not indicate that feeding LQR improves utilization of forages of high water content.

[5]Calculated assuming DM content of the tops to be 20%.

Summary and Conclusions

1. Daily gains of wheat pasture stocker cattle have not been increased by allowing cattle access to grazing on milo stalks.

2. Daily gains of wheat pasture stocker cattle have been decreased as stocking density on wheat pasture has been increased by giving cattle access to grazing on milo stalks.

3. Intakes of wheat straw (WS) and sorghum-sudan hay (SS) by stocker cattle on wheat pasture have been low and ranged from:

   Wheat straw: .068 to .182 kg/head/day

   Sorghum-sudan hay: .159 to .409 kg/head/day

4. Intake of WS and SS by stocker cattle on wheat pasture was only about 5 and 12% of roughage intakes reported in the literature to "effectively control" or aid the prevention of bloat. It seems unlikely that feeding LQR will control bloat of stocker cattle on wheat pasture.

5. Feeding LQR to stocker cattle on wheat pasture has not affected weight gains or wheat forage intake.

6. Data do not indicate that feeding LQR improves utilization of wheat forage.

Areas of Needed Research

1. Determine effects of different amounts of available wheat forage on intake of LQR and utilization of total forage consumed. Minimal amounts of available wheat forage that effect large increases in intake of LQR and changes in cattle performance should be identified.

2. Identify the primary animal and plant factors (i.e., chemical composition of forage) that affect intake of LQR by cattle grazing small grains pastures.

3. Conduct additional studies relative to effects of feeding LQR on the incidence and severity of bloat.

4. Determine minimum amounts of LQR that are capable of reducing bloat of cattle grazed on wheat pasture, and identify the physiological mechanism(s) by which LQR reduce bloat.

Literature Cited

Clark, R. and J. I. Quin. 1945. Studies on the alimentary tract of Merino sheep in South Africa. XIII. The role of prussic acid in the aetiology of acute bloat. J. Vet. Sci. Anim. Ind. 20:209.

Cole, H. H. and M. Kleiber. 1945. Bloat in cows on alfalfa pasture. Amer. J. Vet. Res. 6:188.

Cole, H. H., S. W. Mead and W. M. Regan. 1943. The production and prevention of bloat in cattle on alfalfa pasture. J. Anim. Sci. 2:285.

Colvin, H. W., Jr., P. T. Cupps and H. H. Cole. 1958a. Efficacy of oat hay as a legume bloat preventive in cattle. J. Dairy Sci. 41:1557.

Colvin, H. W., Jr., P. T. Cupps and H. H. Cole. 1958b. Dietary influences on eructation and related ruminal phenomena in cattle. J. Dairy Sci. 41:1565.

Colvin, H. W., Jr. and L. B. Daniels. 1965. Rumen motility as influenced by physical form of oat hay. J. Dairy Sci. 48:935.

Colvin, H. W., Jr., R. D. Digesti and J. A. Louvier. 1978. Effect of succulent and nonsucculent diets on rumen motility and pressure before, during and after eating. J. Dairy Sci. 61:1414.

Colvin, H. W., Jr., S. D. Musgrave and G. F. Williams. 1958c. Effect of a scabrous and a nonscabrous diet on rumen motility and intrarumen pressure. J. Dairy Sci. 41:744.

Davis, G. V., D. W. Arnett and A. B. Ergart. 1973. Nutritive value of milo stalks for growing steers. Proc. Cattle Feeders Day, Garden City, Kansas Agr. Exp. Sta. p. 36.

Ellis, W. C., J. H. Matis and Carlos Lascano. 1979. Quantitating ruminal turnover. Fed. Proc. 38:2702.

Horn, G. W., T. L. Mader, S. L. Armbruster and R. R. Frahm. 1981. Effect of monensin on ruminal fermentation, forage intake and weight gains of wheat pasture stocker cattle. J. Anim. Sci. 52:447.

Hull, J. L., J. H. Meyer, G. P. Lofgreen and A. Strother. 1957. Studies on forage utilization by steers and sheep. J. Anim. Sci. 16:757.

Johnson, A. B., J. L. Arnold, W. C. Ellis, W. W. Smith, H. Lippke, and L. W. Greene. 1983. Associative grazing: Wheat with sorghum grain stubble. Beef Cattle Research in Texas. Texas Agr. Exp. Sta. PR-4093. p. 73.

Mader, T. L. 1981. Effect of feeding low-quality roughages on performance and wheat pasture utilization of stocker cattle. Ph.D. Dissertation. Oklahoma State University, Stillwater.

Mader, T. L. and G. W. Horn. 1980. Effect of low quality roughages on wheat forage utilization and intake of wheat pasture stockers. J. Anim. Sci. 51(Suppl. 1):84.

Mader, T. L. and G. W. Horn. 1981. Wheat forage intake and utilization by steers fed low-quality roughages. J. Anim. Sci. 53(Suppl. 1):277.

Mader, T. L., G. W. Horn, W. A. Phillips and R. W. McNew. 1983. Low quality roughages for steers grazing wheat pasture. I. Effect on weight gains and bloat. J. Anim. Sci. 56:1021.

McMillen, W. N. and W. Langham. 1942. Grazing winter wheat with special reference to the mineral blood picture. J. Anim. Sci. 1:14.

Meyer, J. H., G. P. Lofgreen and N. R. Ittner. 1956. Further studies on the utilization of alfalfa by beef steers. J. Anim. Sci. 15:64.

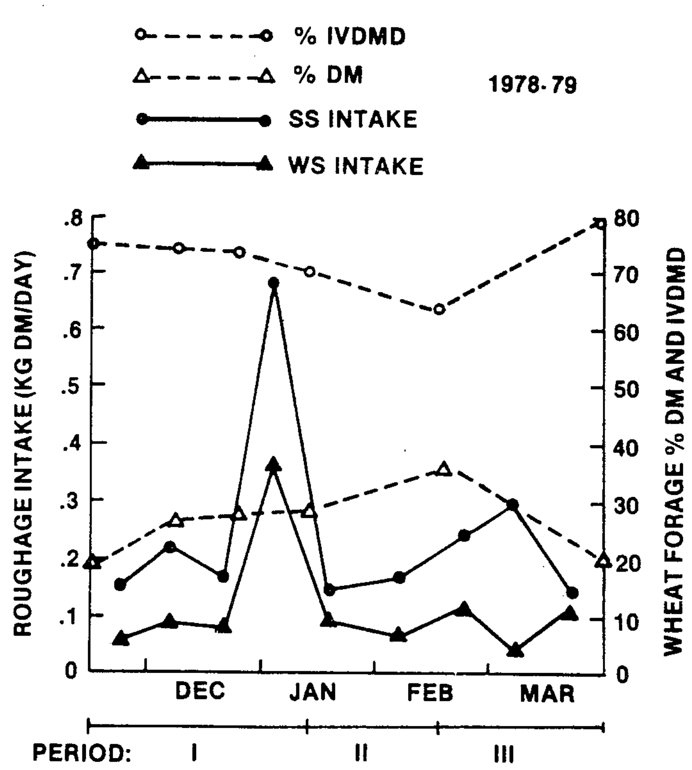


Figure 1. Wheat forage dry matter (DM ± 1.7) and in vitro DM digestibility (IVDMD ± 1.5), and wheat straw (WS ± .05) and sorghum sudan hay (SS ± .06) intake during the 1978 to 1979 grazing season.

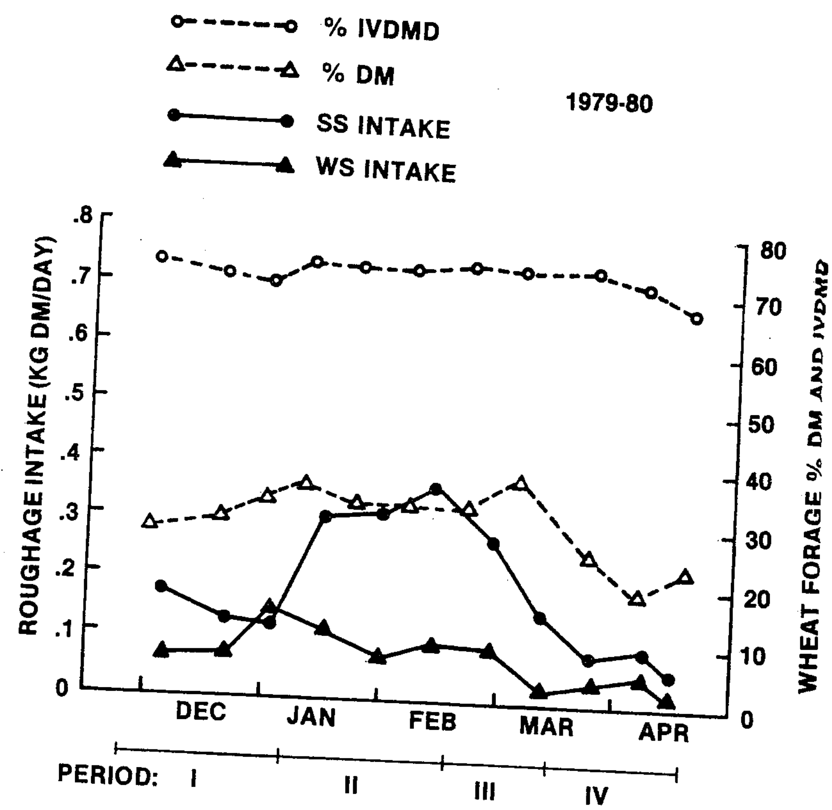


Figure 2. Wheat forage dry matter (DM ± 2.0) and in vitro DM digestibility (IVDMD ± 1.7) and wheat straw (WS ± .07) and sorghum sudan hay (SS ± .06) intake during the 1979 to 1980 grazing season.

VI. ECONOMIC EVALUATION OF WHEAT CROP ALTERNATIVES

ESTIMATING COSTS AND RETURNS FOR WHEAT CROP ALTERNATIVES IN THE SOUTHERN PLAINS--PROBLEMS AND DATA NEEDS

by Wyatte L. Harman, John McNeill and G. B. Thompson*

SUMMARY

Estimating costs and returns for alternative wheat utilization choices is a complex and involved analysis. Economic analyses point out needs for technical production coefficients and economic parameters required to evaluate alternatives. Coefficients may be based on estimates from research data, surveys and production experience. However, some coefficients may be quite variable and would require extensive research expenditures, facilities and time to make further refinements. Highly variable parameters and factors over which producers have little control are most conveniently evaluated in a breakeven analysis. The accompanying analysis evaluates three wheat crop utilization alternatives--wheat for grain production, hay production or stocker cattle utilization by grazing out the crop. Since cattle performance and forage yields are quite variable, a breakeven economic analysis is made with respect to each of these factors and their respective prices.

INTRODUCTION

The process of estimating costs and returns for alternative wheat uses in the Southern Plains is complicated by the diversity of production choices and situations. Wheat producers may choose to graze the crop out, harvest it for grain or even cut it for hay or silage. In addition, the crop may be irrigated or dryland which, in either of the above choices, affects cattle gains, forage and grain yields and production costs. Other factors such as price uncertainties, weather variations and marketing opportunities add even more dimensions to the decision-making process.

After determining the production situation and alternatives to be analyzed, there remains a whole set of technical production coefficients necessary to evaluate the choices such as irrigation levels and costs, fertilizer requirements, stocking rates, daily gains, length of grazing period, forage yields, grain yields, cattle prices, hay prices, grain prices, harvesting costs, interest rates, machinery needs and labor requirements. Many of these factors are interrelated, such as the influence of irrigation and fertility on stocking rates, forage production and grain yields. Thus, estimating profitability of

---

*Respectively, agricultural economist, TAES, Amarillo, Texas; beef cattle specialist, TAEX, Amarillo, Texas and resident director of research and professor of Animal Science, Texas A&M Research and Extension Center, Amarillo, Texas.

Technical Article No. 19033, The Texas Agricultural Experiment Station, Texas A&M University System, College Station, Texas.

alternative wheat uses requires technical estimates from agronomists, animal scientists, irrigation specialists and economists. Each can contribute to improved estimates through research, experience and farm production observations.

ANALYTICAL SITUATION

For purposes of this discussion and to provide some simplicity and brevity, the analytical situation focuses on the major decision in the spring of whether to produce grain, to graze-out or to hay the wheat crop. These three alternatives are available to Southern Plains producers about the time winter wheat emerges from dormancy. To further simplify the analysis, the setting is in early March. Previously purchased stocker cattle are grazing the winter wheat. The producer has three options at this time:

1. Sell the stockers and harvest the grain,

2. Keep the stockers and graze-out the wheat or

3. Sell the stockers and produce wheat hay or silage.

A fourth option, that of selling the stockers and leasing the wheat for graze-out, is not considered in this analysis. Lease prices vary from year to year depending on local demands and availability of pasture, cattle and wheat prices and spring crop conditions.

Recognizing that extraneous factors such as crop conditions, availability and cost of harvesting equipment and the profit/loss situation of the currently owned stocker cattle may influence the decision, this analysis assumes that these factors are not compelling to the decision-maker. The analysis thus implicitly assumes that the currently owned stocker cattle can be immediately marketed at an exact breakeven price. The impacts of a profit or loss from selling the stockers will, however, be discussed.

OBJECTIVE

The three choices given above are analyzed in the following discussion. Technical coefficients needed and price or cost estimates required to evaluate the options will be pointed out in the discussion. Emphasis will also be placed on irrigated wheat production but dryland production and weather risk will also be discussed.

ALTERNATIVE WHEAT UTILIZATION CHOICES

The above described situation presumes that the wheat producer made a decision in the fall to plant somewhat earlier than normal to provide adequate pasture, Figure 1. This decision may have been based on deferred price expectations for grain versus the deferred price expectations for feeder cattle or simply the need to possibly enhance cash flow by producing feeder cattle. By making this decision, he is usually committed to a fall irrigation in addition to the preplant irrigation. The time frame and schedule of operations faced by the producer for the three above options are detailed more completely in Figure 1. The spring operations imply the data needs inherent to this analysis.

Grain Production

After the winter grazing period, the first option--to sell the stockers and harvest the wheat for grain--involves determining the remaining production costs necessary to reach some grain yield goal. The yield objective depends on irrigation water availability, irrigation costs and the expected price of wheat. Using the latest research data from the USDA Conservation and Production Research Laboratory, Bushland, Texas, a production function developed for the recently released short-strawed wheat variety, TAM 105, indicates the maximum profit irrigation level is 20 inches (Musick and Harman).[1/] This is based on an expected wheat price of $3.30 per bushel (1984 loan rate) and an irrigation cost of $4.35 per acre-inch (fuel, labor and interest). Twenty inches of irrigation water applied in the spring results in a yield expectation of 112 bushels per acre based on summer-fallowed and ungrazed research plots. Realizing that in practice, commercial wheat producers grazing wheat during the winter will probably not achieve yields equal to the ungrazed level-border plots, the assumed yield expectation herein will be 90 bushels per acre or about 80 percent of the yields obtained by research. Producers in the area are reporting yields at this level and even higher (Porter).

Production costs during the spring necessary to achieve a 90-bushel yield amount to $75 for irrigation fuel, $10 for irrigation labor, $15 for fertilizer and the top dress application, $31 for harvesting the grain, $13 for insect and weed control and $3 for interest or a total prospective cost to produce grain of $147 per acre. Grain sales amount to $297 per acre at $3.30 per bushel. Thus, aside from all other costs invested in the crop up to this point, which include fertilizer, seed, tillage and fall irrigations, the profit potential from grain production is $150 per acre. The previously incurred expenses to establish the crop and prepare for winter grazing are considered "sunk costs" at this point and do not enter into the decision as to whether to harvest for grain, cut for hay or graze-out the wheat. Machinery depreciation costs are not considered since this may be a one-year decision.

After determining the "opportunity cost" or profit per acre from grain production, a breakeven analysis can evaluate the graze-out and hay options. A breakeven analysis of cattle gains and hay yields, for example, allows developing a matrix of estimates indicating the minimum level of gains or hay yields necessary to make the same profits as from grain production. This type analysis also allows evaluation of several additional parameters such as variations in expected hay, grain and feeder cattle prices.

Graze-out

Conditions necessary for graze-out wheat to be more profitable than harvesting the wheat for grain can be evaluated by the following equations:

$\pi_{go} > \pi_w = \$150$ per acre where (1)

$\pi_{go} = [(Y_b)\ (P_b)] - VC_{go}$ (2)

and π_{go} = profit from stocker cattle on graze-out wheat,

π_w = profit from wheat for grain considering remaining production costs only,

Y_b = yield of beef or gain per acre expected during the graze-out period,

P_b = expected price of feeder cattle and

VC_{go} = the variable costs of producing stocker cattle on graze-out wheat.

To determine the profitability of stocker cattle, the variable costs associated with graze-out, VC_{go}, must be estimated. This analysis is based on the cost of one irrigation (Figure 1), salt, mineral and medicine charges, care costs, sales commissions and hauling costs but no wheat harvesting or weed and insect control costs. Irrigation and labor costs amount to $25 per acre, salt, mineral, and medicine costs are $2 per head, care costs include $4.50 per head for 90 days and additional hauling costs are $4.00 per head.[2/] No death losses are expected since the stockers have been grazing for a previous time period. Assuming a stocking rate of 1.5 head per acre for 3 months, the variable costs total about $43 per acre including $2 interest costs.

A profit or loss in the currently owned stocker cattle if sold in March adds profits (or losses) to the decision to produce wheat for grain. These profits (losses) influence the graze-out breakeven gains, i.e. more profits raise the breakeven gains of the graze-out option and vice versa stocker losses lower gains needed from graze-out. Thus, if a profit (loss) is to be realized from selling currently owned stockers in the event the wheat for grain option is selected the profit estimate from wheat in equation (1) is modified by:

$$\pi_{w+stc} = \pi_w + \pi_{stc}$$

where π_{stc} = profits (losses) from sale of stocker cattle in mid-March

and

π_{w+stc} = total profits from wheat for grain and profits (losses) from sale of stocker cattle in mid-March.

The breakeven beef production per acre, Y_b, and feeder cattle price, P_b, can be determined by solving algebraically for each variable using equation 2 above and substituting the minimum condition of π_w for π_{go}:

$$Y_b = (\pi_w + VC_{go}) \div P_b \qquad (3)$$

and $$P_b = (\pi_w + VC_{go}) \div Y_b \qquad (4)$$

where $\pi_{go} \geq \min.\ \pi_w$.

<u>Graze-out Example</u>. If no profits or losses are likely from selling stockers to produce grain, the breakeven graze-out beef gain per acre, Y_b in equation 3, at a feeder cattle price of 65 cents per pound, for example, is 297 pounds in 90 days [($150 + $43) ÷ $.65]. This equates to a daily gain of 2.2 pounds per head per day at a stocking rate of 1.5

head per acre. In the event a profit of say $30 per head (1 head/acre) can be realized by selling the owned stockers and producing grain, the breakeven gain is raised to 343 pounds or 2.5 pounds per day.

Using equation 4, the breakeven price, P_b, at a daily gain of 2.4 pounds and stocking 1.5 head per acre is 59.6 cents per pound [($150 + $43) ÷ 324 lbs.]. The breakeven price increases to 68.8 cents per pound if a profit of $30 per head exists in the owned stockers in mid-March. The above calculations are based on pay weight. To adjust for shrinkage in handling and hauling, the pay weight, Y_b, in equation 3 is multiplied by 1 plus the estimated percent shrinkage (1.02 for 2 percent shrink) and by 1 minus the shrink in equation 4.

Price Sensitivity Analysis

By varying the price of wheat and, therefore, the profit per acre from grain production, π_w; a third dimension--grain price uncertainty--can be evaluated. Table 1 indicates the breakeven rates of gain for a 90-day graze-out period for alternative feeder cattle prices with two stocking rates of one and 1.5 head per acre and three alternative grain prices--$3, $4 and $5 per bushel. Profit maximizing irrigation levels were determined for each grain price (refer to previous discussion of grain production). The alternative optimum levels of irrigation and resulting grain yields require new estimates of profits at each grain price. Optimum yields were determined to be 90, 91, and 92 bushels (80 percent of the predicted production in footnote 1) at the respective $3, $4, and $5 per bushel wheat prices.

The breakeven daily gains in Table 1 vary from 1.79 to 2.09 pounds with $3.00 per bushel wheat and $60 to $70 feeder cattle prices using a stocking rate of 1.5 head per acre. Breakeven gains rise as the stocking rate drops, as expected cattle prices decline or as the wheat price and profits per acre rise. Based on research at the North Plains Research Field, Etter, Texas, from 1970 to 1972, stocker cattle can be expected to gain about 2.3 pounds per head per day from March 20 to May 1. From May 1 to May 20, gains approached 2.25 pounds per day (Shipley and Regier; Harman). Continued gains at 2.25 pounds per day until mid-June would result in an average daily gain from March 20 of 2.27 pounds per day over the 86-day period. Thus, wheat for grain is more profitable than graze-out if the breakeven daily gain is less than about 2.3 pounds per day. This would therefore, preclude graze-out as a more profitable option than grain production if wheat is $4 per bushel or higher and feeder cattle price expectations do not exceed $70 per cwt. (Table 1). However, if a lower wheat price is expected such as $3 per bushel and the stocking rate is 1.5 head per acre, graze-out is more profitable than grain production at $60 to $70 per cwt. feeder cattle prices. Cattle prices can be substantially lower than $60 per cwt. at a break even level with grain production when stocking 1.5 head per acre.

Hail Insurance. When calculating the breakeven stocker cattle gains in Table 1, a charge for hail insurance could also be included in the variable costs of grain production. If insurance premiums cost $15 per acre, breakeven cattle gains in Table 1 for $60 and $70 per cwt. cattle prices can be lowered by .27 and .23 pounds per day respectively for a stocking rate of one head per acre. With the higher stocking rate of 1.5 head per acre, the breakeven daily gain can be reduced by .18 and .15 pounds per day for the respective $60 and $70 cattle prices.

Stocker Profits (Losses). Considering that a profit or loss may occur if the owned stockers are sold in March to produce wheat for grain, Table 2 indicates the breakeven gains needed if the stocker cattle are not sold and are utilized for the graze-out option. With a stocking rate of 1.5 head per acre, a $65 per cwt. feeder cattle price expectation, $3 per bushel wheat, and a likely loss of $30 per head (versus breakeven), the breakeven gain for graze-out cattle drops from 1.93 pounds per day to 1.58 pounds per day. On the other hand, if $30 profit can be made as opposed to breakeven, the minimum rate of gain for graze-out stockers rises to 2.28 pounds per day versus 1.93 pounds.

Hay Production

A similar breakeven analysis can be made in evaluating wheat for hay or silage. The variable costs associated with baling hay in large round bales amount to $25 for one irrigation, $1 interest, and $8 per acre swathing charge plus $20/ton baling and hauling costs (Texas Crop and Livestock Reporting Service, 1982). Again, no weed or insect control costs are considered. The baling and hauling costs are subtracted from the hay selling price (since both are priced per ton) to estimate the breakeven forage yield. Table 3 gives the breakeven hay yields at three grain prices and alternative hay prices of $50 to $100 per ton. There is no need to consider the profit/loss situation in the owned stocker cattle when considering the hay option since they will have to be sold in either the hay or grain options.

The minimum yields of hay using a $3.00 per bushel wheat price vary from a low of 2.0 tons to a high of 5.2 tons per acre over the range of hay prices evaluated. As wheat price expectations rise, minimum hay yields necessary to breakeven with the higher wheat profits increase to as much as 11.0 tons per acre with the low hay price of $50 per ton.

The amount of hay that can be expected from the new varieties of wheat with one irrigation after winter grazing is not well documented in the literature. Shipley and Regier at Etter, Texas, found regrowth from March 20 to April 30 averaged nearly a ton (corrected to 15 percent moisture) per acre over three years using an older variety of Tascosa wheat. Cowley, et al. report Tascosa regrowth at Bushland, Texas, varied from 1.15 tons to 1.6 tons per acre (15 percent moisture) from the first of April to early June for 1969 and 1971 respectively. Malm, et al. in southeastern New Mexico indicated wide variations in hybrid wheat forage production in 1972. The regrowth from early March to late April of five hybrids averaged 2.1 tons per acre at 15 percent moisture but four of them only made about 1.4 tons per acre average. One hybrid showed exeptionally high forage regrowth during the period. Porter, et al. reported Tam 101 yielded 18 percent less oven dry forage during late April to early June than Concho at Texline, Texas in 1972. Agent and Tam W-103 were the highest yielding of nine wheat varieties while TAM 101 was the lowest yielding at Bushland, Texas, in 1973, for the period late April to late May. Regrowth yields during this period ranged from a low of 1.15 tons per acre to a high of two tons per acre corrected to 15 percent moisture. The nine varieties averaged 1.53 tons per acre. Atkins, et al. reported green silage yields at College Station, Texas, varied from 6.7 to 8.9 tons per acre with a fertility level of 50 lbs. N, 40 lbs. P and 40 lbs. K. These yields would equal from 2.3 to three tons per acre based on 70 percent moisture at harvest and 15 percent moisture at baling time.

Thus, it is evident that varieties, management practices, seasonal climatic factors, and location influence wheat hay production. The extent of winter grazing and take-off date may also affect tillering and, therefore, spring forage yields (Winter). Based on the limited amount of research available, it is evident that more evaluation of wheat hay production practices is needed.

PRICE UNCERTAINTY

The above breakeven analyses focused on parameters considered to be the most uncertain--wheat grain prices, stocker cattle prices, hay prices, carrying capacity, cattle performance and forage yields. However, price uncertainty can be largely avoided through forward contracting or by hedging on the commodity futures (except hay). Thus, the previous analyses estimated breakeven levels of production which producers might have least control over--the breakeven cattle performance and forage yields.

Using Equation 4 above, the breakeven prices of feeder cattle or hay can be determined for evaluating hedging and forward contracting opportunities. Tables 4 and 6 indicate the minimum selling prices at alternative stocking rates and daily gains as well as hay yield expectations, respectively. In the case of a $3 wheat price and stocker cattle gaining 2.5 pounds per day, the breakeven feeder cattle price in Table 4 after shrink is $50.19 per cwt. if 1.5 head per acre is the stocking rate. The breakeven price rises to $73.02 per cwt. if one head is carried per acre, (Table 4). Generally, as wheat profits rise or as the beef produced per acre falls, breakeven feeder cattle prices rise substantially.

If a profit or loss rather than a breakeven situation exists in the currently owned stockers, the breakeven feeder cattle prices will vary from those above similar to the situation previously discussed concerning breakeven gains. Table 5 indicates the minimum prices needed with a range of $60 in losses to profits (- $30 to + $30) with a stocking rate of 1.5 head per acre. At $3 per bushel wheat, the breakeven price drops from $50.19 per cwt. for the breakeven situation to only $41.12 per cwt. if a $30 per head loss is expected upon selling the stockers to produce wheat. Conversely, if a $30 per head profit can be realized, the breakeven price rises to $59.26 per cwt.

Breakeven hay prices at $3 per bushel wheat range from $51 to $177 per ton for yields of five to one ton per acre, respectively, Table 6. If wheat prices are expected to be $4 or $5 per bushel, the respective breakeven hay prices range from a low of $68 to a high of $351 per ton.

WEATHER RISK--THE DRYLAND CASE

Weather risk is usually of minor concern with supplemental irrigation when grazing-out wheat. Hay quality, however, could be deteriorated by untimely rains just as grain and hay yields could be hurt by hail. If irrigation is not available, probably the greatest weather uncertainty stems from the lack of rainfall. Dryland producers face extremes in forage and grain yield variability. Thus, stocking rates and gains will be quite variable and related to forage availability. To evaluate the three options of harvesting for grain, graze-out or hay production, historical dryland grain yields for the farm, field, soil situation or even the area can aid the producer in evaluating weather risk. The same breakeven analyses can be made as in the irrigated example above. However, in this case, the dryland grain production profits will need to reflect both price and yield variability.

Table 7 indicates historical dryland wheat yields over the past decade for several Texas panhandle counties (Texas Crop and Livestock Reporting Service, 1973-1982). These could be used by producers in developing grain profit estimates. Similar data are available to producers in other states. The wheat yields in Table 7 represent county averages of both continuous and summer-fallowed wheat. A regression analysis of yields with respect to time was made to evaluate trends and standard deviations. Dryland wheat yields over the past decade show no significant correlation with time. Standard deviations range from over four to under six bushels per harvested acre.

No attempt is made to analyze these wide extremes in production due to space limitations. Similar cost estimating procedures and equations as used in the previous irrigated wheat analysis are applicable to a dryland situation. The breakeven analyses for evaluating hay yields or prices and stocker cattle performance or prices are equally applicable.

RESEARCH NEEDS

The most obvious lack of production data needed in the previous analysis is a production function relating wheat hay and silage yields to irrigation water application rates. If a similar function existed to that for grain yields (see footnote 1), the producer could more reliably judge the irrigation level for profit maximizing hay yields. The above analysis has assumed only one irrigation in the spring and, therefore, lacks the proper decision-making data to maximize profits from hay production.

Identifying variability in wheat grain and hay yields as well as stocker cattle performance is usually time-consuming and expensive research. However, producers and scientists alike should be aware of this variation. Scientists can contribute to identifying the variation by publishing coefficients of variability of their research findings.

SUMMARY AND CONCLUSIONS

The process of estimating costs and returns of alternative wheat utilization choices is a complex and involved analysis. The above analysis points out the needs for technical production coefficients and economic parameters required to evaluate the alternatives--wheat for grain, hay and graze-out. Some coefficients are relatively sound estimates based on available research data, surveys and production experience while others are highly variable and would require extensive research expenditures, facilities and time to evaluate. These latter coefficients are most conveniently evaluated in a breakeven type of analysis.

For example, stocker cattle performance is dependent on a variety of factors--type of cattle, management expertise, weather conditions, forage availability, stocking rate, etc.--that a breakeven analysis can provide benchmarks for the minimum performance needed. Producers can also view the profitability potential of stocker cattle over a range of economic parameters such as wheat prices and feeder cattle prices.

If hedging or forward contracting is utilized as a management tool to minimize price uncertainty, breakeven feeder cattle and hay prices can be determined for the purpose of "locking in" profits over and above grain production profits. The previous analysis, however, has not attempted to factor in management expertise (or lack thereof), weather cycles or price and supply/demand conditions. No presumptions are made by the authors as to actual prices for hay, grain or feeder cattle over the next year but rather a means is indicated by which these factors can be evaluated.

FOOTNOTES

1/ The estimated production function is:

$$Y = 26.966 + 4.387X^{***} - .075X^2 + .2698N^{***}$$

with $R^2 = .938$ and S.D. = 5.23 bushels where

X = Irrigation water (inches) applied April 1-June 15,

N = Percent of normal rainfall April 1-June 15 (100 = Normal) and

*** = Significant at the 1% level of confidence.

The maximum profit level of irrigation is determined by:

$$\frac{dY}{dX} = \frac{P_w}{P_g}$$

where dY/dX = partial derivative of the production function,

P_w = cost of water and

P_g = price of wheat grain.

Thus, the maximum profit level of irrigation given below is about 20 inches if water costs $4.35 per acre-inch and the wheat price is $3.30 per bushel:

$$4.387 - .15X = 4.35/3.30$$

$$X = 20.5$$

2/ Hauling costs of heavier grazeout stockers would be higher than if sold earlier in March. Sales and commission costs are considered to be the same regardless of sale date.

REFERENCES

Atkins, I.M., O.G. Merkle and Paul E. Pawlisch, "Influences of Growth habit, Fertility Levels and Clipping Treatments on Production of Grain, Winter Forage and Silage of Small Grain Varieties," PR-2652, Texas Agr. Exp. Station, 1969.

Cowley, Charles, R.C. Thomasen, G.L. Peterson and W.W. Watson, "Small Grain Forage Production on the High Plains of Texas," Symposium on Grazing Small Grains, Bushland, Texas, August 5, 1971.

Harman, Wyatte L. "Economic Considerations of Grazing Wheat," Southwest Farm Press, April 15, 1982 and High Plains Journal, March 15, 1982.

Malm, Norman R., John S. Arledge and Carl E. Barnes, "Forage Production from Winter Small Grains in Southeastern New Mexico," New Mexico Agr. Exp. Station Bulletin 607, August, 1973.

Musick, J.T. and Wyatte L. Harman, "TAM 105 Wheat Yield Response to Alternative Irrigation Levels, Texas High Plains," under review, Texas Agricultural Experiment Station Progress Report, 1983.

Porter, Kenneth B., personal communication, wheat breeder, Texas Agr. Exp. Station, Amarillo, Texas, 1983.

Porter, Kenneth B., Charles Cowley and Gary Peterson, "Choice of Small Grains for Fall, Winter and Spring Grazing," Grazing Symposium, Bushland, Texas, July 31, 1973.

Shipley, John and Cecil Regier, "Optimum Forage Production and the Economic Alternatives Associated with Grazing Irrigated Wheat, Texas High Plains," MP-1068, Texas A&M University, College Station, Texas, December, 1972.

Texas Crop and Livestock Reporting Service a, "1981 Texas Custom Rates Statistics," USDA, Austin, Texas, July, 1982.

Texas Crop and Livestock Reporting Service b, "Texas Small Grain Statistics," USDA, Austin, Texas, 1973-1982.

Winter, Steve, personal communication, agronomist, Texas Agr. Exp. Station, Amarillo, Texas, 1982.

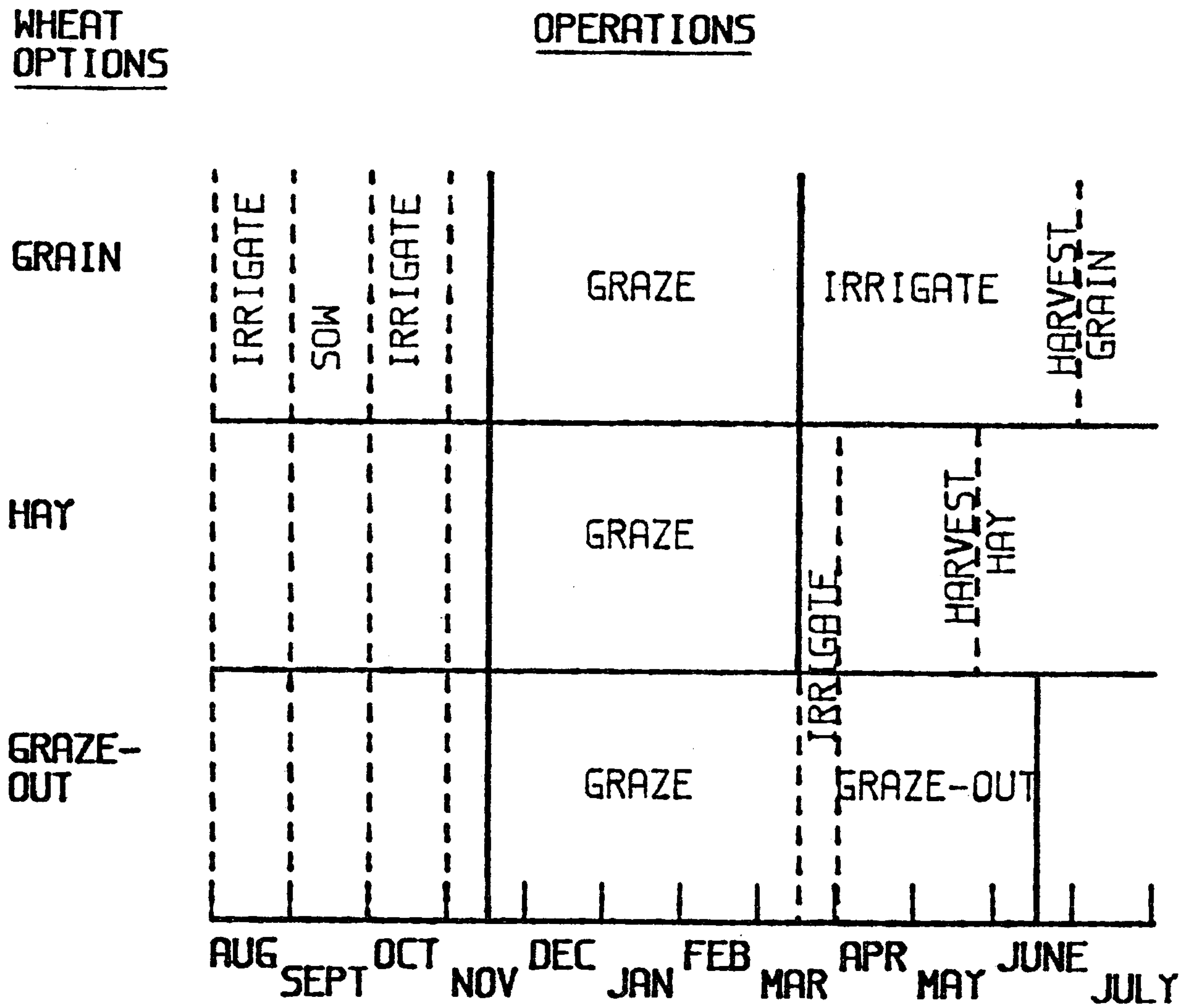


FIGURE 1. DEPICTION OF WHEAT PRODUCTION OPERATIONS WITH ALTERNATIVE WHEAT UTILIZATION OPTIONS.

Table 1. Breakeven Rates of Gain for Graze-out Stocker Cattle with Alternative Grain and Feeder Cattle Prices.*

Feeder Cattle Price ($/cwt)	Stocking Rate (hd/acre)	Wheat Price/Profit per Acre		
		$3.00/ $123	$4.00/ $208	$5.00/ $297
		- - - - lbs gain/day - - - -		
$60	1.0	3.04	4.65	6.33
	1.5	2.09	3.16	4.28
$65	1.0	2.81	4.29	5.84
	1.5	1.93	2.92	3.95
$70	1.0	2.61	3.98	5.42
	1.5	1.79	2.71	3.67

*Based on 2% shrink at sale time, 90-day graze-out period and optimum wheat yields of 90, 91 and 92 bushels with $3, $4 and $5 wheat price respectively. Currently owned stocker cattle will break even if sold in anticipation of producing grain.

Table 2. Breakeven Rates of Gain for Feeder Cattle on Graze-Out Wheat at Alternative Profit (Loss) Levels of Owned Stocker Cattle, Stocking Rate of 1.5 Head per Acre.*

Feeder Cattle Price	Profit (Loss) Situation of Owned Stockers[1/]	Wheat Price/Profit per Acre		
		$3.00/ $ 123	$4.00/ $ 208	$5.00/ $ 297
($/cwt)	($/head)	- - - - lbs gain/day - - - - -		
$60	- $30	1.71	2.78	3.90
	$ 0	2.09	3.16	4.28
	+ $30	2.47	3.54	4.66
$65	- $30	1.58	2.57	3.60
	$ 0	1.93	2.92	3.95
	+ $30	2.28	3.27	4.30
$70	- $30	1.47	2.39	3.35
	$ 0	1.79	2.71	3.67
	+ $30	2.11	3.03	3.99

*Based on 2% shrink at sale time, 1.5 head per acre, 90-day graze-out period, and optimum wheat yields of 90, 91, and 92 bushels with $3, $4, and $5 wheat price respectively.

1/ The current (mid-March) situation if owned stockers are sold to produce wheat for grain at a current stocking rate of one head per acre.

Table 3. Breakeven Wheat Hay Yields with Alternative Grain and Hay Prices.

Hay Price1/ ($/ton)	Wheat Price/Profit per acre $3.00/ $123	$4.00/ $208	$5.00/ $297
	- - - - -tons/acre- - - - -		
$ 50	5.2	8.1	11.0
$ 60	3.9	6.1	8.3
$ 70	3.1	4.8	6.6
$ 80	2.6	4.0	5.5
$ 90	2.2	3.5	4.7
$100	2.0	3.0	4.1

1/ Subtract $20 per ton to pay for baling and hauling costs when calculating breakeven yields.

Table 4. Breakeven Price for Feeder Cattle on Graze-out Wheat with Alternative Stocking Rates, Daily Gains and Grain Prices.*

Expected Daily Gain (lbs/day)	Stocking Rate (hd/acre)	Wheat Price/Profit per Acre $3.00/ $123	$4.00/ $208	$5.00/ $297
		-------	$/cwt-	-------
2.0	1.0	$91.27	$139.46	$189.91
	1.5	62.74	94.86	128.50
2.5	1.0	73.02	111.56	151.93
	1.5	50.19	75.89	102.80
3.0	1.0	60.85	92.97	126.61
	1.5	41.82	63.24	85.66

*Based on 2% shrink and a 90-day graze-out period. To calculate Y_B in equation 4, multiply expected daily gain by stocking rate for 90 days and multiply by .98 to reflect 2 percent shrink. Currently owned stocker cattle will break even if sold in anticipation of producing grain.

Table 5. Breakeven Price for Feeder Cattle on Graze-out Wheat at Alternative Profit (Loss) Levels of Owned Stocker Cattle, Stocking Rate of 1.5 Head per Acre*.

Expected Daily Gain (lbs/day)	Profit (Loss) Situation of Owned Stockers[1/] ($/head)	Wheat Price/Profit per Acre: $3.00/ $ 123	$4.00/ $ 208	$5.00/ $ 297
		$/cwt		
2.0	- $30	51.40	83.52	117.16
	$ 0	62.74	94.86	128.50
	+ $30	74.08	106.20	139.84
2.5	- $30	41.12	66.82	93.73
	$ 0	50.19	75.89	102.80
	+ $30	59.26	84.96	111.87
3.0	- $30	34.27	55.68	78.11
	$ 0	41.82	63.24	85.66
	+ $30	49.37	70.80	93.21

*Based on 2% shrink and a 90-day graze-out period. To calculate Y_B in equation 4, multiply expected daily gain by stocking rate for 90 days and multiply by .98 to reflect 2 percent shrink.

[1/]The current (mid-March) situation if owned stockers are sold to produce wheat for grain at a current stocking rate of one head per acre.

Table 6. Breakeven Hay Prices with Alternative Forage Yields and Grain Prices.*

Forage Yield (tons/acre)	Wheat Price/Profit per Acre		
	$3.00/ $123	$4.00/ $208	$5.00/ $297
	$/ton		
1.0	$177	$262	$351
2.0	99	141	166
3.0	72	101	130
4.0	59	81	103
5.0	51	68	86

*$20 per ton is added to the breakeven price of hay to compensate for baling and hauling costs per ton.

Table 7. Dryland Wheat Yields per Harvested Acre, 1973-1982, Selected Counties for Areas of Texas Panhandle.

Year	NC/ Moore	SC/ Swisher	NW/ Dallam	SW/ Deaf Smith	NE/ Lipscomb	SE/ Collingsworth
	Panhandle Location/County					
	bushels/acre					
1973	25.4	24.3	22.2	26.4	22.2	17.0
1974	6.4	8.6	6.5	7.5	9.7	10.8
1975	11.2	17.2	13.2	22.2	16.4	16.2
1976	19.1	16.5	21.3	19.6	14.9	25.4
1977	11.9	19.6	20.6	14.5	11.2	21.1
1978	8.8	10.1	10.5	11.4	7.2	15.6
1979	19.9	17.1	17.8	19.4	26.5	20.7
1980	18.5	13.9	21.0	14.3	19.4	15.9
1981	17.8	16.4	11.2	11.0	12.2	14.3
1982	14.8	12.7	14.6	16.5	17.5	14.1
10-Yr. Avg.	15.4	15.6	15.9	16.3	15.7	17.1
St. Dev., S_x	5.8	4.6	5.5	5.7	5.9	4.2
Correlation with years[1/], R^2	.004	.090	.003	.120	.004	.010

[1/] Years indicated by 1 = 1973, 2 = 1974, ..., 10 = 1982.

Linear Programming Analysis of Wheat Crop Alternatives[1]

Orlan Buller[2]

Introduction

In recent years over 24 million acres of winter wheat have been planted in Kansas, Oklahoma and Texas. Although the primary purpose of the wheat has been grain production, it also provides an important source of livestock feed. Years when top growth is abundant and weather is favorable for grazing nearly one-half of the acreage is pastured during some part of its growing season (Anderson). The use and practice of winter wheat for pasture supplementing grain production is well established in the southern High Plains. With proper management about 120 days of grazing may be available in many years. The relative dryness of many winters and freedom from snow cover often make it feasible for livestock to obtain a major portion of their feed requirements from wheat pasture.

Grain yields generally are not materially reduced if pasturing is managed properly by moderate grazing. If wheat is planted in a well prepared seed bed and adequate soil moisture is available to provide good vegetation growth and not over-grazed or grazed too long in spring then grain yield should not be affected.

In recent years, interest in other uses of winter wheat has increased. This study will compare three other methods of using winter wheat for livestock; as hay, silage or graze-out. A linear programming method is used to compare these alternatives taking into consideration cost, returns, labor requirements and nutrients provided by each.

Wheat Crop Alternative

Wheat Hay: Research at Kansas State University and reported by Kuhl, Oltjen and Bolsen shows that wheat hay is an excellent roughage for starting, growing and finishing cattle. Wheat is reported to be similar to high quality brome hay in nutritional value. Their studies show that the dough stage of kernel maturity provides the best combination of high dry matter yield and maximum hay quality. Quality differences among varieties are not consistently found in research results. Quality of hay is greatly influenced by the maturity at harvest, method of handling, rain damage and amount of protection while in storage. Growing conditions will effect the grain content, quality of the grain, protein and fiber of the forage, and these factors contribute to the quality of the hay.

---

[1]Paper presented at National Wheat Pasture Symposium, Stillwater, Oklahoma, October 24-25, 1983.

[2]Professor of Agricultural Economics, Kansas State University, Manhattan, Kansas.

Balers, swathers, mowers, etc. generally available are suitable to harvest wheat hay. Round bales or bread loaf stacks show less deterioration caused by rainfall then rectangular bales if not sheltered.

One problem with wheat hay or silage is that it is harvested at a time of highest seasonal rainfall. Late May and early June have the fewest number of field work days as compared to other times of the year. Consequently, the availability of harvesting equipment is critical for the successful harvest of high quality hay.

Wheat Silage: Wheat ensiled in the soft dough stage is comparable in feeding value to high grain forage sorghum and to 80 percent of corn. Wheat silage will have about 2-3 percent more protein than sorghum or corn silage. For highest quality wheat should be ensiled at 60-65 percent moisture if stored in a bunker or upright silo.

For the best combination of quality and quantity of silage, wheat should be ensiled at the soft dough stage. Earlier harvesting will increase the percent crude protein; harvesting later will increase the percent dry matter. Harvest at dough stage should be completed in 10 to 14 days. The same problem of limited number of days for ensiling hold as for harvesting wheat for hay.

Some disadvantages of making wheat silage are (1) a larger investment in harvesting and storage facilities may be needed as compared with harvesting wheat hay, (2) ensiling may require more labor per acre than either hay or grain harvesting, (3) silage nor hay are as liquid an asset as grain. If wheat silage is put in an upright silo, combined harvesting and storage losses may be less than for wheat hay.

Wheat for pasture and graze out: A wheat graze-out system intensively grazes the wheat pasture until about June 1; no grain is harvested. The wheat pasture or graze-out system requires less labor and capital per unit than either the wheat hay or silage method. Some disadvantages of wheat graze-out are the limited duration when the feed supply is available, and the large loss of feed caused by trampling or left ungrazed. It is estimated that 50 to 60 percent of production is harvested if grazed as compared to silage.

Two increased health problems for cattle on wheat pasture are that of grass tetany and bloat. Both can cause serious economic losses if not treated properly and promptly. Providing a high magnesium mineral and salt mix help prevent grass tetany. Feed additives containing bloatgaurd or poloxalene used when rapid growth of vegetation occurs help prevent bloat.

Stocking rate is greatly influenced by location, year, fertilization, moisture and temperature conditions, size of animal and duration of grazing period. Anderson reports that 3 to 7 acres of wheat may be required to carry an adult beef cow in fall: 2 to 4 acres during early spring. Calves in fall require about half and yearlings about two-thirds the acreage of adult animals. The greatest carrying capacity is normally from mid-April to the end of the month when 1/2 acre will carry an animal unit.

Stocking rates for wheat graze-out systems will be heavier in the spring than specified above. Laudert reports "theoretical stocking time for graze-out wheat occurs after jointing because forage growth is very rapid and nutrient quality declines as the wheat plant matures. Thus, it is important to stock heavy enough so the wheat does not get too far ahead of the cattle".

Crop and Livestock Enterprises Included in Model

A linear programming model is used to evaluate and compare the economics of alternative wheat crop alternatives. The model is based on resources representing a south central Kansas cash crop-livestock farm. Farm Management Association records are used to determine the mix of land, labor and capital available. The farm situation will be descriptive of farm situations in north central Oklahoma as well as south central Kansas.

The resource base is one full-time operator and 600 acres cropland. The crops considered are:

wheat for grain,
wheat for grain and pastured until April 1,
wheat for grain and pastured until May 1,
wheat for hay,
wheat for silage,
wheat graze-out,
grain sorghum,
sorghum silage,

One livestock enterprise is considered; stocker steers purchased October 1, weighing 400 pounds and sold May 1, except for the graze-out situation in which case they are sold June 1. The four different ways considered in handling stocker steers are:

steers on sorghum silage and wheat pasture,
steers on wheat hay and wheat pasture,
steers on wheat silage and wheat pasture,
steers on sorghum silage and wheat graze-out,

Steers are purchased October 1 and put on wheat pasture two weeks later, October 15. The two weeks allow time to dehorn, castrate, vaccinate, implant, deworm and delice if needed. All steer alternatives use wheat pasture beginning October 15 until December 31. These dates must be considered approximate as the grazing periods will vary from year to year and among regions. Northern Oklahoma will likely have longer periods when wheat can be pastured than South Central Kansas.

Some details of the steer alternatives are provided in table 1;

tables 2 and 3 provide cost and return data for the steer and crop alternatives, respectively. Other details about the alternatives in the model are considered next.

Wheat for Grain

Wheat is used for grain only and no steers are allowed to pasture. Wheat is planted about October 1 to reduce hessian fly problems. The data used represents continuous cropping with some rotation with grain sorghum to control cheat.

Wheat for Pasture until April 1

Wheat is planted primarily for grain but some grazing is allowed. Wheat is planted September 15 to allow the stand to grow and become established before grazing begins on October 15. The earlier planting will increase the hessian fly problems and grazing may affect the wheat stand so a heavier seeding rate and amount of fertilizer applied is increased to offset these factors.

Steers are removed from pasture by April 1, before jointing stage to avoid reducing grain yield.

Wheat for Pasture until May 1

This alternative is the same as the previous one except that steers are allowed to graze until May 1. Because the grazing season for native grass begins on May 1, this alternative would allow a continuous grazing program if desired.

Wheat for Hay

Wheat cultural practices are the same as for the wheat pasture alternatives, except that no grazing is allowed after January 1. Wheat is swathed and baled during the soft dough stage. In the model 14 days total are allowed for harvesting,however, in central and east central Kansas, only 7 to 9 field work days are available in the first half of June. Also it was assumed that swathed hay required 1 day for curing so the number of days when haying can be done is 6-8 days in the first two weeks of June. Time available for wheat hay harvesting was limited to this amount in the model.

In the model only the amount of wheat hay needed for feed is harvested and is determined by herd size. Wheat is custom swathed and baled. Because the grain combine is not needed on acres mowed, depreciation, insurance and taxes are reduced. Wheat hay is custom harvested at costs of $7.00 per acre for swathing and $6.50 per 1500 pound bale.

Wheat for Silage

Wheat cultural practices are similar to the wheat pasture alternative except no grazing is allowed after January 1. The same time constraint problems are applied to silage harvesting as for hay harvesting.

Wheat silage is custom harvested and only the amount needed for feed is cut. The custom rate used is that reported for harvesting rowed crop which is $4.15 per ton. This rate includes labor for cutter, power and machinery for chopping, hauling and filling silo.

Wheat for Graze-Out

Cultural practices are similar to the wheat pasture alternatives. Stocking rate increases in spring to take advantage of the rapid vegetative growth. In the model, because the number of steers in spring are kept the same as in fall, the acreage for grazed-out is reduced, thereby increasing the stocking rate on the acres pastured. The steers are assumed to be off the wheat not for graze-out by April 1. Grain is harvested from those acres not grazed.

Steers on Wheat Pasture

The wheat and steers are managed in such a way as to avoid or minimize damage to wheat. When not grazing, the steers are fed grain sorghum, sorghum silage and protein supplement. When grazing, steers are fed grain sorghum and a mineral salt mixture to avoid grass tetany problems and additives added to control bloat. With these precautions, a death loss should be no greater than 1 percent, which is the loss assumed in the budgets.

For the alternative that allows grazing until April 1, it is assumed that the steers are placed into a drylot after April 1 until May 1.

Steers on Wheat Hay

When not on wheat pasture, the steers are in a drylot fed a ration of wheat hay, grain sorghum and protein supplement. No grazing is allowed after January 1. The number of steers is determined by the amount of wheat available for pasture. The fall stocking rate is 2 acres per steer. While on pasture steers are fed grain sorghum, mineral salt and bloat control additive.

Steers on Wheat Silage

The management practices are similar to the steers on wheat hay alternative except that wheat silage is fed replacing hay while steers are in drylot.

Steers on Wheat Graze-Out

Management practices are similar to that of steers on wheat pasture until April 1 alternative. Acreage for graze out is reduced after April 1 to one acre per steer. Intensive grazing allows better utilization or less waste of the forage. While in drylot, steers are fed grain sorghum, sorghum silage and protein supplement.

The Model

A linear programming model is used to select wheat crop alternatives that provide the highest return to operator labor and cropland. Operator labor and cropland limit the size of the steer and crop enterprises. Labor required and the amount available is specified for each of the 12 months and 4 specialized harvesting periods:wheat hay harvest, wheat silage harvest, wheat grain harvest and grain sorghum harvest.

The number of steers purchased is limited to a maximum of the number that can be pastured on wheat in fall. The stocking rate specified is two acres per steer so that the maximum number of steers possible is one-half the number of wheat acres.

All operating capital needed can be borrowed at an annual cost of 14 percent. It is assumed that all operating capital is borrowed for 6 months.

Part-time labor can be hired for three months during the summer; 518 hours per person for $2640. This would likely be high school and/or college student labor.

Custom harvesting of wheat is allowed. It is assumed that this farm situation has one combine. If more capacity is needed, custom harvestors can be hired for $13.00 per acre. Custom harvesting of grain sorghum is not allowed.

Results

Results of four scenarios are reported in Table 4. Scenario two allows the selection of any combination of alternatives to gain the highest return to land and labor; the other scenarios consider the selection of wheat for grain with one of each of the following; wheat for pasture, wheat for hay, wheat for silage or wheat for graze-out alternatives.

Scenario 1:Wheat for Graze-Out: This alternative is considered first, because the results show several significant points: (1) graze-out does not pay because using one acre for grazing provides $6.99 less return than if it is used for grain production. Consequently the result is cash crop only. (2) comparing the results of scenarios 2, 3,and 4 to this run shows the increase in returns from the steer enterprise.

Results show returns would be increased $33.45 for each acre taken out of wheat and put into grain sorghum. Limiting grain sorghum acreage to 309 acres is based on the time available for harvesting. If farmers in this region can acquire more harvest capacity in fall, they might well consider a higher percentage of their crop acres for grain sorghum. However, the percent of acres in grain sorghum is larger than that reported in farm management association records.

The penalty of $6.99 per acre for graze-out would be removed if the price of wheat were decreased $.21 and all other prices, costs and crop acre limits remain the same.

Scenario 2: Any Combination of Wheat Alternatives: This scenario allows the greatest flexibility in selecting enterprises within upper limits imposed on wheat and grain sorghum harvest time. This scenario, as expected, has the highest return to land and labor, $27,790.

This scenario selects 514 acres of wheat which is grazed until April 1, 257 steers, 35 acres of sorghum silage and 51 acres of grain sorghum. The sorghums are the forage and grain used in the ration. The steers are on pasture from October 15 to December 31 and again from February 15 to April 1. They are in drylot from October 1 to 15, January 1 to February 15 and April 1 to May 1.

No labor is hired as the flexibility to choose enterprises allows those combinations that use the available labor supply most efficiently, however, 222 acres of wheat is custom harvested so at this time labor and combine capacity available is inadequate to meet requirements.

Over 85 percent of the cropland is in wheat. This proportion is probably too high to allow adequate rotation with spring planted crops to avoid cheat problems.

The combination of crops selected by the model are also the combination frequently found on south central Kansas farms. The model selected the wheat pasture until April 1 alternative as providing the highest returns to operator labor and capital. The wheat acreage provides grain for cash market and pasture for 257 steers and the grain sorghum and sorghum silage are needed as livestock feed.

Grain sorghum acreage does not reach the upper limit specified. However, the combination of 35 acres sorghum silage and 51 acres grain sorghum and 257 steers' uses most of the fall labor available.

Scenario 3: Wheat for Hay: This scenario allows selecting wheat for either grain or for hay: the model does some of both. The selection of the crops and number of steers reduces the objective 6 percent below that for scenario 2.

Labor and time available to harvest wheat hay limits the number of acres for hay and consequently the number of steers purchased. In the model, some additional labor is hired to help with wheat hay and grain harvest. A value of $4.46 per hour is imputed to the value of labor for haying. If a manager does not organize activities very efficiently during the haying operation, or if rain frequently interrupts the work, then the returns for this scenario begin to decrease dramatically.

Most of the cropland, 92 percent, is planted to wheat, either for grain or hay. This specialization in wheat could cause problems in regard to control of cheat or other cool season annuals. Chemicals are available to help control or eliminate some of the weed or grass problems that can arise, but the management of that type of control is different than currently practiced by most farmers in the region.

Scenario 4: Wheat for Silage: This scenario allows selecting either wheat for grain or wheat for silage: the model does some of both. The returns to land and labor decrease 8 percent compared to scenario 2.

Scenario 4 has many similarities with scenario 3. The major difference is that more labor is hired and used mostly to help harvest wheat silage. Harvesting wheat silage has most of the same management problems as harvesting wheat hay. The equipment is different but the urgency and timeliness of the operation is the same as for a haying operation.

Summary

The alternatives of wheat for pasture, hay or silage are very feasible compared with wheat for grain. However, the alternatives represent very different management of crops and livestock and it appears that this is the major and significant difference among them. A wheat graze-out alternative does not seem to fit in except for some situations that require compliance with a government program such as PIK.

The potential for greatly increasing returns to land and operator labor by adding a steer enterprise to utilize a wheat forage seem reasonable if the farmer is a good manager of both, crops and livestock. Assuming good livestock management, the traditional program of utilizing wheat by fall and winter grazing supplemented with grain sorghum and sorghum silage is sound. This combination provides a good distribution of labor use throughout most months.

Two alternatives, wheat for hay or silage appear to provide nearly the same returns to land and labor as wheat pasture. The difficulty with these alternatives is the limited time and the weather problems during the critical 10-14 day harvest. Providing good quality forages, as is assumed in the model, could be a problem in many years. With lower quality wheat hay or silage, the feeding efficiency could be decreased.

Wheat put up for hay has some advantages over pasturing. Wheat land for pasture requires fencing either temporary or permanent; it may be inconvenient or very time consuming to provide supplemental grain, minerals or forages if the pasture is distant from the homestead; the size of the wheat field may be too small to allow pasturing many animals and providing adequate water may be difficult or time consuming. If only small parcels of land are available, then herds of the 200-257 size must be divided into smaller groups and located on several fields further increasing the inconvenience of watering and supplemental feeding. Wheat haying or ensiling operations can be done on small or parts of fields, although large and regular shaped fields are most desired.

Areas of Needed Research

Research is needed to identify strengths and weaknesses of other livestock alternatives in relation to different ways of using wheat pasture, hay or silage. Combining crop and livestock enterprises increases the complexity of the system. The need of managerial skill increases whenever the number and diversity of enterprises increases. The cash crop-livestock farmers need to do well in both areas to show good returns to the total farm. There are numerous ways that a livestock enterprise can interface with the crop system: there are numerous livestock systems and each with unique technical and management requirements. Models of farms are needed that test combinations of the multitude of crop and livestock enterprises to determine the effect on farm income and resource use.

Feeding wheat hay or silage expands the market for wheat. Research is needed to determine the advantages and disadvantages of these market alternatives. Until the time of hay or silage harvest, the farmer has several alternative ways of marketing the crop. But if the wheat is put up for hay, or silage or kept for grain, the marketing flexibility decreases.

Using wheat for hay, silage or pasture changes the risk element of farming. The extent of increasing or decreasing risk needs to be studied. These uses of wheat change the time when feeds are harvested as compared to the traditional system; it changes the labor use during the year; it changes machinery use; it can change when livestock are marketable and marketed and it can change cropping practices. The challenge will be to describe the elements of the risk involved in a meaningful and operational way to farmers.

References

Anderson, K.L., "Winter Wheat Pasture in Kansas", Kansas Agricultural Experiment Station Bulletin 345, 1956 pp. 1.

Kuhl, G, Scott Laudert, "Wheat for Silage and Hay", Kansas Focus on Feedlots, Department of Animal Science, Kansas State University, April 1983.

Laudert, Scott, "Wheat Pasture Graze Out", Southwest Extension Livestock Specialist at Garden City, Kansas, Kansas State University.

Oltjen, J.W., Keith Bolsen, "Wheat Barley and Oat Silages for Beef Cattle" Kansas Agricultural Experiment Station Bulletin 613R, April 1983, Manhattan, Kansas.

Oltjen, J.W., K. Bolsen, L. Johnson, "Small Grains for Hay or Silage for Beef Cattle", Great Plains Beef Cattle Handbook GPE-2902.

Table 1: Ration, grazing practice, stocking rate and wheat grain and forage production byforage system, for south-central Kansas.

	wheat for grain only	wheat for grain and pasture until April 1	wheat for grain and pasture until May 1	wheat cut for hay	wheat, graze out	wheat, cut for silage
Wheat Planting Time (S.C. Kansas)	Oct. 1	Sept. 15	Sept. 15	Sept. 15	Sept. 15	Sept. 15
Wheat seeding rate, pounds per acre	60	75	75	75	75	75
Fertilizer application						
pounds N	50	67	67	67	67	67
pounds P_2O_5	25	31	31	31	31	31
Yield per acre						
grain, bushel per acre	34	34	30	0	0	0
forage, ton per acre				3.4		
silage, ton per acre (40% D.M. is grain)						8.5
Pasture periods	-	10/15-12/31 2/15-4/1	10/15-12/31 2/15-5/1	10/15-12/31	10/15-12/31 2/15-6/1	10/15-12/31 -
Number of Days on wheat pasture	-	120	150	75	180	75
Date steers purchased	-	Oct. 1	Oct. 1	Oct. 1	Oct. 1	Oct. 1
Date steers placed on wheat pasture	-	Oct. 15	Oct. 15	Oct. 15	Oct. 15	Oct. 15
Date steers removed from wheat pasture	-	April 1	May 1	Dec. 31	June 1	Dec. 31
Date steers sold	-	May 1	May 1	May 1	June 1	May 1
Number of days owned	-	211	211	211	241	211
Beginning weight, pounds	-	400	400	400	400	400
Ending weight, pounds	-	770	770	770	825	770
Rate of gain, pounds per day	-	1.75	1.75	1.75	1.75	1.75
Stocking Rate, head per acre						
Oct 15 - Dec 31	-	.5	.5	.5	.5	.5
Feb 15 - April 1	-	1.3	1.3	-	1.3	-
April 1 - May 1	-	-	1.3	-	1.0	-
May 1 - June 1	-	-	-	-	1.0	-

Table 1, cont'd

Ration						
Oct. 1 - Oct. 15 (15 days)						
grain sorghum (2.4 lbs/steer/day)	-	36	36	36	36	36
sorghum silage (26.7 lbs/steer/day)	-	400	400		400	
wheat hay, pounds	-			160		
wheat silage, pounds						400
protein supplement, pounds	-	23	23	7.5	23	4
Oct. 15 - Dec. 31 (75 days)						
grain sorghum (3 lbs/steer/day)	-	195	195	195	195	195
wheat pasture	-	x	x	x	x	x
Jan. 1 - Feb. 15 (45 days)						
grain sorghum (3 lbs/steer/day)	-	135	135	135	135	135
sorghum silage (34 lbs/steer/day)	-	1530	1530		1530	
wheat hay, pounds				612		
wheat silage, pounds	-					1530
protein supplement, pounds	-	86	86	26	86	9
Feb. 15 - April 1 (45 days)						
grain sorghum (3.2 lbs/steer/day)	-	142	142	142	142	142
sorghum silage	-	(pasture)	(pasture)		(pasture)	
wheat hay (14.0 lbs/steer/day)	-			634		
wheat silage (35.3 lbs/steer/day)						1587
protein supplement, pounds	-			48		13
April 1 to May 1 (30 days)						
grain sorghum (3.4 lbs/steer/day)	-	102	102	102	102	102
sorghum silage (38 lbs/steer/day)	-	1150	(pasture)		(pasture)	
wheat hay (13.6 lbs/steer/day)	-			407		
wheat silage (3.8 lbs/steer/day)	-					1150
protein supplement, pounds	-	66		36		12
May 1 to June 1 (30 days)						
grain sorghum (3.4 lbs/steer/day)	-	(sold)	(sold)	(sold)	102	(sold)
Total feed requirements, per steer						
grain sorghum, pounds	-	610	610	610	712	610
sorghum silage, pounds	-	3080	1930		1930	
wheat hay, pounds				1740		
wheat silage, pounds						4667
protein supplement, pounds	-	175	109	118	109	38

Table 2. Cost and return budgets for wheat crop alternatives

	Wheat for grain	Wheat for grain and pasture(1)	Wheat for grain and pasture(2)	Wheat for hay	Wheat for silage	Wheat graze out	Grain sorghum	Sorghum silage
Yield per acre, bushel	34	34	30				55	
ton				3.4	8.5			12.8
Unit price	3.50	3.50	3.50	-	-		2.50	-
Costs:								
Seed	6.00	7.50	7.50	7.50	7.50	7.50	3.35	3.35
Herbicide	2.50	2.50	2.50	2.50	2.50	2.50	10.00	10.00
Fertilizer	15.00	19.50	19.50	19.50	19.50	19.50	16.60	16.60
Fuel & oil	10.50	10.50	10.50	8.00	8.00	8.00	12.50	12.50
Machinery & equip. repairs	11.00	11.00	11.00	9.00	9.00	9.00	13.00	13.00
Miscellaneous	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Custom Harvest				29.47	35.28			53.26
Real Estate taxes	5.10	5.10	5.10	5.10	5.10	5.10	5.10	5.10
Depreciation on crop machinery	17.85	17.85	17.85	12.85	12.85	12.85	19.65	14.65
Taxes, Insurance on machinery	12.50	12.50	12.50	10.00	10.00	10.00	13.75	11.25
Total	84.45	90.45	90.45	114.92	113.73	78.45	97.95	143.71

1. Hay and silage tonnage based on grain yield: 40 percent of total dry matter comes from grain.
2. Custom harvest rates used: $4.15 per ton for silage, $7.00 per acre for swathing hay and $6.50 per 1500 lb. bale.

Table 3. Cost and returns budgets for stocker steer budgets

	steer on pasture	steer on wheat Hay	steer on silage	steer on graze out
Beginning weight, pounds	400	400	400	400
Purchase price, $ per c.w.t.	71	71	71	71
Selling weight	770	770	770	825
Selling price, $ per c.w.t.	66	66	66	66
Daily rate of gain, pounds	1.75	1.75	1.75	1.75
Costs				
Mineral salt	3.50	3.50	3.50	3.50
Rumensin	2.95	2.95	2.95	2.95
Grain processing	2.72	2.72	2.72	2.72
Veter., drugs & supplies	8.00	8.00	8.00	8.00
Marketing (3% of gross inc)	15.25	15.25	15.25	16.34
Fuel, oil, repairs	16.00	16.00	16.00	16.00
Death loss (1% of gross inc)	5.08	5.08	5.08	5.45
Depreciation, barns and pens	6.25	6.25	6.25	6.25
Depreciation, hay storage		.98		
Depreciation, silo and equip.	2.55		4.00	
Insurance, taxes	7.92	6.51	9.23	5.63
Total	70.22	67.24	72.98	65.38

Table 4. Returns to land and labor, selection of enterprises and value of additional units by scenario.

	unit	Scenarios 1	2	3	4
Return to land and labor	$	20372	27790	26134	25600
Enterprise selection					
Wheat for grain	acre	290	-	477	473
Wheat pasture until April 1	acre	-	514	-	-
Wheat pasture until May 1	acre	-	-	-	-
Wheat for hay	acre	-	-	76	-
Wheat for silage	acre	-	-	-	74
Wheat graze out	acre	($6.99)	-	-	-
Sorghum silage		-	35	-	-
Grain sorghum	acre	309	15	47	52
Number of steers	no	-	257	238	236
Borrow capital	$	16318	98084	85897	84056
Custom harvest wheat	acre	55	222	209	95
Hire labor	no	-	-	.55	2.0
Value of an additional unit					
Grain sorghum	$ per acre	33.45	-	-	-
July labor	$ per hr.	13.54	13.54	13.54	13.54
Wheat hay labor	$ per hr.	-	-	4.14	
Wheat silage labor	$ per hr.	-	-	-	5.86
Cropland	$ per acre	21.19	39.06	37.63	35.58

MICROCOMPUTER ANALYSIS OF WHEAT GRAIN-GRAZEOUT ALTERNATIVES UNDER THE 1984 GOVERNMENT PROGRAM

Kim B. Anderson and Odell L. Walker*

Summary

Producers willing to participate in government programs can reduce risks and increase expected returns by choosing the 30 percent ARP program wheat option for 1984. However, results depend on wheat yield and price and grazing return expectations. A microcomputer program allows evaluation of alternatives quickly and accurately. The program used in this study also considers risks of farmers' alternatives. Results indicate that changes in government program provisions could cause substantial swings in cattle demand across the wheat pasture season.

Introduction

Federal farm programs designed to influence grain production and prices also affect winter and grazed out wheat pasture acreages and seasonal prices of stocker cattle. Grain producers who have cattle operations or rent out pasture can consider the value of pasture in analyzing program alternatives. Policymakers, commodity buyers and handlers, and input suppliers must analyze program alternatives to anticipate probable farmer decisions. A microcomputer program to aid producers and others in evaluating farm program alternatives is illustrated in this paper (1).

Time consuming and tedious calculations are required to determine which farm program alternative to select. The microcomputer is ideal for handling the calculations, and program changes from one year to the next are easily incorporated into the computer program. As a result, the user can emphasize the development of suitable price and yield data and interpretation and analysis of results.

1984 Wheat Program Provisions

Basic provisions of the 1984 wheat program are as follows:

1. The target price is $4.45/bushel.

2. The national average loan rate is $3.30/bushel. This implies a maximum deficiency payment of $1.15/bushel.

3. There will be no advanced deficiency payments.

---

*Authors are Assistant Professor and Extension Economist and Professor, Department of Agricultural Economics, Oklahoma State University.

4. Producers must limit 1984 wheat planted acres to no more than 70 percent of the farm's wheat base and devote to conservation use an acreage of eligible cropland equal to 42.86 percent of the 1984 planted and PIK acreage.

5. The 1984 base will be the average of planted and considered planted acres for 1982 and 1983. Yields per rotation farms are the average of last two planted years.

6. A 10 to 20 percent PIK will be offered.

7. PIK compensation will be 75 percent of the ASCS program yield and will come from outstanding loans or reserve wheat or the producer can plant for PIK. But, if sufficient wheat is not produced to meet PIK needs, compensation will not be paid.

8. Haying will not be permitted on the conservation use acreage.

9. Grazing will be allowed during the six principle growing months (e.g. Nov. - Apr.).

10. There will be no immediate entry into the reserve program. USDA may limit entry into the 1984 reserve program.

11. Contracts signed by program participants for either the ARP or PIK will be considered binding, and penalties will be assessed for non-compliance.

12. Sign-up will be between January 14 and February 26. Contracts can be withdrawn before February 26 with no penalty.

Program Analysis

The data inputs at the top of Table 1 are required in the analysis. Risk is introduced by defining optimistic, expected and pessimistic wheat yields and prices. The chance of a yield or price between the optimistic and pessimistic price is four-in-six, the chance of a yield or price greater than the optimistic level is one-in-six and the change of a yield or price less than the pessimistic level is one-in-six.

Price data are based on a Kansas City Board of Trade, July 1984 Wheat Futures price of $3.89 minus a $.50 basis. A 12-month forecast of wheat prices based on the Futures price has a root mean squared error of 18 percent (2). Thus, the optimistic and pessimistic prices are the expected prices times 1 + .18 [i.e. 3.39(1.18) = 4.00 and 3.39(.82) = 2.78]. Optimistic, expected and pessimistic yields can be based on farmers yield experiences. ASCS program yields are assumed to equal the expected yield.

Production costs are \$105 per harvested acre and \$85 per acre for non-harvested acre. The costs imply a \$20 harvesting cost. The possibility that harvesting costs will vary with yields is not programmed in the microcomputer model.

Optimistic, expected and pessimistic returns per acre are presented in Table 1 for the program options, including non-participation. Expected net returns per havested acre are:

$$[E(P) - \frac{Cost}{E(Y)}]\, E(Y) = \text{Expected net returns per bushel times expected yield}$$

Assuming that returns are normally distributed, optimistic and pessimistic returns are expected returns plus or minus one standard deviation of returns. The standard deviation of returns from wheat was approximated by:

$$\sqrt{Var(P - \frac{cost/acre}{Y})}$$

times expected yield. A correlation of -.1 was assumed between price (P) and yield (Y).

To provide a base reference point the net return per acre results in Table 1 do not reflect a value for either winter or spring grazing. Assuming that the total acres in the non-participation alternative are the same as participation acres, the 30 percent ARP alternative is more profitable and less risky than the non-participation alternative.[1] Non-participation allows a large chance of a negative return. Non-participation has a one-sixth chance of a return less than \$-18 per acre compared to \$2 for 30 percent ARP. The upside potential is slightly greater for non-participation. The major reason for favorable returns from ARP is the potential \$1.15 per bushel deficiency payment. The deficiency payment is paid on the ASCS program yield for harvested acres. The two alternatives have the same winter grazing but the ARP alternative would allow .3 of the total acreage to be grazed out. Hence, it may be even more profitable. The effect of the grazeout on expected returns and risk needs analysis.

Value of Grazing

Inputs and results for program alternatives with pasture values included are presented in Table 2. Values of pasture are based on a pasture rental rate of \$2.25 per cwt. of cattle per month. Optimistic, expected and pessimistic head per acre stocking rates for a 450 pound steer in winter are .5, .35 and .2, respectively. Rates for a 600 pound steer in spring are 1.5, 1 and .5.

---

[1] Arithmetic in the program adjusts net returns per acre for the portion of an acre harvested and non-harvested so that net returns per acre times total acres equals total net returns.

As expected, the pasture adds to the advantage of placing land in a conserving use and receiving program benefits. All participation options have higher expected returns than non-participation (Table 2). Valuing pasture makes expected returns from the participation options very close.

The standard deviations of returns from winter and spring grazing were included in the risk analysis. Pasture did reduce risks of all alternatives, including non-participation. However, a zero correlation between grain and grazing returns was assumed. The two PIK alternatives allow .4 and .5 acres to be grazed out. Their expected returns are lower, the downside risks are slightly greater and the upside potential is lower.

Many livestock-grain producers buy stockers for winter grazing and then consolidate them on fewer acres in the spring when pasture growth explodes. For example, if wheat stocked at .5 stockers per acre in winter will carry 1.67 stockers per acre in spring, stockers on 100 acres can be consolidated to 30 acres and just match the 30 percent conservation acres under the ARP alternative. The additional grazing from the two PIK alternatives would allow a lower spring stocking rate (1.25 head per acre with 10 percent PIK and 1.0 head per acre with 20 percent PIK). Alternatively, additional cattle could be brought in or extra pasture could be rented out. However, with no value assigned for the additional grazing from PIK acres, the worst PIK alternative has a higher expected return then non-participation ($31.58 vs. $27.83).

Wheat price and yield expectations will differ among producers, as will potential returns from grazing. The microcomputer model is convenient for evaluating a wide range of values and alternatives. For example, breakeven yields, prices or grazing returns can be computed by iterative techniques.

In some cases a producer's ASCS base acres may be substantially less than the potential planted acres. For example, under non-participation the planted acres might be 300 whereas the base acreage is only 150. The appropriate comparison is returns from the 300 acres with non-participation versus returns from the 300 acres with participation in one of the options. If grazeout is the only other land use alternative, the computer model can be modified to calculate grazing returns from the additional acreage.

Table 1

Inputs and Results: 1984 Wheat Program Base Analysis--
No Value for Pasture

Inputs:	Price/Bu.	Yield/Acre
Optimistic	$4.00	41
Expected	$3.39	35
Pessimistic	$2.78	29
ASCS Program Yield		35

	Non-Participation	30% ARP	30% ARP 10% PIK	30% ARP 20% PIK
	---Net Return/Acre---			
Optimistic	$41	$36	$30	$23
Expected	$14	$17	$14	$ 9
Pessimistic	$-18	$ 2	$ 1	$-2
Probability of a Loss	33%	13%	14%	20%

Table 2

Inputs and Results: 1984 Wheat Program--
Value of Pasture Included

Inputs	Winter Grazing	Grazeout
	---Net Return/Acre---	
Optimistic	$20	$40
Expected	$14	$27
Pessimistic	$18	$14

	Non-Participation	30% ARP	30% ARP 10% PIK	30% ARP 20% PIK
	---Net Return/Acre---			
Optimistic	$56.01	$59.70	$57.25	$53.78
Expected	$27.83	$39.09	$38.77	$36.98
Pessimistic	$-4.69	$22.74	$23.74	$22.77
Probability of a Loss	.20	.01	.01	.01

References

1. Anderson, Kim B. and Daryll E. Ray. Risk Rated Decision Making Series: Viscalc Template to Analyze the 1984 Government Wheat Program, Oklahoma Agricultural Extension Current Report, No. 326, November 1983.

2. Just, Richard E. and Gordon C. Rausser. Commodity Price Forecasting with Large Scale Econometric Models and the Futures Market, American Journal of Agricultural Economics 63 (1981): 197-208.

VII. FUTURE USE OF WHEAT PASTURE IN BEEF CATTLE PRODUCTION SYSTEMS

International Markets and the Wheat-Feed Grain Industries*

by

James S. Plaxico**

In the early 1970's a series of events combined to bring about a fundamental structural change in U.S. agriculture. It is unlikely that we will ever go back to a 1960's like structure. Yet, unfortunately, we have been slow to recognize the importance of international markets, prone to assume that many of the events of the past decade are short term aberations, and that the old structure will be reestablished. Consequently we have failed to restructure our agricultural policies and strategies in a manner consistent with current realities.

In this paper the forces which have restructured agricultural trade are outlined, some of the major trends are traced, and some major policy alternatives are identified. Finally, some major implications for the livestock industry are cited, with emphasis on the small grain grazing sector.

What Happened?

We all prefer simple explanations, but simple answers to complex questions too often lead to erroneous actions. A truly remarkable set of inter-related policy decisions occurred in the early 1970's. After three decades of fixed exchange rates, the United States in 1973 opted to go to essentially floating exchange rates. At that time the U.S. dollar was "overvalued", thus floating rates had the effect of reducing the cost of U.S. farm commodities to buyers in other countries. About the same time we established closer diplomatic ties with several countries, notably China and Russia. Meanwhile, significant economic development was occurring in certain third world countries. In addition, the Soviets decided to import grain to make up their production short-fall rather than restrict consumption.

Each of these events, more accurately policy decisions, enumerated above had the effect of increasing world trade in agricultural commodities. Since the U.S., at that time, was the only nation with the commodity stocks and productive capacity to serve the increasing demand, U.S. exports literally exploded. Farm income in

---

* Presented at the National Wheat Pasture Symposium, Okla. State University, Oct. 23-35, 1983.

** Professor, Department of Agricultural Economics, Oklahoma State University.

1973 reached an all time high that, in per capita terms, surpassed non-farm incomes for the first time ever in any country in any year. Agricultural policy administrators and farm leaders were euphoric. Storage bins were demolished, farmers invested heavily to expand production capacity, and a continuing "golden age" for agriculture was widely, but not wisely, predicted.

Agricultural exports grew rapidly during the 1970's with each year setting a new record in terms of dollar values (Figure 1). The dollar volume of both wheat and feed grain exports increased rapidly during the 1970's and the physical volume of grain exports also trended upward. But all was not well in the agricultural economy. We soon discovered that producers in other countries are responsive to price incentives and that policies can be modified and changed.

Our agricultural exports declined in fiscal 1982, and again in 1983. The "simple" explanation for the decline in our exports is the 1980 embargo on exports to USSR. A more viable rationale is that there have been shifts in the same variables that stimulated the boom of the early 1970's. The dollar has become very valuable in terms of other currencies, world economic growth rates have slowed, and diplomatic relations with several countries have "cooled". Each of these changes have reduced the demand for US products in world markets because the cost of the goods in terms of local currencies has increased and foreign exchange is limited by slow growth rates.

In addition to the demand factors cited above, other nations are competing vigorously for international markets and we have been on the verge of ruinous "trade wars" with other exporters, notably the ECC. Finally in 1983, US grain stocks reached levels unacceptable to either farmers or consumers. The expensive PIK program may contribute to stock reductions and the dry summer of 1983 could have major impact. It should now be obvious that domestic agricultural income and price support programs impact on exports. Still there is little evidence that we are developing a coherent export policy, with a consistent set of domestic programs that properly serve the interests of producers and consumers.

After a remarkably stable two decades during the 1950's and 1960's, the 1970's and so far in the 1980's have been extremely volatile in terms of agricultural prices and incomes. It should now be apparent to all that we are no longer an economic island nor a self contained economy. Rather the U.S. is a part of what is rapidly becoming a one-economy world linked by international capital markets. This being the case, the U.S. is no longer isolated from economic fluctuations generated in international markets and agricultural incomes are export dependent. Consequently domestic fiscal-monetary programs and agricultural programs are less cost effective than had been true in the past when events in other parts of the world could be conveniently ignored.

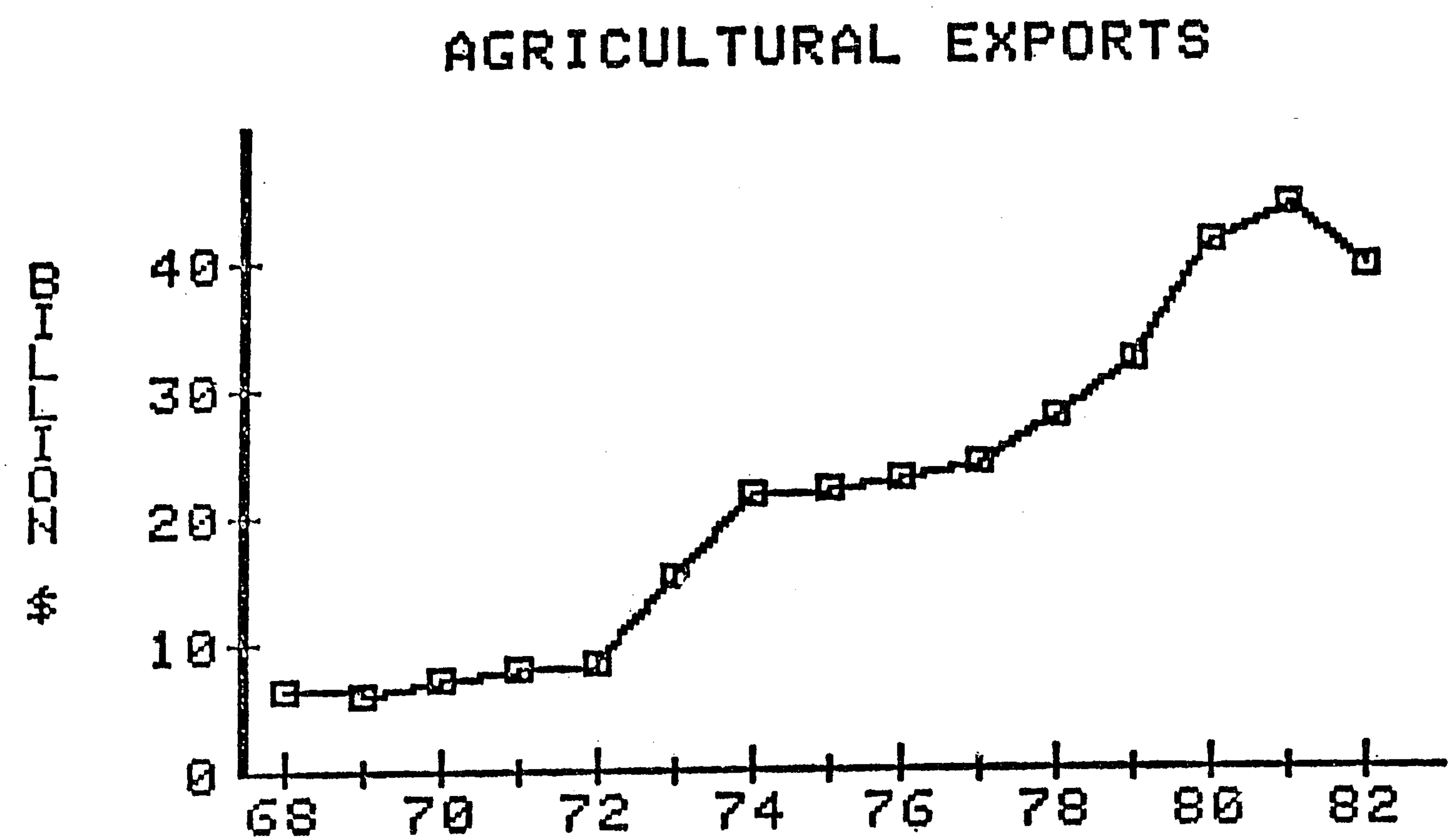

AGRICULTURAL EXPORTS
BILLION $
0
10
20
30
40
68
70
72
74
76
78
80
82

FIGURE 1

The Policy Choices

An unfortunate fact is that, to date, no coherent U.S. agricultural export policy exists. It is generally agreed that increasing exports benefit producers and the general economy. Consumers in this country indirectly benefit from agricultural exports, but consumers become apprehensive when food prices rise as a result of export demand. Livestock producers find it difficult, to say the least, to adjust to volatile export volumes. All would benefit from greater stability in exports.

The range of policy alternatives available may be roughly summarized as follows:

(1) Seek to expand and stabilize export markets through trade promotion activities supported by negotiations directed to a greater stability of demand and improved access to markets.
(2) Develop bi-lateral trade agreement with various countries in order to stabilize and expand demand.
(3) Create a national system or institution to manage export promotion and sales.
(4) Create an organization of major producing countries to develop and manage world trade in major agricultural commodities.

Increased emphasis on export market development seems to enjoy general support. However the manner in which such efforts are organized is a subject of much discussion. Currently U.S. export development activities are dispersed among the Office of the Special U.S. Trade Representative, and the Departments of State, Agriculture, Commerce, and Treasury. A current administration proposal is to consolidate trade matters in a new cabinet level Department of Trade.

There are inevitable trade-offs in trade development negotiations. Although agriculture is one of our very few internationally competitive industries, it is not clear that the industry has fared well in the various series of negotiations. Already concern in being expressed that agricultural interests would not be properly represented in a Department of Trade.

Currently the U.S. has three bilateral trade agreements. These are with Mexico, China, and U.S.S.R. This is in contrast to Canada with 13 bilateral trade agreements. In the past, we have avoided bilateral agreements. The basis for our posture on this issue is not clear but seems to be based on the concern that if substantial quantities of grain is committed in bilateral agreements, a hardship would be imposed on developing countries in periods of short supplies. However, it appears that with other exporters activity seeking such agreements, we are again placed in the uncomfortable position of being residual suppliers. Thus a reconsideration of our posture may be in order.

For all practical purposes private companies, both domestic and foreign, trade US grains in world markets. In contrast, Canadian wheat exports are controlled by the Canadian Wheat Board. However the private trade handles many of the logistical details of Canadian exports. Much has been written and said about the relative merits of the two systems. Valid comparisons are difficult due to the different production conditions in the two countries and because of a very special transportation agreement in Canada. Perhaps each country has the optimum system for it's own situation. Nevertheless, the need for a better integration of domestic and export programs is obvious. Thus a closed "mind-set" with regard to our grain export system would appear inappropriate.

As noted above, other producing countries are responsive to prices and have greatly expanded their capacity to produce grains for the export market. This tendency is particularly evident in the EEC where farmer prices are supported at very high levels and production has increased at a rapid rate. Consequently stocks have grown to the point that exports are being heavily subsidized. Without doubt the EEC subsidies have affected U.S. exports. As is the case in this country, the EEC urban press is highly critical of the high cost of farm programs, including the export subsidies. For us to attempt to match subsidy levels is unlikely to be rewarding. Perhaps a better tactic would be to join with other export nations for the general benefit of exporters. Research in the area is surprisingly sparse, but results to date suggest that the U.S., Canada, Australia, and the EEC control a sufficient portion of the world wheat and feed grain production so that with effective market management, producer incomes could be substantially enhanced.

Not everyone finds producer country control groups acceptable. It is easier to find fault with an alternative than to analyze the merits of the proposal. Most economists are prone to emphasize the organizational difficulties and the always present incentives to over-produce and thus render the organization ineffective. Some economists continue to predict dire results "just around the corner" for OPEC. Unfortunately there appears to be little visible current farmer or general political support for a multi-country grain marketing organization. Nevertheless, in light of current realities, it is an alternative that merits extensive discussion and consideration.

Implications for Grain and Livestock Producers

Agricultural production, particularly livestock production, involves long production periods. Investments made and plans activated bear fruit many months later. This lag between the time a production decision is made and the time the product comes to market, can be a serious problem in a volatile environment. A greater degree of stability in agricultural commodity prices could be beneficial to both producers and consumers.

Although livestock constitute a rather modest portion of US trade, livestock producers are not immune from the impacts of trade volume gyrations. Domestic government commodity programs do not directly affect livestock output or prices, but they have major indirect impacts. It is very difficult for program administrators to anticipate trade demand, and the cost of a wrong decision are high. Thus programs are typically announced too late to permit systematic planning. Late program announcements are a major problem for both grain and livestock producers. The magnitude of year to year change in programs is also a problem. Reflection over the nature of programs over the past few years should illustrate this point quite well.

In many respects the livestock industry is the "buffer" that absorbs variations in year to year grain supply-demand balances. Modest changes in available grain supplies can be absorbed by the livestock industry, without great stress, by marginally expanding or contracting numbers, adjusting weights, etc. Large supply shifts are another matter because they require major adjustments. It seems clear that the "wrong end" of the mid 1970's cattle cycle was intensified by the tremendous demand for grain for export which in turn dictated a major contraction in the livestock sector.

Volatile exports affect wheat grazing operations in several ways. Grain supplies impact on the demand for cattle coming off wheat pasture, program regulations affect the supply of wheat pasture, and large changes in the availability of "graze out" wheat can have significant impacts on livestock prices and the value of the grazing. Thus although wheat pasture operations are far removed from the export market, they are certainly not insulated from it's effects.

It should now be abundantly clear to all that domestic programs no longer have the capacity to stabilize nor raise farm commodity prices at acceptable levels of government costs. It would appear that the alternatives are clear. Either producers and consumers must learn to live with volatile prices and incomes or we must develop institutions consistent with current realities relating to international markets. Either alternative involves costs. Volatility inevitably leads to higher production costs due to resource misallocations caused by uncertainty. On the other hand, institutions that reduce uncertainty involve loss of individual producer freedoms.

Agricultural trade and policy issues are researchable. During the late 1920's and the 1930's, numerous agricultural policy and program ideas were advanced, evaluated, and discussed. Unfortunately, the last "new" agricultural program idea was developed in 1945 when the notion of "forward pricing" of agricultural commodities was advanced. That idea is the basis for our target price - current deficiency payments programs. In this, the post 1970's new agricultural environment, there is a dire need for ideas and evaluative research. There is little doubt that world agricultural production will more than adequate over the decade. Until we structure international and domestic institutions and policies in a manner consistent with current economic realities, the agricultural industry will make a less than optimal contribution to the nations economic growth and development.

IMPACTS OF GOVERNMENT POLICY DECISIONS ON PRODUCTION AND USE (GRAIN HARVEST VERSUS GRAZING) OF WHEAT PASTURE

Kim B. Anderson and Luther Tweeten*

Only minor changes have been made in the government wheat program since the domestic allotment was dropped in the 1973 wheat program. In the 1973 program, the target price, deficiency payments, base area and base yields were introduced (Table 1). Disaster payments were included in the government programs through 1979.

TABLE 1
GOVERNMENT WHEAT PROGRAM SUMMARY

YEAR	LOAN	TARGET	SET-ASIDE	BEGINNING STOCKS
				(Thousand Bu.)
1971	$1.25	N/A	YES	
1972	$1.25	N/A	YES	
1973	$1.25	N/A	YES	985
1974	$1.37	$2.05	NONE	599
1975	$1.37	$2.29	NONE	339
1976	$2.25	$2.29	NONE	435
1977	$2.25	$2.47	NONE	666
1978	$2.25	$3.05	20%	1,113
1979	$2.35	$3.40	20%	1,178
1980	$2.50	$3.63	NONE	924
1981	$3.20	$3.81	NONE	902
1982	$3.55	$4.05	15%	989
1983	$3.65	$4.55	20% + PIK	1,164
1984	$3.30	$4.65	30% + PIK	1,541

To participate in the government program, a producer was required to sign-up and declare planted acres, harvested acres and yield per acre. Also, during periods of relatively high wheat stocks, producers were required to set-aside a certain percentage of the base acres.

Set-aside acres were required in 1971, 1972, 1973, 1978, 1979, 1982, 1983 and 1984. In 1978, 1979, 1983 and 1984, haying and grazing in the six principal growing months were allowed. In 1982, winter wheat producers were allowed to graze past the six principal growing months if the wheat had been planted before the program was announced. In 1983, grazing after the six principal growing months was allowed if the producer signed-up for the minimum payment-in-kind program.

Planted Versus Harvested Acres

Set-aside acres affect the profitability of grazing-out stockers. As discussed in an earlier paper by Anderson and Walker and the paper by

*Presented by Keith Scearce

Trapp, government programs reduce the cost of providing wheat pasture after the traditional winter grazing period. If the government program offers the highest total net return without stockers, then the only additional cost of providing pasture is the additional fertilizer costs. Of course, this assumes that wheat producers plant wheat as a cover crop on the set-aside acres. Some producers use volunteer wheat as cover. For them, the wheat pasture costs would be higher.

An important consideration is the amount of set-aside required to graze-out stockers. Generally, it is not profitable to purchase stockers just for spring grazing. Thus, winter stockers are required to have the graze-out alternative. If the winter stocking ratio is one stocker to two acres and the spring stocking ratio is one and two-thirds stockers per acre, than a set-aside of 30 percent would be ideal. Only in the 1983 program which included PIK and the 1984 program were the set-aside requirements 30 percent or more. In prior years, stockers had to be sold, a lessor number wintered than possible, or wheat grazed-out rather than harvested.

Data is not readily available to determine historically how many stockers have been grazed-out. But, the acres available for graze-out can be calculated by subtracting the harvested acres of winter wheat from planted acres. Not all planted acres of winter wheat had sufficient growth to support winter stockers. But, the change in harvested minus planted acres could indicate changes in wheat graze-out.

Data shows that harvested wheat acres are always less than planted acres. A plot of planted compared to harvested acres is shown in Figure 1, and a plot of planted minus harvested acres of winter wheat is shown in Figure 2. Comparing the differences between harvested and planted acres for years that set-aside acres were and were not included in the government wheat program does not lead to a direct conclusion that less wheat pasture was available for years that set-aside was included in the program. This could be because many wheat producers may not have the desire nor knowledge to raise stockers.

If the government program is announced before winter wheat is planted, an option is to not plant the wheat. This appears to be the case in 1978 and 1979. The difference between planted acres and harvested acres (the increase in the acres available for grazing) increased in 1972, 1976, 1977, remained level in 1978 and 1979, declined in 1980 and remained relatively low in 1981, and increased in 1982 and dramatically in 1983. Set-aside was associated with the relatively high differences. Only in 1973 was there a relatively low difference and a set-aside program. The inference could be drawn that there is some relationship between set-aside and the tendency to graze-out.

Future Farm Policy

The best guess is that 1985 legislation will contain current farm programs in modified form. Before listing some possible modifications, let's look at some new directions in farm policy being proposed. The changes are designed to reduce Treasury outlays while providing farmers income protection and competitive pricing in world markets without supply control. Four proposals are:

(1) Revenue insurance: Farmers and the government would share premium costs of an insurance program. Price supports and production controls would be terminated. Farmers could elect coverage of 50, 60 or 75 percent of normal receipts, with higher premiums for the successively higher levels of revenue protection. Given problems encountered by the government in administering crop insurance and aversion of farmers to paying costs of an income stabilization program, this proposal will have few supporters.

(2) A two-price program: Mandatory controls to reduce output to levels that would bring favorable farm prices and incomes without payments to farmers seem out of the question politically because much of the farm export market would be lost. A two-price program is more appealing. It would operate by issuing farmers certificates based on a domestic allotment. Domestic buyers would be required to pay at least say 75 percent of 1910-14 parity prices on certificate commodities. Additional output would be sold in the international market at world prices.

Because farmers would receive the lower world price on additional output--a strong disincentive to overproduce--supply control would not be required. This approach would make the U.S. competitive in world markets. Farmers wishing to compete in export markets would be restricted only by price. The domestic certificate portion would be very difficult to police and consumers would strongly oppose higher food costs.

(3) A direct payment program: Some farmers and many nonfarmers concerned with farm legislation strongly favor a "structure" policy to discourage large farms and encourage small farms. They favor stringent payment limitations in a program to focus payments solely on small and medium-size family farms. Payments might be made only to farm operators so that efforts of landlords to divide large units among many operators to get full payments would bring about more small farms.

Because larger operations that account for most farm production must be included to control supply, tight payment limitations of only say $10,000 per recipient could virtually rule out voluntary acreage diversion programs. A cap would probably be placed on the Farmer-Owned Reserve.

(4) An export marketing board or cartel: Some are saying that farmers could get good income by using an export marketing board or cartel of food exporters to discriminate among markets. The objective would be to charge Japan, the common market and centrally planned countries a high price. Developing countries, whose market is sensitive to price, would be charged a lower price; thus, expanding imports and

increasing revenue. The proposal would raise receipts for a few years but would eventually reduce our export receipts as other countries expand production and take over markets.

Despite talk of a crisis in farm policy and of radical departures from current programs, the above proposals have little chance of legislative approval. The best guess is that Washington will stay with "comfortable" current programs but with modifications to reduce Treasury costs and to be more responsive to world markets.

Candidates for modification include using a moving average of market prices to set loan rates and target prices--if target prices are retained at all. The moving average support might be from market prices of seven previous years, dropping the highest and lowest year. A variant would be to retain target prices adjusted according to a moving average of market prices but to give the Secretary of Agriculture flexibility in setting loan rates. In this, he would be constrained from setting loan rates too high by the high cost of excess production and stocks generated thereby. He would be constrained from setting loan rates too low by the high deficiency payments that would result.

This scenario would require retention of voluntary acreage diversion program provisions to control excess output likely to be generated. Because large farms which account for most farm output must be included to make acreage control programs effective, this program would not place much emphasis on payment limitations. The Farmer-Owned-Reserve (F-O-R) would be retained. A cap on F-O-R would serve little purpose because it would cause surplus commodities to fall into the hands of the Commodity Credit Corporation when loan rates exceed market prices. F-O-R stocks are preferred to government-owned stocks.

FIGURE 1. U.S. WINTER WHEAT

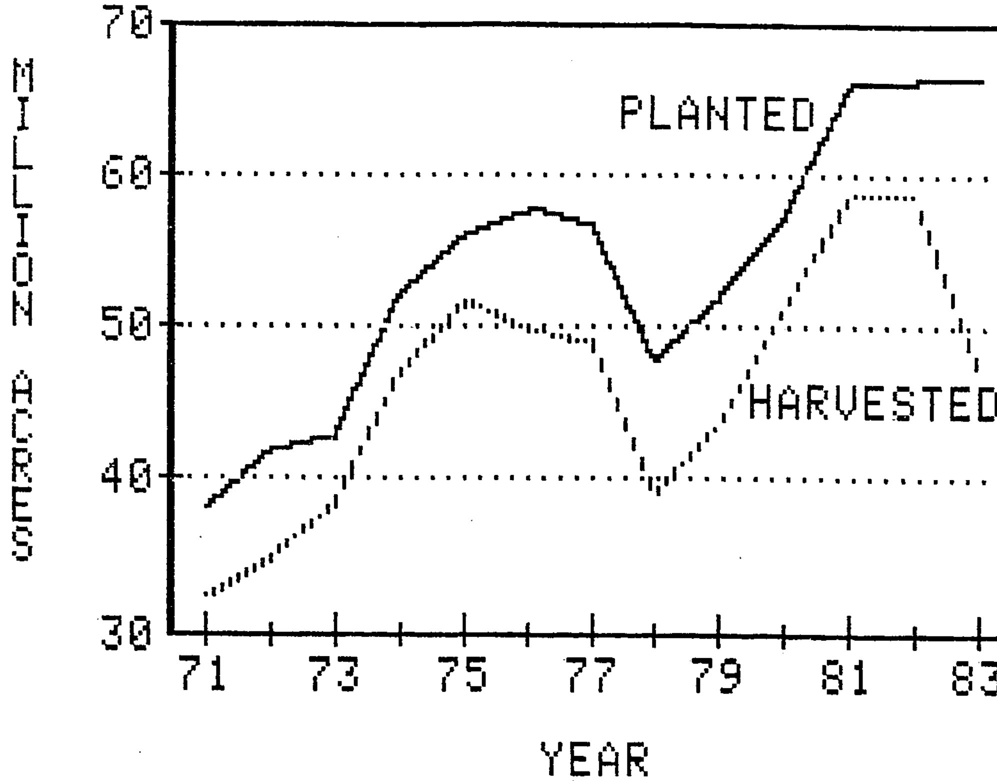
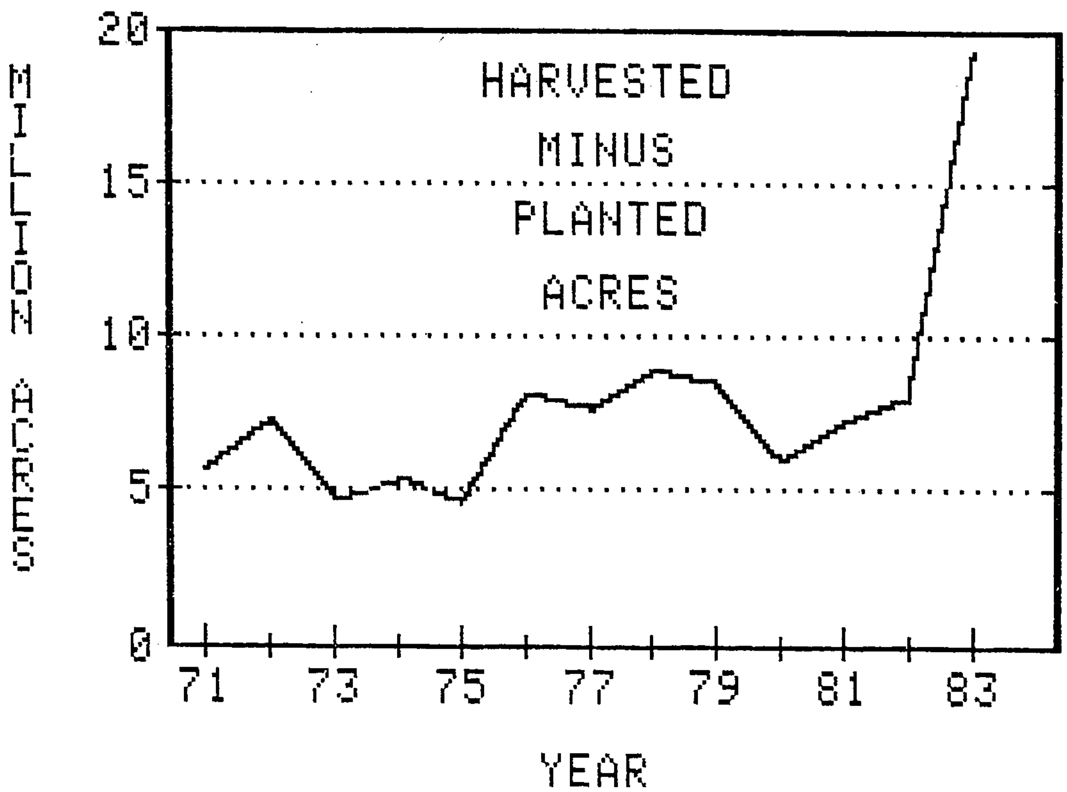


FIGURE 2. U.S. WINTER WHEAT



ECONOMICS OF THE MEAT MARKET AND ITS IMPLICATIONS FOR THE FUTURE USE OF WHEAT PASTURE IN BEEF CATTLE PRODUCTION SYSTEMS

by

James N. Trapp
Associate Professor of
Agricultural Economics
Oklahoma State University

Summary

In analyzing the future of wheat pasture grazing systems in the plains states it is useful to distinguish between two distinct grazing systems, winter grazing as a complimentary activity to wheat production, and wheat grazeout for roughage. Winter wheat grazing appears to be an economically competitive production system for the future. There appears to be little doubt that its utilization will continue and perhaps even increase relative to other beef production systems. The main impact of economic activity in the meat sector upon the future of winter wheat pasture grazing would appear to be that of determining the size of the beef herd and hence the number of animals available to utilize wheat pasture. Several factors indicate that the future growth rate of the beef industry will be much slower than that experienced over the past 20 to 30 years. Per capita consumption of all meats has stabilized since 1970 and the population growth rate in the United States has been, and is expected, to continue to steadily decline. In addition, poultry has been increasing its share of the meat market at the expense of beef and pork.

The practice of grazing out wheat does not appear to be a viable standard practice in most major Plain's State wheat producing areas. The grazeout of wheat, as opposed to grain production, is economically practical in most cases only when subsidized by some type of government program. In terms of the pounds of beef that can be produced by grazing out wheat versus harvesting wheat and in turn feeding the wheat, it can be shown that wheat grain production/feeding typically produces more pounds of beef than wheat grazeout. Furthermore, the economics of grain demand and supply generally will prevent wheat from being priced low enough to be more valuable as a livestock feed than a foodgrain. Hence the future of wheat grazeout systems in the plains states would appear to be highly dependent upon unstable government grain program provisions that subsidize wheat grazing rather than basic economic competitiveness. Under these conditions, long range planning and extensive capital investment in wheat grazeout systems would appear to be a risky and ill-advised standard use of cropland when cash grain production is a possible alternative.

Introduction

The future of wheat grazing in the Plains State Region will be heavily dependent upon the future of the beef industry in general and various government regulatory programs affecting wheat production. Producers can do much to improve their own profitability from wheat grazing by making good use of available management practices and by being informed decision makers. This is especially the case with regard to the decision to grazeout wheat since the factors affecting this decision tend to change rapidly. However, numerous forces beyond the immediate control of the wheat/stocker cattle producer will have to be dealt with. As they are dealt with they will have significant influences upon wheat pasture beef production systems. One major force of this type is that of the general competitiveness of beef versus other meats in the consumer's diet. A second major external force is that of government programs affecting the production methods for wheat, and the general supply and prices for wheat and feedgrains. This paper will focus upon the evolving nature of these two forces, with special emphasis on the evolving nature of the meat market and its influence upon wheat pasture beef production systems.

In looking at the future of wheat grazing in the High Plains, it is useful to look at wheat grazing in terms of two separate types of grazing activities. The first being winter grazing, that is grazing done prior to the onset of the jointing stage of wheat plant growth, and the second being grazing wheat out as opposed to harvesting the wheat for grain. The following two sections of this paper will consider these two grazing activities.

The Future of Wheat Grazeout Production Systems

The grazing out of wheat naturally occurs in those situations where, for some reason, wheat becomes more valuable as a roughage than as a grain. In the past, the most frequent event prompting wheat grazeout has been the advent of a government program trying to reduce wheat production. Such programs often in effect subsidize wheat grazing to achieve the objective of reduced wheat production. No doubt various government programs in the future will again bring about favorable conditions for the grazing out of wheat.

If one looks at the economics of grazing out wheat versus harvesting the wheat for grain, the conclusion can be drawn that a free market will not present conditions favorable for grazing out wheat for any prolonged amount of time. Conditions may arise favorable to wheat grazeout, but they will be disequilibrium conditions that will soon be altered by the market. To illustrate this point consider the table calculations presented below. The table is designed to be a broad generalization of "typical" conditions in the Central High Plains. Many unique cases more favorable, or less favorable, could be developed and should be for decision making in specific cases. Several computerized models have been developed at Oklahoma State University for doing this (see Anderson and Brorsen).

Table 1. Stocker Grazeout for North Central Oklahoma

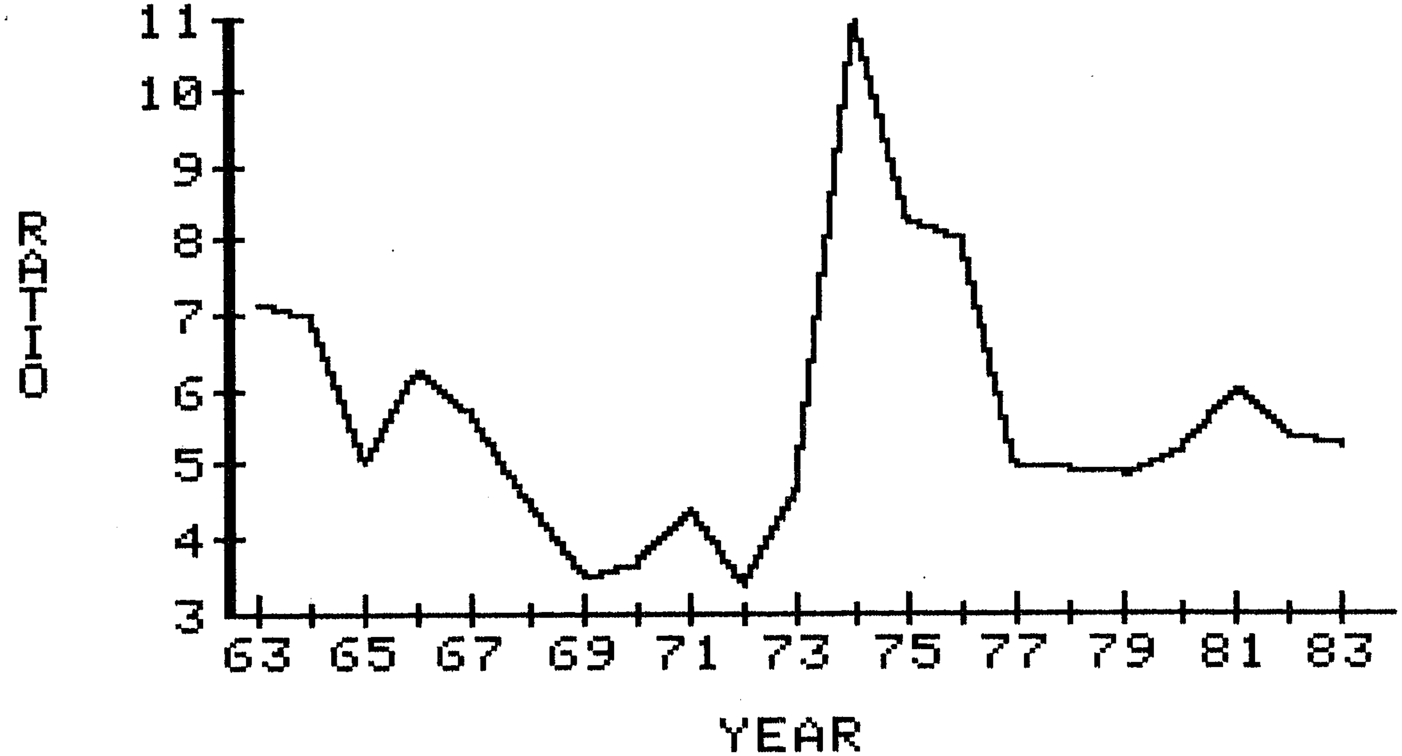
		Expected	Likely Deviation
	Grazeout Option		
1)	Place 600 lb. stockers on wheat March 1		
2)	Graze until June 1. During this period one acre of wheat provides roughly 1,760 pounds of dry matter which converts to stocker pounds at a rate of approximately 9.5 to 1 for this weight of cattle.	+185 lbs.	50 lbs.
3)	Death loss of 2% at an average weight of 700 lbs.	- 14 lbs.	14 lbs.
4)	Price discount loss. 785 lb. stockers in a typical year sell for about 5% less per pound than 600 lb. stockers. In terms of pounds, a 5% price drop on 600 lb. steers is a loss of 30 lbs.	- 30 lbs.	15 lbs.
5)	Labor charge in terms of lbs. of stocker	- 5 lbs.	2 lbs.
6)	2% shrink when sold	- 15 lbs.	5 lbs.
	Effective Gain	+121 lbs.	86 lbs.
	Wheat Option		
1)	Grain yield 33 bu. per acre	+ 33 bu.	4 bu.
2)	Harvesting cost in bushels	- 5 bu.	2 bu.
3)	Weed and Insect Control, March 1 to June 1	- 2 bu.	2 bu.
	Effective Yield	+ 26 bu.	8 bu.

Breakeven Price Ratio Calculation

$$\frac{\text{121 pounds of stocker}}{\text{26 bushels of wheat}} = \frac{\text{Price of Wheat}}{\text{Price of Stockers}} = 4.65$$

Given the assumptions made in Table 1 the breakeven price ratio calculation for wheat versus stockers indicates that it is typically more profitable to graze out wheat than harvest it when the price ratio of wheat to stocker prices is less than approximately 5 to 1. For example $3.00 per bushel wheat and $.60 per pound stockers would indicate about equal returns from either grazing out wheat or

FIGURE 1. JUNE WHEAT/STOCKER PRICE RATIO



harvesting it. It is possible for normal variations in production conditions to cause this ratio to vary a great deal. Ratios between four and six seem quite plausible in different areas and under different conditions.

History has not presented very many cases in which the ratio of wheat prices to stocker prices was significantly below 5 to 1. Figure 1 indicates that such conditions occurred in 1969 through 1972 and marginally so again in 1977 to 1979. During both of these periods the effective price of wheat was above the actual market price for those participating in government programs due to government loans, diversion payments, or target prices. For those outside the government program these years were favorable years for grazeout. For areas which may consistently experience breakeven price ratios of 6:1 a majority of years between 1963 to 1983 would have proven to be profitable graze out years. However such areas are believed to be the exception instead of the rule. Further research regarding the breakeven price ratio for various wheat producing areas is needed.

An argument can be developed that an unregulated market will never price wheat such that grazeout is preferred to harvest. Wheat as a grain would appear to be more valuable as a feed than wheat as a forage. If the 26 bushels of wheat effectively harvested in Table 1 were evaluated in terms of the pounds of stocker it could produce, the pounds produced would exceed that of the grazed out wheat pasture. Again, generalizing and using rough figures, 26 bushels of wheat at 12% moisture content would yield about 1,373 pounds of dry matter. Conservatively figured, the conversion rate of 600 to 700 pound stockers being fed a wheat ration is at least 6 to 1. Thus the 1,373 lbs. of harvested wheat would produce at least 229 lbs. of stocker weight, which is significantly in excess of the 185 lbs. produced in the grazeout option. It must be granted that feed preparation and labor costs would be greater in the wheat feeding process than the grazeout process, but not to the extent that the 3 to 4 lb. superior conversion rate of wheat grain versus wheat roughage would be overcome. Given this technical relationship and an unregulated market, market prices would not in general ever drop so low as to make wheat grazeout preferable to wheat harvesting and subsequent feeding. In addition, past experience shows that when wheat prices are low enough to cause substantial use of wheat as a feed, losses are being encountered by wheat producers.

Given no government subsidization, the presence of economic losses for wheat production will eventually lead to wheat production cutbacks and subsequently higher wheat prices. Numerous temporary market disequilibrium situations can be envisioned where wheat prices might temporarily drop low enough to promote wheat grazeout. One such case would be the presence of huge feedgrain and wheat stocks. But such conditions would be expected to quickly generate grain acreage reductions which in turn would lead to higher grain prices. Temporary shortages of roughage and/or grain during the grazeout season could lead to feasibly profitable grazeout situations. Likewise situations in the cattle market where light weight stockers were temporarily at discounts to heavy weight stockers during the grazeout season could make grazeout a profitable activity. But by-in-large the grazeout option for wheat in the future, as in the past, will likely be profitable only in cases where government policy causes it to be, or the market is in an unusual and temporary situation. Managers must be alert to when these situations will occur and should understand how to determine when they have or might occur. However, a standard management practice of grazing out wheat pasture would appear ill-advised.

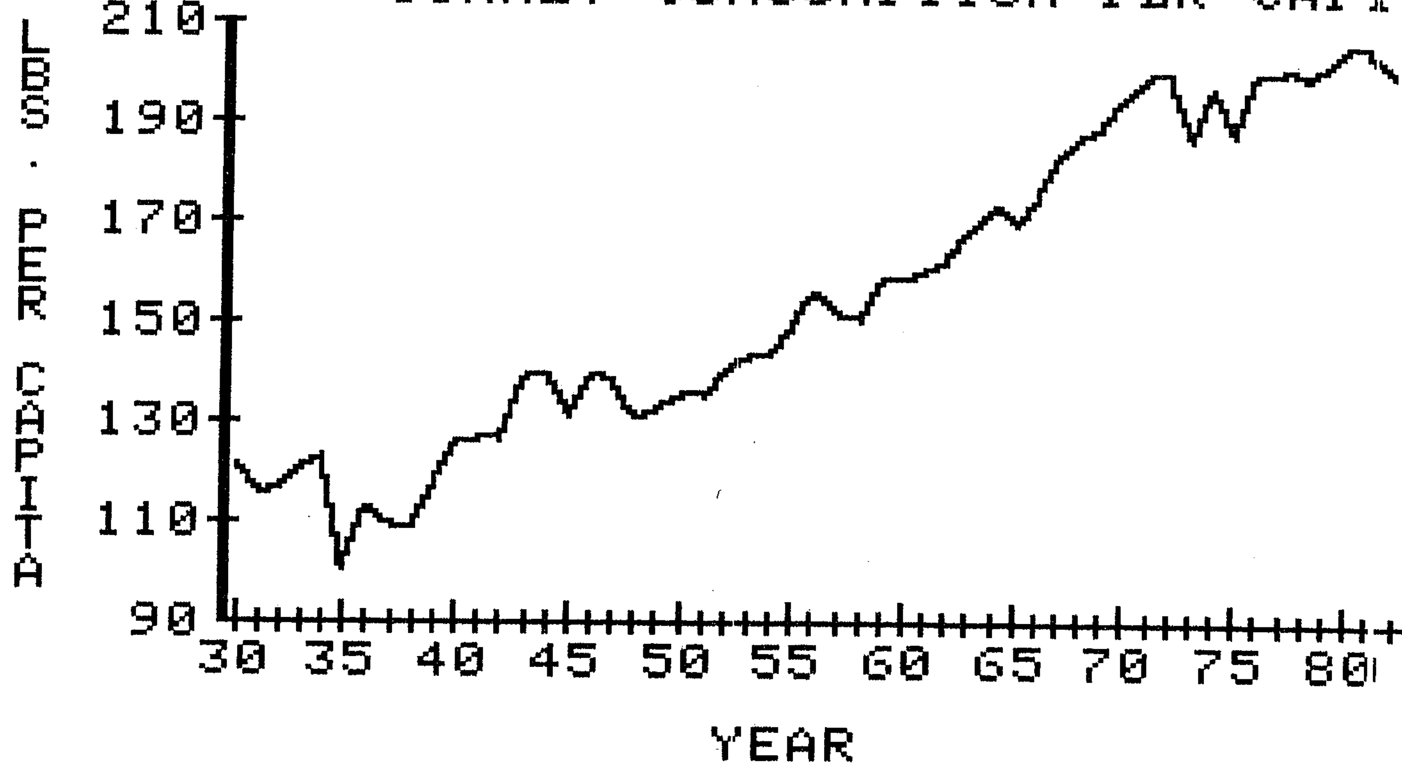
The Future of Winter Wheat Pasture Grazing Systems

The future of winter wheat pasture grazing in the Plains State Region will be closely linked to the future of the beef industry in general. Winter wheat pasture grazing will likely be one of, if not the last, form of beef production to cease in the Plains area. Its complementary nature to wheat grain production makes it one of the cheapest and highest quality roughage sources available for beef production. The major question to be answered in determining the future of winter wheat pasture grazing is how many cattle will be produced to graze on wheat pasture. Wheat pasture grazing will likely continue whether cattle are grain fattened or roughage fattened. Hence, the main impact of the future success or failure of feedlot beef production will be in its contribution to keeping beef competitive as a consumer meat product. The comments to follow will argue that the future size of the beef industry will be heavily affected by its ability to remain cost competitive to other types of meat production. In this regard, the continued utilization of wheat pasture to produce a significant amount of low cost beef will be vital.

Is the Meat Industry a "Mature" Industry

In looking at the future growth potential of the beef industry, one of the first questions many contend needs to be answered is whether or not the meat industry is a "mature" industry. By this they mean will the per capita consumption of meat in general continue to increase, or have we reached a plateau with regard to per capita pounds of meat consumption in the United States? Many argue that the meat industry has matured. Indeed in viewing Figure 2 it does appear that total combined per capita consumption of beef, pork, chicken and turkey has stabilized as of about 1971. Some would argue that this stabilization occurred over a period when real per capita income growth stagnated. Therefore, they argue that when/if per capita income growth resumes so will growth in per capita meat demand. This argument may have some merit. Nevertheless, prior to 1971 per capita consumption of these four meats had been increasing at 2 to 3 percent per year. However, since 1971 there has been virtually no increase in per capita pounds of consumption of these four meats. Added to the stabilization of per capita meat demand is a continued slowing of the rate of population growth itself. During the 60's population in the

FIGURE 2. TOTAL BEEF, PORK, CHICKEN AND TURKEY CONSUMPTION PER CAPITA



United States was growing at about 1.35 percent per year. During the 70's population grew at only 1.1 percent per year. Some projections of future U.S. population growth rates include the possibility of a zero rate of population growth. Hence, a strong argument exists that the future rate of increase in meat demand will not be nearly as rapid as in the past and may indeed be almost nonexistent. Under such a situation, any growth in demand for one single meat type will have to be at the expense of the market share of another meat type. Hence the competitiveness of a given meat becomes increasingly important to the future growth of that meat's production.

The Competitive Position of Beef in the Meat Market

The competitiveness of beef in the meat market depends upon the strength of consumer preferences for beef and upon the cost competitiveness of beef production. Recent trends in beef consumption tend to indicate that beef has lost its competitiveness relative to poultry and pork in one or perhaps both of these ways. Figures 3 and 4 show the consumption of beef, pork, chicken and turkey. Both chicken and turkey have steadily increased their respective per capita consumption levels and market shares. Pork experienced a short-lived rise in consumption and market share from 1979 to 1981. However, the basic trend in pork's market share since 1955 has been negative. The temporary rise in pork consumption during 1979 to 1981 may have largely been due to the reduced real income levels that occurred during that period. Observation of pork versus beef consumption in previous recessions shows a pattern similar to that of 1979 to 1981. For example, consider 1933 to 1939, or the recession of the mid 50's from about 1954 to 1957.

Why has beef lost its hold on market share since 1976 and is this trend likely to continue? Much attention has been focused upon the consumer's preference for beef. Evidence is mounting that some consumer preference for beef has been lost (see Chavas). Economically defined, this means that at a given price for beef relative to given prices for pork, chicken and turkey, consumers will purchase less beef per capita than before. A simple reduction in beef's market share may not mean a loss in preference for beef (economically speaking). If the loss in market share was caused by higher beef prices relative to other meat prices, the loss is not deemed to be due to changing preferences, but instead due to a response to the changing prices. In theory, if consumers are reacting to prices and have not changed their preferences, they will once again return to consuming just as much beef as before when prices return to their previous relationship.

While their is some evidence that beef has lost a marginal amount of consumer preference in the late 70's and early 80's, there is even stronger evidence that beef has lost production cost competitiveness throughout the 60's and 70's. Figure 5 presents estimated historical breakeven prices (i.e. total cost of production estimates) for beef, pork, and chicken. Cost of production data, profits estimates, etc. such as those presented in Figure 5 are always difficult to obtain and

FIGURE 3. PER CAPITA POUNDS OF MEAT CONSUMPTION BY MEAT TYPE

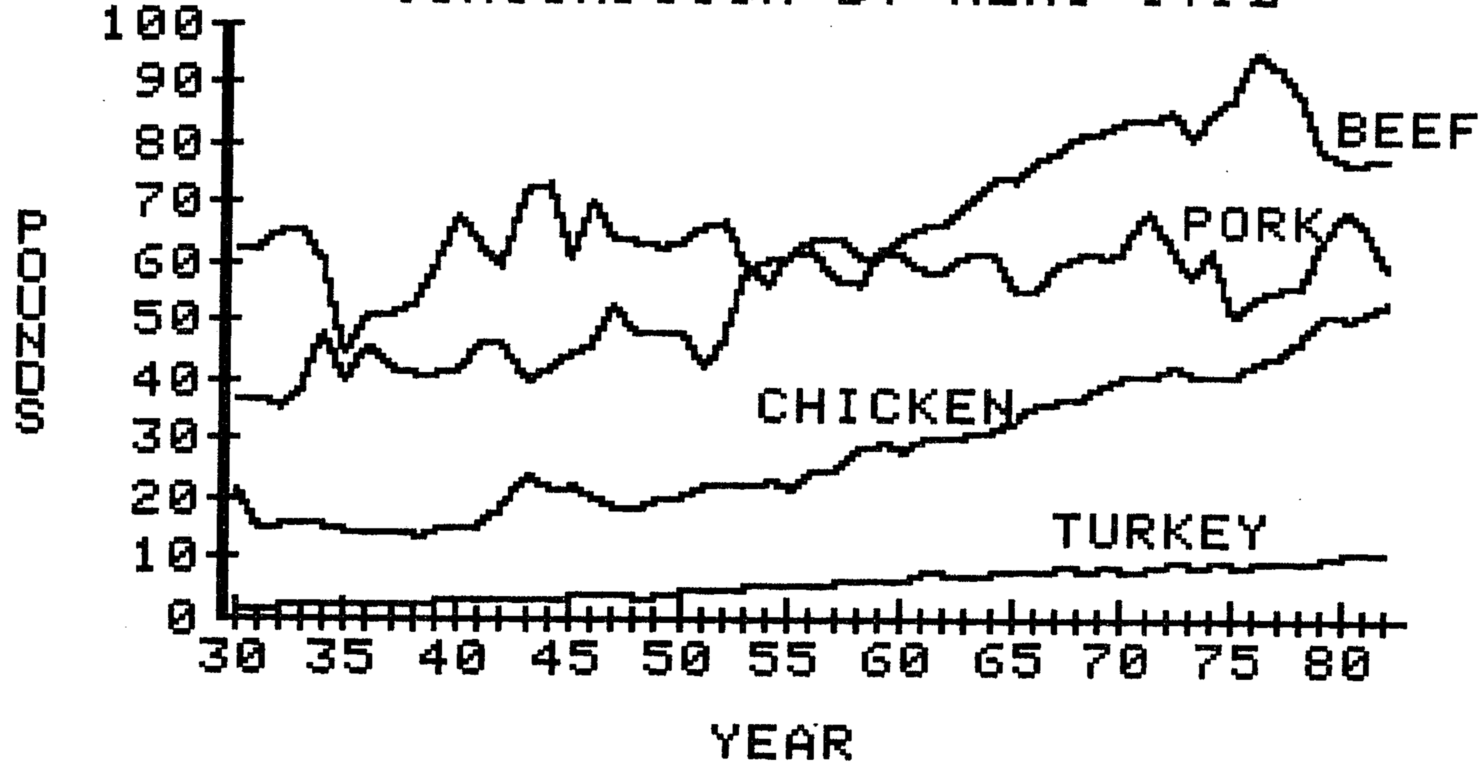


FIGURE 4. MARKET SHARE OF EACH MEAT TYPE

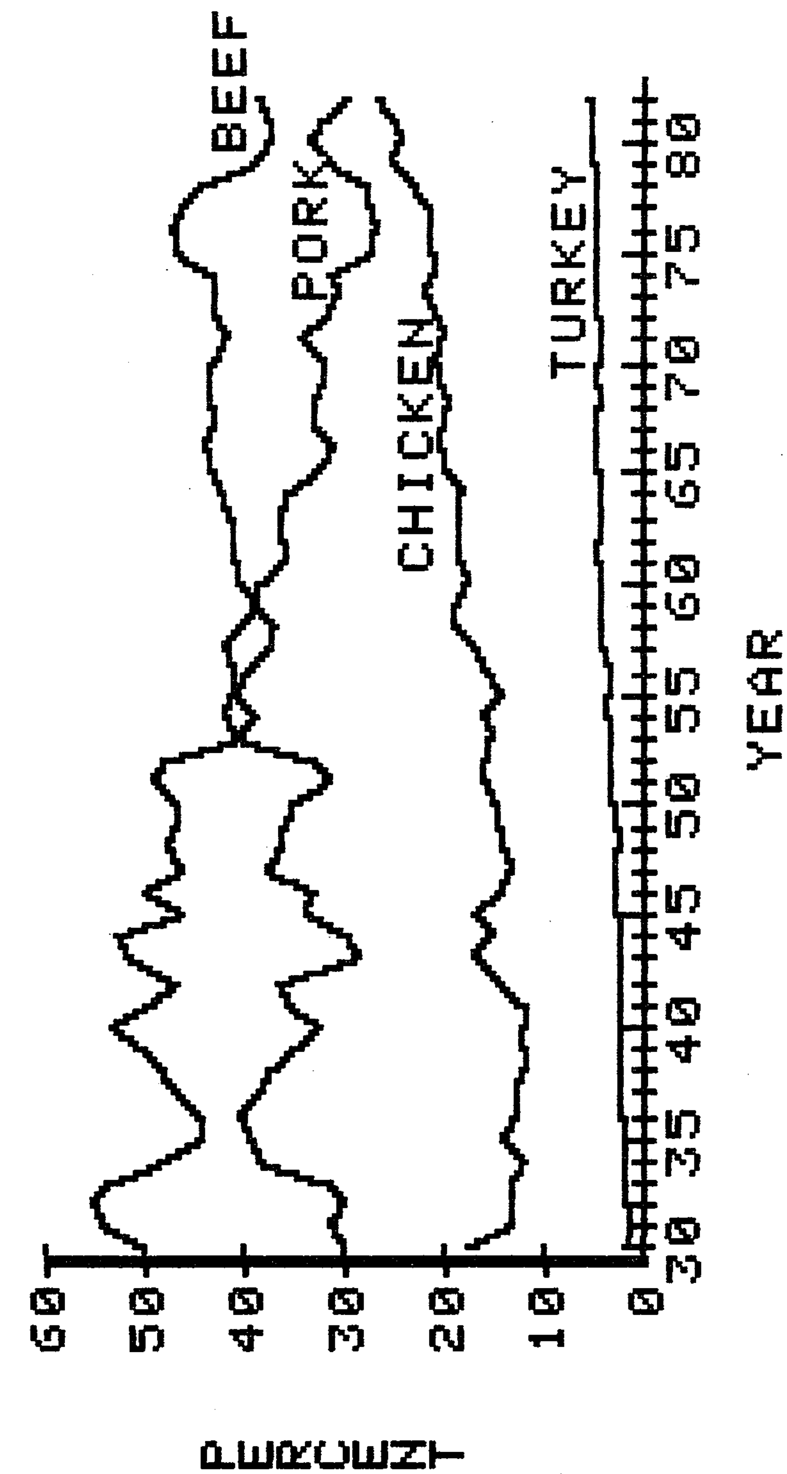
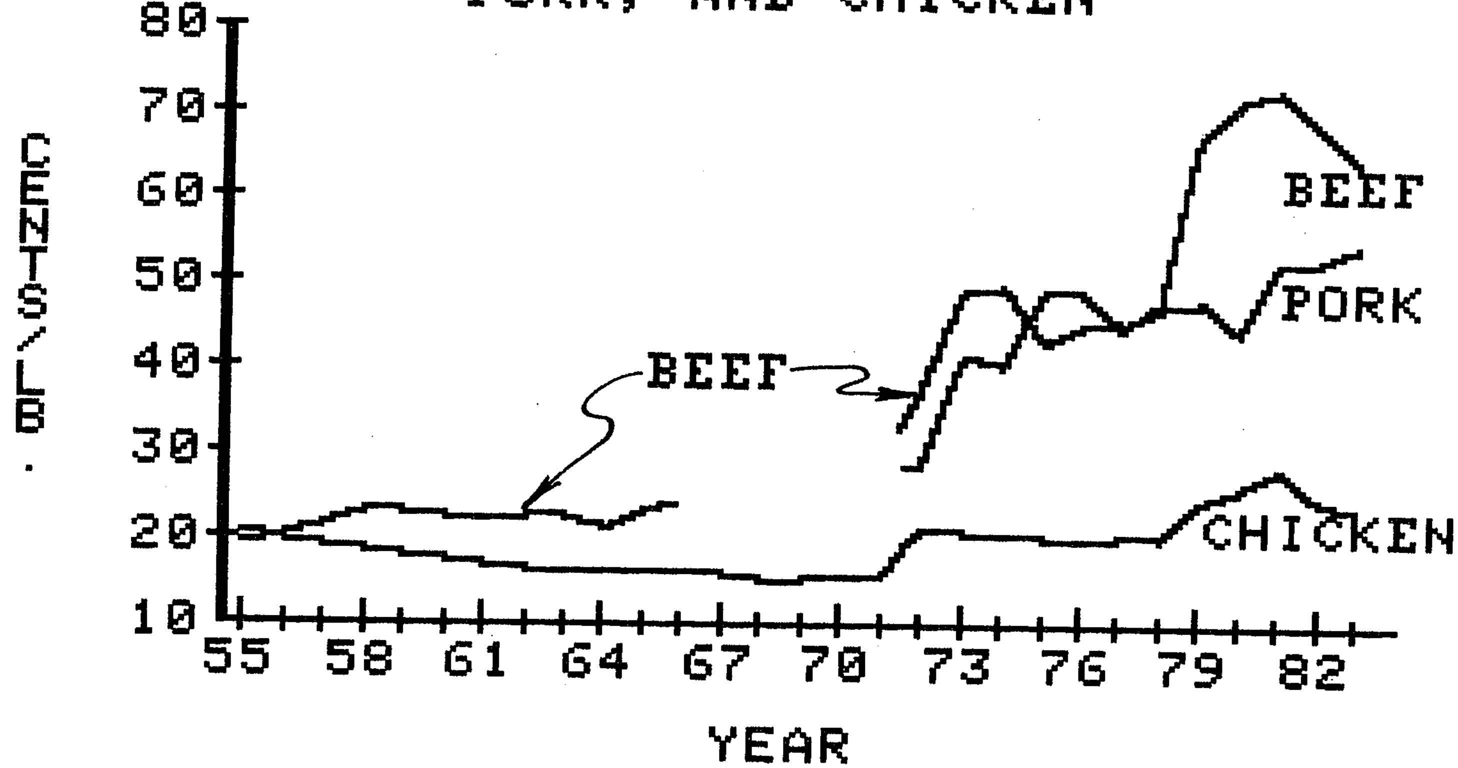


FIGURE 5. BREAKEVEN PRICES FOR BEEF, PORK, AND CHICKEN



define and thus should be viewed with caution. Care was taken in collecting the cost data used in Figure 5 to try to use consistent definitions and collection procedures so that the general shifts in relative production costs overtime would be accurately reflected. Despite the lack of comprehensive data over the period from 1955 to 1972, it is clear from Figure 5 that beef production costs per pound have steadily increased relative to chicken. In fact, in 1955 beef is indicated to have had a production cost slightly below that of chicken. By 1982 the cost of beef production relative to chicken production was nearly 3 to 1. All meat production costs are indicated to have jumped sharply in 1972 as grain prices rose rapidly during the Russian grain export years. In fact pork production costs are estimated to have exceeded beef production costs for two years shortly after the Russian grain export years, i.e. specifically in 1975 to 1976. Since that time, the cost of beef production has risen to nearly twice that of pork.

The responsiveness of meat market shares to changes in relative cost of production is visually evidenced by looking at pork versus beef's market shares in Figure 4 for the years 1975 and 1976. Pork hit an all time low with regard to market share in 1976 while beef was at its highest point since the early 1950's. It is not by coincidence that this occurred when pork production costs exceeded beef production costs for one of the few times in recent history. Research by Ikerd and others documents and quantifies the responsiveness of beef, pork and poultry market shares to changing relative market prices.

While cost of production and market price may not be exactly the same at any given point in time they will never be far apart in the long run in a competitive industry such as the meat industry. Based on this logic regarding the determination of market shares, and the cost data presented in Figure 5, it is not surprising that beef has lost market share to the benefit of chicken. What may be most surprising is that beef's market share has not declined even more as consumers responded to beef's price becoming clearly the highest of beef, pork or chicken.

The Past and Future of Beef Production Costs

If beef production costs continue to rise relative to chicken and/or pork it is a relative certainty that beef will continue to lose its current share of the meat market. As a consequence, beef production and winter wheat pasture utilization by beef animals will decline. What factors have caused beef production costs to rise relative to other meat production costs? Specifically why have poultry production costs remained low relative to beef? The basic intuitive answer is technology has improved and been adopted more rapidly in the poultry industry than in the beef industry. Since the late 1950's poultry has transformed itself from a backyard secondary enterprise using morning and evening chore labor, to a full scale, capital intensive, specialized firm business. Beef production methods and technology have also changed, but not to the degree seen in the poultry industry. To a lesser degree the pork industry is currently in the midst of a production technology transition similar to that the poultry industry has gone through.

A brief look at the current composition of the production costs of the beef, pork and chicken industry is insightful with regard to the current and recent past meat market situation. Table 2 reports estimated capital, land, labor and operating costs per pound of beef, pork and chicken as of 1981. Capital, as defined here, consists mostly of breeding stock, (which is quite significant in the case of beef) buildings, and equipment. Operating costs consist primarily of feed with minor expenses for fuel, medicine, etc. (see Trapp for further discussion of cost definitions).

Table 2. 1981 Beef, Pork and Chicken Capital, Land, Labor and Operation Costs Per Pound of Live Weight Produced Assuming a 10 Percent Rate of Return to Capital and Land Investment

Type of Cost	Beef	Pork	Chicken
		(cents/lb.)	
Capital	13.394	3.500	2.784
Land	32.568	.564	.010
Labor	8.779	2.471	1.204
Operating	46.131	46.334	24.999
Total	100.872	52.869	28.997

Observation of Table 2 reveals that the estimated 1981 production costs for beef, including returns to capital and land are extremely high relative to 1981 market prices, i.e. market prices for beef, pork and chicken respectively averaged approximately 64, 45 and 28 cents per pound in 1981. Further observation reveals that capital and land costs constitute a much larger portion of the cost of production for beef versus pork and chicken. Table 3 further illustrates this point.

Table 3. Ratios of Capital and Land Costs Versus Out-of Pocket Costs for Labor and Operation

Meat Type	Cost		Ratio
	Capital & Land	Labor & Operation	
Beef	45.962	54.910	.837
Pork	4.064	48.805	.083
Chicken	2.794	26.204	.107

Observation of Table 3 indicates that the ratio of long term investment costs to short term out-of-pocket costs is nearly ten times greater for beef than pork or chicken. This relationship causes, among other things, the cost of beef production to be much more sensitive to interest rates (i.e. the rate of payment to land and capital investments) than are pork and chicken. In fact land costs as calculated in Table 2 constitutes nearly one-third of the cost of beef production. The cost of land in pork and chicken production by comparison is negligible. It is useful when considering the impact of land prices upon beef production costs to think of beef firms as producing two products, land and cattle. Indeed one has often heard the term "land and cattle company", but never the term "land and chicken company." This justly reflects the importance of land in the cattle industry. Land, unlike other forms of operating and capital inputs, tends to appreciate in value over time. Hence part of, if not most of, the payment to land is expected in most cases to be covered by the land's appreciation in value. Therefore, when the land input for beef, pork and chicken is "full costed" it is not surprising that the spread between beef production costs and its market prices is the widest of the three cost/market prices spreads. If land costs are removed, the cost of beef production per pound is reduced from slightly over one dollar to 68 cents per pound. A cost level of 68 cents per pound is only a few cents above the average market price of 64 cents received for beef in 1981. In most years the market price has covered the cost of beef production with land cost excluded. But market prices have not, and likely never will cover beef production costs when land costs are added in.

Although it may be argued that the cost of land should not be included in the production cost of any livestock product, the large magnitude of land and capital costs in the beef budget points out a significant problem for the beef industry. The economic rule and observed practice that firms should continue to operate in the short-run only as long as they cover short-term out-of-pocket costs takes on significant implications in the meat industry. Pork and chicken both have relatively low "fixed" long-term capital and land payment commitments. Hence a relatively small drop in profits, i.e.

less that 10 percent, will cause chicken and pork producers to cease production in the short-run because they are no longer covering out-of-pocket costs. Their losses become less by ceasing to operate and just paying their long-term fixed cost commitments. On the other hand, in the case of beef, fixed long-term cost commitments constitute 13 to 46 percent of total production costs, depending on how land and costs are treated. Hence profits must drop significantly more in the beef industry before it is better for producers to cease production in the short-run versus continuing to produce. This tends to lead to relatively long and severe periods of losses in the beef industry before cutbacks in production occur.

The inability of the beef industry to adjust to changing profit situations relative to pork and chicken is further hindered by the longer biological lags involved in beef production. When the profit insensitivity caused by beef's cost structure is combined with the industry's slow reaction time due to long biological production delays, the result is a slowly changing production pattern that tends to over compensate. Hence prolonged periods of over supply and under supply relative to demand often exist in the beef industry. This in turn generates the cycles we have seen in both beef prices and beef animal numbers. With regard to wheat pasture cattle numbers this leads to cyclical numbers of animals which may or may not correspond well with wheat acreages and government programs favorable to wheat grazing. Hence wheat pasture producers are often faced with extended "strong" and "weak" markets for wheat pasture according to the current phase of the cattle cycle.

Summary

The future of wheat pasture grazing is best discussed in terms of the future for wheat grazeout systems and winter wheat pasture grazing. The future of wheat grazeout systems would appear to a volatile one. For wheat grazeout to be a viable option to wheat grain production, wheat must be forced into the unnatural situation of being competitive as a livestock feed. It can be argued that even as a feed, wheat is more valuable as a grain than as a roughage. When uncontrolled, the market will theoretically price wheat roughage and grain this way, thus making wheat grazeout systems uneconomical. However, the grazing out of wheat has been economically viable at certain points in the past and will likely be again. Profitable graze out situations in the past have generally been caused by government programs which in essence have subsidized wheat grazeout to reduce grain production. These types of programs will likely occur again in the future when wheat stock levels become excessively high. It is also feasible that an unregulated market will also offer occasional years when wheat grazeout is a viable option due to temporary market disequilibriums.

Winter wheat pasture appears to face a much more certain and positive future. Given the low cost and high quality of wheat pasture roughage it will likely be one of the last forms of cattle feeding to be abandoned in the Plains area. However, the economics of the meat industry today raises serious questions as to the future continued growth of the beef industry. American consumption of meat in general appears to have stabilized over the past ten years and population growth rates are slowing. Hence, the demand for meat in general may grow only slightly in the years to come. Beef's ability to hold its current market share of the total meat market is being seriously challenged by poultry. Questions are currently being raised as to whether consumer preference for beef has declined. The more serious and visibly existent problem for beef with regard to holding its market share is the continually decline of beef's cost competitiveness relative to poultry over the last twenty years. Beef production costs have risen nearly three times as much as poultry's production costs over the past twenty years. Meat demand analysis indicates that for each 5 percent rise in beef price relative to other meat prices, beef will lose approximately 1 percent of the total meat market. If beef does not regain some of the cost competitiveness it has lost over the past twenty years, the industry can expect to stay at its current size in the future. Further reduction in size can be expected if the adverse trend being experienced in beef production cost is not halted.

As the future size of the beef industry changes so will the demand for wheat pasture. Wheat pasture demand will also inevitably be subject to expansion and contraction as beef cattle numbers continue to be subject to cyclical swings in production. The cost structure and biological nature of beef production will continue to generate beef production cycles irregardless of the size of the beef industry.

REFERENCES

Anderson, Kim. "Risk Rated Decision Making Series: VisiCalc Template to Analyze the 1984 Government Wheat Program." Forthcoming Oklahoma State University Current Report, 1983.

Brorsen, Wade W. "Economic Analysis of Stocker Cattle Production Alternatives Using a Computer Simulation Model." Master's Thesis, Oklahoma State University, 1980.

Brorsen, Wade W., Odell L. Walker, Gerald W. Horn, and Ted R. Nelson. "A Stocker Cattle Growth Simulation Model." Southern Journal of Agricultural Economics. Vol. 15, Number 1, July 1983, pp. 115-122.

Chavas, Jean-Paul. "Structural Change in the Demand for Meat." American Journal of Agricultural Economics, Vol. 65, Number 1, August 1983, pp. 148-153.

Ikerd, John E. "A Total Meat Demand Approach to Forecasting and Explaining Beef Prices." Applied Commodity Price Analysis and Forecasting Conference. Ames, Iowa, October, 1981.

Trapp, James N. "Production Cost Comparisons Between Beef, Pork and Chicken." National Beef Symposium and Oklahoma Cattle Feeder's Seminar. Stillwater, Oklahoma, March, 1982.

FUTURE TRENDS IN THE BEEF CATTLE INDUSTRY AS AFFECTED BY CHANGES IN PRODUCTION TECHNOLOGY AND PRODUCT DEMAND

R.L. Preston
Thornton Distinguished Professor
Animal Science Department
Texas Tech University

SUMMARY

Beef cattle make a positive instead of negative contribution to the human food chain. Their ability to convert feed materials that cannot be consumed by humans into highly palatable, highly nutritious food remains their chief competitive advantage.

The use of grain in the feeding of cattle is not as wasteful as it may first appear. The feeding of grain allows cattle to reach a slaughter weight that maximizes, approximately, their efficiency for protein production with acceptable or desirable eating qualities before they are too old to have these qualities. Nevertheless, greater use of roughages, pastures and by-products will take place in cattle feeding, and eventually beef cattle efficiency will be determined by the minimum amount of concentrate required to produce a pound of beef.

The industry must increase its efficiency if it is going to remain competitive with other meats and still produce significant quantities of beef that will allow producers to remain in business. Development, acceptance and application of technology is the major competitive disadvantage of the beef industry.

Major areas of potential improvements in efficiency for the industry include reproductive improvements, realistic grading standards and decreased transportation costs and losses. The beef industry must seek out and apply new technologies if it is going to continue to supply a major commodity in the U.S. food supply.

INTRODUCTION

The title seems to say that one has some perspective about the future of the beef cattle industry. Winston Churchill said that one can only see as far ahead as they are aware of the past. With 60 cent feeder and fat cattle along with $3.50/bushel corn, it makes having any perspective about the future of the beef cattle industry a little fuzzy. Couple that with a government policy that tries to assure a return to grain farmers by decreasing grain production adds to the total problem of the livestock industry.

Perhaps it would help our perspective to step back and ask, "What is the real purpose of beef cattle?" The first thing that is apparent throughout the world is that beef is a by-product of milk production. In our own country, the dairy industry provides about 20% of our beef supply. With the current national and worldwide surplus of dairy products and the subsidy that will promote the slaughter of dairy cows, greater quantities of lower quality beef from dairy cattle will have a negative impact on the cow beef market for the next several years.

A second purpose of beef cattle is to harvest land unsuitable for more intensive cultivation of crops that are directly consumable by humans. This is where the "romance" of the cattle industry is, and as the late Jerry Litton said, everyone in the U.S. is wanting a piece of the country in their way of living. Cow-calf producers own and/or manage large tracts of land. Because economic use of this land requires that they own cows (or ewes), their major emphasis has been on calf production. Almost any economic study of cow-calf production will show that if total interest on land investment must be carried by the cow, cow-calf production is not a viable industry. Land prices and interest rates have become too high for the poor cow to carry this economic burden. This is why cattlemen live poor (unless they also produce oil or something else) but die rich. They have made money over the past 30 or more years on land appreciation while trying to maintain their cash flow with their cows. Since land values are not appreciating as before, this source of income is declining. This is no doubt a temporary situation, but it may last longer than many cattle producers.

Where are beef cattle (as opposed to dairy cattle) found in the world? It was Jonathan Garst who said that the function of beef cattle is to burn off the excess carbohydrate and to concentrate the high quality protein. In other words, where carbohydrate is produced in excess -- either as roughages (fiber) or concentrates (starch) -- is where beef cattle are found. Starch is produced in excess in only a few areas of the world -- U.S., Canada, France, Australia. Therefore, the major purpose of beef cattle is to harvest excess carbohydrate in the form of roughages and other by-products not consumable by man and convert these into human food.

Beef cattle also serve other purposes. They are an art form for some people, a social focus for others and a tax write off for others. These activities make true economic evaluation of the beef industry somewhat difficult.

The efficiency of beef cattle is often compared with other animals producing food for human consumption. Beef cattle always come out last in any gross efficiency comparison. However, beef cows are fed feeds that humans cannot eat. Furthermore, half of the feed fed to backgrounding and feedlot cattle is not consumable as human food. Therefore, if efficiency comparisons are made considering only those feeds consumable by humans, the true efficiency of beef cattle in the production of high quality protein for human consumption is 60-65% instead of 5% that is so often quoted. Until all available land used for photosynthesis yields food that is completely consumed directly by humans without any loss of by-product material, beef cattle will make a positive contribution to the supply of human food.

In the use of concentrates, beef cattle seem to compare unfavorably with other animals. Cattle generally require 4-7 pounds of concentrate per pound of gain whereas swine require about 3 and poultry 2 pounds of concentrate per pound of gain. This depends on the production system used to produce beef, however, since in research which we did at Washington State University utilizing pasture and other roughage, Choice beef was produced with as little as 1.8 pounds of concentrate per pound of gain.

The reason concentrates are used in the production of beef is because concentrates are and have been the cheapest source of energy for feeding cattle. Roughages, especially harvested roughages, are more expensive sources of energy. This is also somewhat misleading depending upon the context in which this evaluation is made. Many studies have shown that corn silage increases the cost of gain, increases the time on feed and therefore increases the interest cost on feedlot cattle. However, if the economic evaluation is a farming question rather than a feeding question, beef produced and returns per acre farmed are greatly increased if the corn crop is fed as silage rather than grain. Since pasture or range can only be harvested by grazing cattle (or sheep), obviously this is the only way an economic return can be realized from this land. Wheat pasture is a little like corn silage. Returns per acre are increased if wheat is grazed, but returns on the cattle may or may not be increased.

We should not lose sight of the fact that beef, and animal products in general, not only supply high quality protein in diet of humans, they supply many minerals (Fe, Zn, P) and vitamins (thiamin, niacin, B_6 and B_{12}) in concentrations greater, relative to the calories they supply, than required in the total diet. This fact makes diet balancing easy with animal products in the diet.

It is unfortunate that beef and other animal products in the human diet have been questioned from the standpoint of the diet-health issue, considering their positive contribution to the nutrition of humans. The primary problem with the U.S. diet is the quantity available at a price which is the cheapest in the world, expressed as percent of income spent for food, all of which leads to the overconsumption of food and a general obesity problem in the U.S. The nation's health and the agricultural industry both might be better off if the percent of income spent for food was 18-20% instead of 16% where it has been for several years.

Supply and demand still operate as major factors in determining the price of any commodity and therefore the return to producers. This is the major factor at work in the relative demand and price for the three major meats -- beef, poultry and pork. This was elegantly described by John Ikerd at the meeting held at Oklahoma State University last year on the Future of the Beef Cattle Industry. His analysis indicated that 80% of the variation in the price of beef was related to the per capita supply of beef. The major factor in the competitive position of beef relative to pork or poultry is price. While total meat consumption increased during the 60's, actually the rate of increase for beef consumption was greater than for poultry. During the 70's, especially the last half of the 70's, beef lost ground to poultry and perhaps also pork primarily because they were cheaper.

The meaning of these findings for beef producers is clear. Beef must be produced at a lower cost or less of it must be produced. If less is produced, that means fewer producers and/or less beef produced by each producer. With current feed-to-cattle price relationships, this may be already happening.

A reduced supply of beef without a reduction in the cost of beef to me has serious long range consequences for the beef industry. The price of beef will put it out of reach as a "staple" food for many people which will result in a permanent decrease in the consumer preference for beef. It may be that consumer preference has already changed away from beef because of relative price or other reasons.

Why has poultry sold at a relative declining price since the 50's? In my opinion, it is because of the development of technology applicable to the industry and the rapid adoption of this technology by the industry. Rapid adoption of new technology, in my opinion, is a major difference between the poultry and beef industries. The swine industry is also rapidly becoming a "high tech" industry.

It is a little disconcerting to review the overall efficiency changes of the beef cattle industry over the past 35 years. Reproductive efficiency has basically remained the same. Feedlot efficiency improved somewhat in the mid 50's, probably due to the introduction of hormonal growth promotants and again in the late 70's with the introduction of ionophores. You may ask is this lack of improved efficiency a fault of the industry or the scientist, and my answer is that it doesn't make any difference; we both may be out of a job unless the efficiency of beef production improves and the relative price decreases. Too often the reaction of the cattle industry has been that technology advances lead to overproduction and lower prices. This is the only way, in my opinion, that the beef industry can stay competitive and still market a sizable amount of beef.

AREAS OF NEEDED RESEARCH

What will be the future trends in the beef cattle industry? Because the contribution of beef cattle to the human food chain is maximized through the feeding of roughages, pastures and by-product feeds, I feel this aspect must continue to be emphasized in research and by the industry. Someday grains will be in permanent short supply, although it seems that given a little profit incentive, the U.S. and Canadian grain farmer can still bury the world in grain. The feedlot industry is so ingrained with high concentrate rations, however, that ration specifications often preclude the use of roughages or by-product feeds that at times might represent more economical sources of energy. Someday we will measure feedlot performance and research results in terms of concentrate per pound of gain rather than total feed.

A change that I feel must take place to improve the efficiency of growing-finishing beef cattle is the destruction of the Choice grade myth. Feeding cattle to grade Choice and feeding them to an acceptable eating quality are two different things, in my opinion. The eating qualities of beef must be defined in such a way that grades can be applied using criteria that account for much more than 10% of the variation in eating quality, which is all that marbling is able to do. Research is needed to make this definition. Perhaps the major benefit of feedlot feeding of cattle comes in their reaching an acceptable weight and dressing percentage before they are too old to eat well.

Another major loss in economic efficiency in the beef cattle industry is the "transportation overhead" on the industry. Truck drivers are like lawyers -- they get paid whether their client survives or not. Not only is the transportation of cattle a large expense, it is also a major loss in efficiency, morbidity and mortality. I'm not sure how this can be changed without greater vertical integration. The fact remains that transportation of cattle is a major economic loss to the industry.

Efficiency of the reproducing beef female is still low and has not materially changed. Comparative reproductive rates between the various food animals always puts the beef cow at a serious disadvantage. Research in this area will probably reap the greatest benefits for the cattle industry.

Improved calving rates will result in improved efficiency, but the quantum leap in reproductive efficiency will only come when the cow produces more than one calf each year. What I mean is twinning. I fully realize that twins on the beef ranch are a problem rather than a blesssing, but this is only because the present day cow cannot adequately nurse twin calves and/or our production system does not accommodate twin calves. Ewes have twins and are able to cope with the situation. Why not cows? How this can be accomplished is not clear. Hormonal induction does not result in just twins. Embryo transfer is expensive and uncertain. Genetic induction of twinning probably has been selected against rather than for by the beef cattle industry.

Larger beef breed types have swamped the industry largely because of their increased efficiency and leanness at a fixed slaughter weight. Earle Klosterman said that if there was an ideal size of beef cow, she should have been discovered by accident by the industry. I hear producers say with increased frequency that they are calving heifers as three year olds instead of two year olds in spite of considerable research at Oklahoma State University and other places showing the increased reproductive, as well as genetic, efficiency in calving as two year olds. Why are more producers thinking the opposite? I think it is because producers are either unable or unwilling to feed the level of nutrition required to assure that larger type heifers reach puberty by 13 months of age which will allow them to be bred and calve one month ahead of the main cow herd. To me this is the major point on which the decision to move to larger type cattle should be based. Larger heifers must be fed higher energy rations, including perhaps some grain, to assure calving as two year olds.

Another important loss in reproductive efficiency in beef cattle is the postpartum interval, the time between calving and first estrus. In first calf heifers, the maximum length of this period is only 90 days if they calve one month ahead of the main cow herd and only 70 days in the rest of the cow herd. Those that do not cycle in a 40-50 day breeding period either extend the calving season over a long time, are carried over to the next year as open cows or are found open and sold. All three represent a reduction in reproductive efficiency. The major factor that determines the length of the postpartum interval is the condition of the cow at calving and the level of energy nutrition relative to the cow's requirement during the first 3-4 weeks after calving. We found at Washington State University that the cow must have between 16-20% body fat at calving to assure a short postpartum interval. Too many beef cows are fed poorly during the last trimester of pregnancy to have a reasonable chance of coming into estrus in time to maintain a yearly calving interval.

LITERATURE CITED

Bartle, S.J., J.R. Males and R.L. Preston. Effect of energy intake on the postpartum interval in beef cows and the adequacy of the cow's production for calf growth. J. Anim. Sci., submitted for publication (1984).

Garst, Jonathan. No need for hunger. Random House, New York (1963).

Ikerd, J.E. The battle among beef, pork and poultry for the consumer's meat dollar. The Future of the Beef Industry, pp. A1-A22. Oklahoma State Univ. (1982).

Klosterman, E.W. Beef cattle size for maximum efficiency. J. Anim. Sci. 34:875 (1972).

Martin, E.L., R. Mills and D.C. Anderson. How much concentrate for desirable carcasses? Proc. Beef Information Day, pp. 1-7. Washington State Univ. (1979).

Pinney, D.O., L.S. Pope, D. Stephens and L.M. Henderson. Lifetime performance of beef cows wintered on three different levels. Feeding and Breeding Tests, pp. 63-70. Oklahoma State Univ. (1962).

Preston, R.L. Land use - a time for reconsideration. J. Anim. Sci. 45:1467 (1977).

Preston, R.L. Nutritional implications in economy of gain of feedlot cattle. J. Anim. Sci. 35:153 (1972).

Willham, R.L. Genetic potential of beef, pork and poultry: Today and in the future. The Future of the Beef Industry, pp. B1-B8. Oklahoma State Univ. (1982).

VIII. RESEARCH BRIEFS

HISTAMINE CONTENT OF THE BLOOD FROM COWS AFFECTED WITH TETANY

RESEARCH PERSONNEL:

Rodney L. Preston, Ph.D.

DATE PROJECT INITIATED:

January 1965

SCHEDULED DATE OF TERMINATION:

Completed

RATIONALE FOR DOING WORK:

Better understand the metabolic alterations during grass tetany

OBJECTIVES OF PROJECT:

Determine if histamine release is a factor in grass tetany

MOST SIGNIFICANT RESULTS TO DATE:

Grass tetany (hypomagnesemia) occurs in cows with lowered serum Mg levels. Tetany is not observed in all cows with lowered serum Mg. Therefore, other factors may play a role in the onset of symptoms observed in this disorder. Histamine has been suggested. Blood samples were obtained from 14 lactating cows which were in a state of tetany; 12 were diagnosed grass tetany and 2 were diagnosed parturient paresis. Histamine content of the whole blood was determined using the fluorimetric procedure of Shore, et al; serum Ca and Mg were determined using atomic absorption procedures and confirmed the above diagnosis. Whole blood histamine of normal cows was found to range from 13-20 μg./100 ml; plasma values were near 4 μg./100 ml. Thus, 75-85% of the normal whole blood histamine concentration is bound in the cellular (platelet) fraction. Whole blood histamine observed in cows with tetany ranged from 2.6-12.1 μg./100 ml. The onset of certain tetany symptoms may be associated with the endogenous release of histamine from bound sources within the body or the removal of cellular elements (platelets) from the blood by certain tissues. (Supported by U. S. P.H.S. Fellowship 1F3 AM-23, 682-01 during sabbatical leave from the University of Missouri.)

PUBLICATIONS TO DATE:

Preston, R.L. 1967. Histamine content of the blood from cows affected with tetany. Fed Proc. 26:632.

Geelen, M.J.H., D.L. Van Rheenen, H.J. Hendriks and L. Seekles. 1966. Histamine in the blood of dairy cows in connection with nutrition tetany (grass tetany). Tijdschr. Diergeneesk. 91:1577.

GRAZING WINTER ANNUALS

Research Personnel: L. W. Lomas[1] and J. L. Moyer

Date Project Initiated: September 10, 1981

Scheduled Date of Termination: This is a continuing project and a date of termination has not yet been scheduled.

Rationale For Doing Work:

Wheat and other small grain forages are frequently pastured during the late fall and early spring in southeastern Kansas. Wheat is often the crop of choice especially if the primary objective is grain production. However, if pasture is the main consideration, there may be other small grains that will yield more forage and produce greater beef cattle gain per acre than wheat.

This project was conducted to determine which winter annual small grains will result in maximum forage and beef production.

Objectives of Project:

To evaluate and compare various winter annual small grains with respect to forage and beef production.

Most Significant Results to Date:

<u>Experiment A</u>

On September 10, 1981 one 2.02 ha pasture was seeded with 101 kg/ha of Newton wheat and another 2.02 ha pasture was seeded with 112 kg/ha of Dessert Grazer Blend No. 1 triticale. Each pasture was fertilized with 56-45-45 kg/ha of N-P_2O_5-K_2O at time of seeding. Since moisture was not adequate to produce fall pasture, grazing did not begin until February 3, 1982. Ten steers with an initial weight of 240 kg were grazed continuously on each pasture from February 3 until May 20, 1982 (106 days). All cattle received 3 lb of rolled milo per head daily and had free acess to monensin blocks. Initial and final steer weights were taken following a 16 hour shrink from feed and water. Fertilizer (112-45-45 kg/ha) was applied to each pasture on March 15, 1982 for the benefit of the present crop as well as that of a summer annual that was planted after the wheat was grazed out. Forage samples were collected from ungrazed exclosures in early April.

---

[1]Southeast Kansas Branch Experiment Station, Parsons, KS 67357.

Results of Experiment A are listed in the following table:

Experiment A

	Wheat	Triticale
Liveweight beef gain, kg/ha	157	304
Animal days/ha	524	524
Average daily gain, kg	.30[a]	.58[b]
Dry matter, kg/ha	5656	4860
Crude protein	24.0[c]	27.2[d]

[a,b]Means with different superscripts differ significantly ($P < .01$).

[c,d]Means with different superscripts differ significantly ($P < .05$).

Experiment B

A similar experiment was conducted in 1982-83 with 2.02 ha of triticale seeded at 123 kg/ha and 2.02 ha of a Bonel rye-Newton wheat mixture seeded at 67 kg rye and 34 wheat kg/ha. Prior to planting which occurred on August 20, 1982, 56 kg of actual N/ha was applied to each pasture. On September 29, 1982, 28-73-78 kg/ha of $N-P_2O_5-K_2O$ was applied to each pasture. An additional 56 kg of actual N/ha was applied April 18, 1983. Pastures were grazed from November 18 to December 16, 1982 (28 days) and from February 23, 1983 until May 31, 1983. Pastures were stocked according to the availability of forage. All cattle received 5 lb of rolled milo per head daily. Results of Experiment B are listed below:

Experiment B

	Rye + Wheat	Triticale
Liveweight beef gain, kg/ha	557	171
Animal days/ha	435	377
Average daily gain, kg	1.28[a]	.46[b]

[a,b]Means with different superscripts differ significantly ($P < .01$).

Publication to Date:

Moyer, J. L. 1983. Cattle performance on annual pastures. Kansas Agricultural Experiment Station Report of Progress 433, p. 42

Anticipated publication: Kansas Agricultural Experiment Station Report of Progress.

RESEARCH BRIEF

SHEEP AND CATTLE GRAZING EFFECTS ON TILLERING DYNAMICS AND GRAIN YIELD OF WINTER WHEAT.[1]

Research Personnel: Scott Christiansen, Tony Svejcar, W. A. Phillips, T. D. A. Forbes and J. D. Trent[2]

Date of Project Initiation: September 1982

Date of Project Termination: September 1986

Rationale for Doing Work:

Wheat (*Triticum aestivum* L.) grazing is an important practice in the Great Plains of the United States and it adds appreciably to the economy of the region. It is necessary to understand the physiology of the wheat plant under grazing to explain the reports of stimulated grain production from wheat that has been grazed (Swanson, 1935; Hubbard and Harper, 1949; Sprague, 1954; Morris and Gardner, 1958).

High irradiance in the Great Plains compared to other regions may cause increased leaf production, more total leaves, and a faster rate of tillering (Friend, 1965). In ungrazed wheat late-developed tillers are less likely to survive due to mutual shading (Ong, 1978; Ong et al., 1978). It has been theorized that cereal crops may produce vegetative growth in excess of that required to support grain yields and that grazing represents an efficient utilization of the excess.

Defoliated plants are more apt to redistribute photosynthate among tillers than undefoliated plants (Quinlan and Sagar, 1962; Gifford and Marshall, 1973; Ong, et al., 1978). It is possible that moderate grazing may increase tillering, assimilate transfer and incident light reaching secondary tillers. In grazed wheat more tillers may be given a better chance to produce grain than in ungrazed wheat where main stem and primary tillers have a more sequential development and dominance (Hay 1978).

---

[1]A contribution from the USDA-ARS Southwestern Livestock and Forage Research Station, P.O. Box 1199, El Reno, OK 73036 Phone: (405) 262-5291

[2]Research Agronomist, Research Agronomist, Research Animal Nutritionist, Visiting Research Associate, and Graduate Student, respectively.

Objectives:

The objectives of this study were to investigate tillering dynamics and the components of yield in wheat left ungrazed or grazed by sheep or cattle.

Materials and Methods:

Wheat (cv. 'Triumph-64') was planted at a rate of approximately 100 kg/ha at the USDA-ARS Southwestern Livestock and Forage Research Station near El Reno, Oklahoma on 22 September 1982. The soil was a Bethany, fine, mixed, thermic Pachic Paleustoll. Anhydrous ammonia was applied before planting at a rate of 50 kg/ha actual nitrogen.

Wheat pasture was fenced to provide cattle and sheep plots 0.3 and 0.06 ha in area, respectively. Additional areas were enclosed to provide ungrazed control plots. Three grazing pressures were established as treatments in a randomized, complete block design with two replications. The ungrazed control areas were replicated three times.

In each ungrazed area 12 plots (8x7m) were marked to provide five plots that were clipped once on 15 February, 9 March, 22 March, or 22 April at 2.5 cm height. The clipping treatments were designed to assess the effect of a single, severe defoliation through advancing stages of growth on subsequent wheat grain yields. The remaining seven plots in each block were controls for estimating yields from unclipped plants.

Poor wheat growth in autumn 1982 prohibited grazing until spring. Two grazing periods of approximately five day's length were used to defoliate the wheat prior to stem elongation in mid-March when animals were removed. High, medium and low grazing pressures were imposed by using either eight, six, or four animals per sheep or cattle paddock.

Wheat samples were dug and washed free of soil from 20x20 cm quadrats taken randomly from wheat drill rows. Samples were taken before and after grazing during the vegetative phase as well as at the joint, dough and ripened stages. Four subsamples were taken from cattle treatments and two from sheep treatments at all sampling dates.

Measurements included counts of live and dead tillers, separations into leaf, stem, crowns and dead tissue, and summations of leaf, stem and dead for quantification of herbage yield. At harvest, spikes were removed from sample areas $1m^2$ in size. Spikes/m^2 were counted and then threshed. Weight of 1000 seeds was determined for each sample; seed weight, number and seed per spike were calculated.

Most Significant Results to Date:

An important lesson learned in this preliminary study was that variability must be strictly controlled or adequately described in order to find significant treatment differences. Random sampling of nonuniformly grazed wheat characterized the variability but was not representative of the treatment. The cattle and sheep grazed in patches, hence future efforts will attempt to stratify sampling into several plant utilization categories. Because of the method of sampling, significant differences in tiller numbers or grain yield among grazing pressure treatments were not revealed. As a result the data presented in this paper are the means of high, medium and low grazing pressure treatments.

Although there was tremendous variability in the counts of live and dead tillers some meaningful results were found. In Fig 1 the live and dead tillers for ungrazed, cattle- and sheep-grazed wheat are graphed across the season. Little meaning can be inferred from the variability of tiller counts during the vegetative phase, except to say that tiller numbers increased until early March. The tiller abortion seen just prior to and at jointing describes the high tiller production characteristic of wheat. The atrophy of tillers is well described (Fraser, et al., 1982) but whether the wheat plant salvages assimilate from these tissues is not well understood. Fig 1 suggests that a higher number of dead tillers occurred early in May and decreased through June. The 14 June sampling was much later and most dead tillers were largely indistinguishable from the surface litter.

The components of yield in cereals are spikes/m^2, number of seed/spike and seed weight. In Fig 2 the histograms show the components of yield for grazed wheat or for wheat clipped once, but at different dates in the spring. The results are compared to an undefoliated control. Spikes/m^2 were increased by grazing or a single clipping treatment on 28 February, whereas clipping treatments on 15 February, 9 March and later caused a loss of spikes/m^2 (Fig 2a). The clipping was severe and removed all leaf area. Effects of the defoliation on 28 February were apparently overcome by the rapid wheat growth rates. One explanation for the lower spike number on 15 February is that these wheat plants may have been influenced by the same factors as present in the control plots. The wheat had time to accumulate abundant growth and self-shading may have reduced tillering. A comparison of the 15 February clipping to the control histograms in Fig 2 shows much similarity. Jointing occurred the third week of March, therefore some growing points may have been removed on 22 March and later. The results from the late clipping on 22 April were surprising in that the wheat was still able to produce 325 seed bearing spikes/m^2 from secondary tillers.

Seed weight (Fig 2b) was not greatly altered by grazing. Slightly higher seed weights were associated with the cattle grazing treatment. Up until stem elongation there was little change in subsequent seed weight caused by clipping, whereas clipping after jointing had a large negative effect on seed weight.

Fig 2c shows the histograms for numbers of seeds/spike. Clipping of wheat on 15 February through 22 April caused a progressive decline in seed formation. The sheep and cattle grazing resulted in a decrease of seed/spike compared to the control. The wheat that was grazed by cattle had fewer seeds/spike than the wheat grazed by sheep, but seed weight was higher for the cattle treatment when compared to the sheep treatment (Fig 2b). Therefore, seeds/spike and seed weight counterbalanced to yield equal weight of seed/spike for the grazed treatments (Fig 2d).

Total grain yield for cattle, sheep and control treatments were the same (Fig 3), however, yield components differed. The uncut wheat had fewer spikes/m^2 (Fig 2a), but higher seed weight/spike (Fig 2b). Hence, spikes/m^2 and weight of seed/spike counterbalanced to result in the same grain yield for uncut and grazed wheat.

The increase in herbage mass for undefoliated wheat is shown along with information on components that contributed to the forage yield in Fig 4. As mentioned, jointing occurred about 20 March and this corresponds to the sharp increases seen in stem production and total herbage mass. The senescence process began between the 4 April and 5 May samplings as indicated by the loss in weight of leaves. The separations of plant components was discontinued at the dough stage. However, by using information from Fig 3 and Fig 4 it is easy to calculate that 210 g/m^2 (2100 kg/ha) grain yield represents almost 40 percent of the total dry weight harvested at the end of the experiment.

TABLE 1. Average dry weight of stems harvested 5 May 1983 in the dough stage of ungrazed wheat or wheat grazed by cattle or sheep during the vegetative stage.

Grazing Treatment	Stem Dry Weight (kg/ha)
Control	3283
Sheep	2538
Cattle	1897

In order to determine whether grazing reduced straw weights the stem weights from 5 May were averaged for the three treatments and are shown in Table 1. As reported elsewhere (Washko, 1947; Sprague, 1954; Morris and Gardener, 1958), defoliation in the vegetative stage of wheat reduced the resulting straw component. It appears that the wheat plant "conserves" assimilate for grain in deference to normal partitioning to stems that occurs in the non-grazed condition.

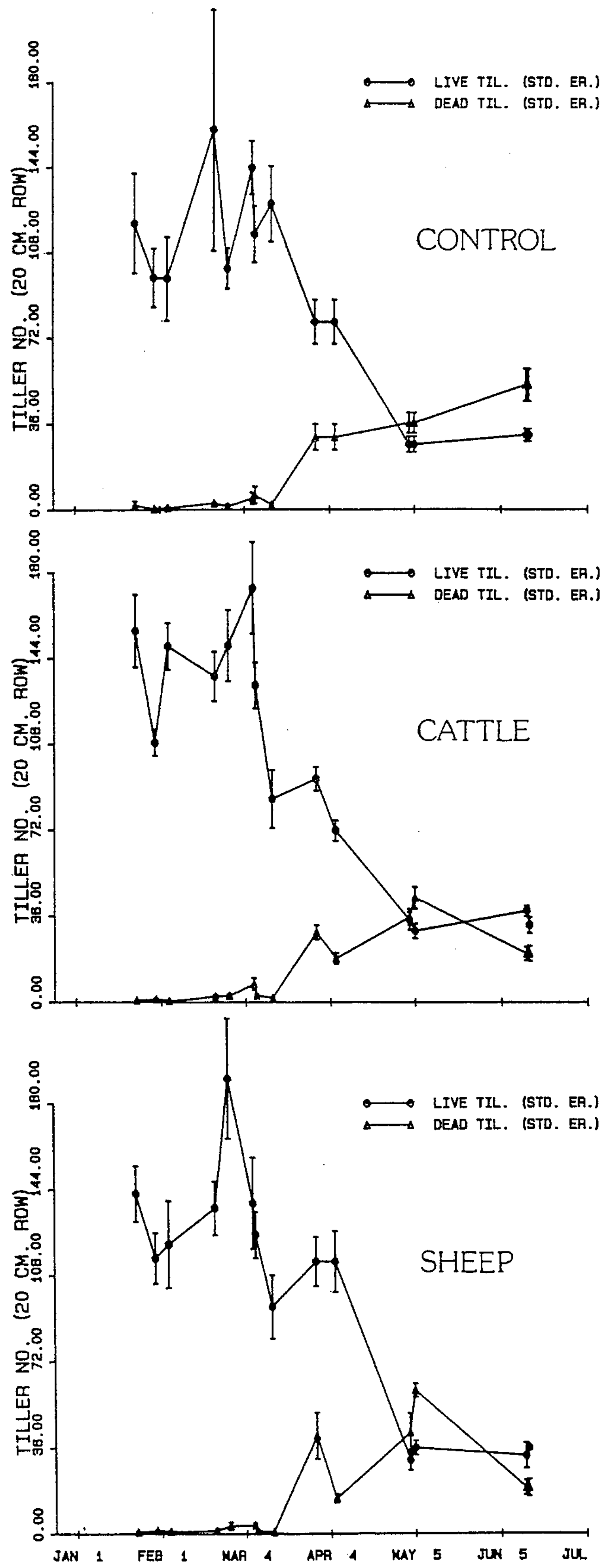


Fig 1. Live and dead tiller (TIL.) counts for ungrazed and grazed wheat. Brackets represent the standard error about the mean.

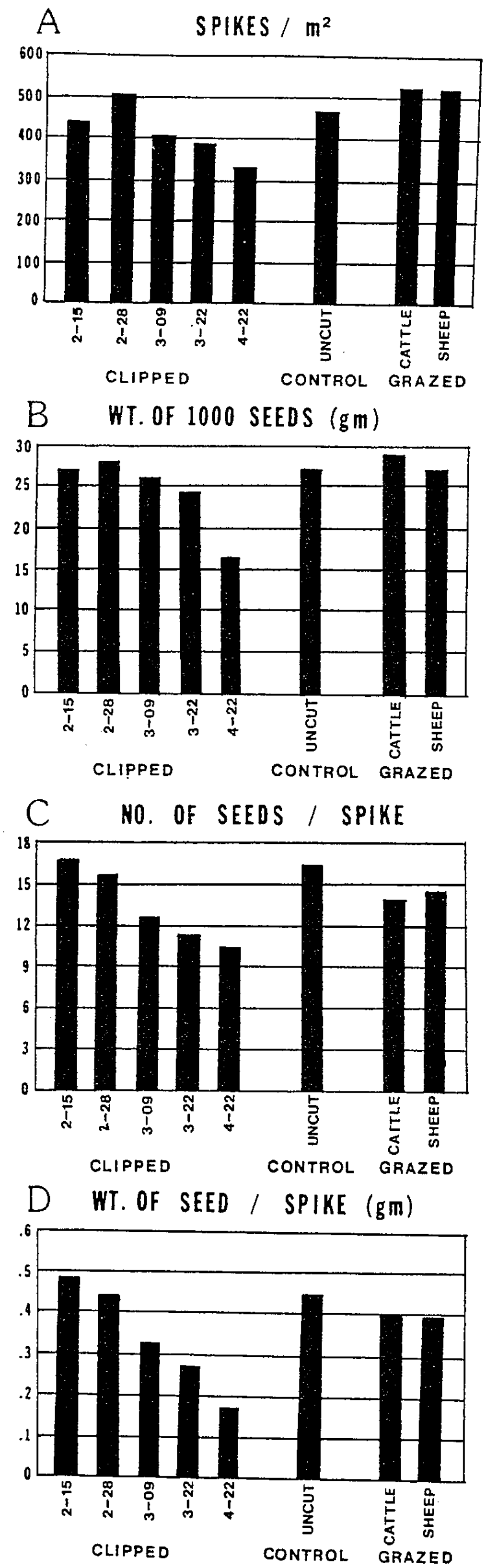


Fig 2. Components of yield for wheat that was clipped once, grazed by cattle or sheep or undefoliated in 1982-1983.

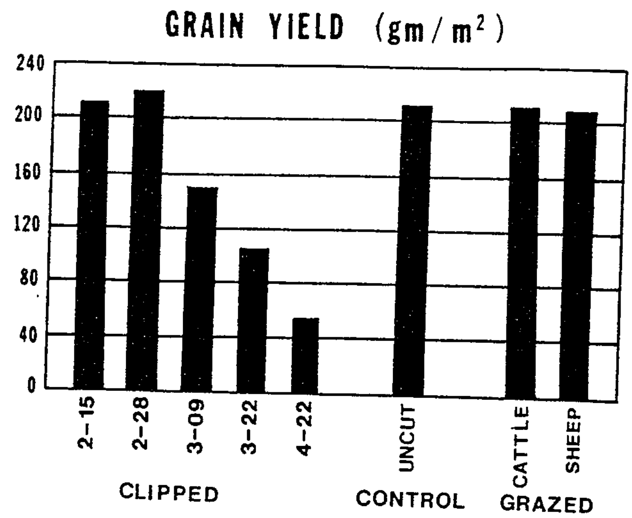


Fig 3. Grain yield of wheat that was clipped once, grazed by cattle or sheep, or undefoliated in 1982-1983.

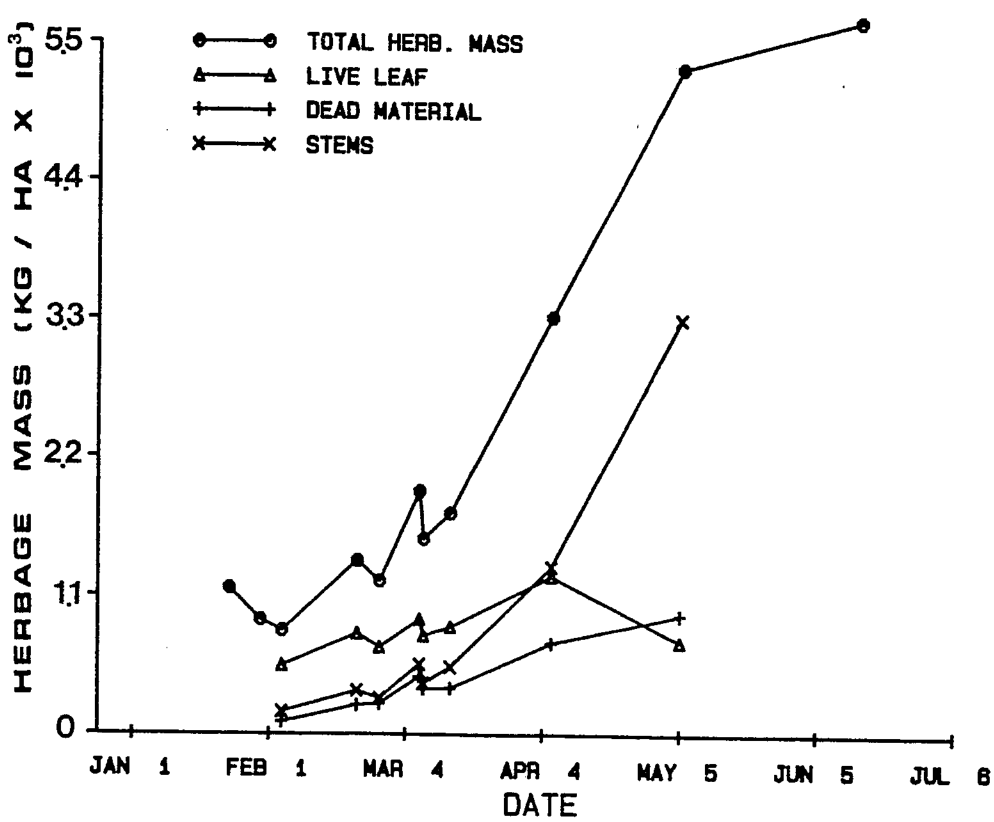


Fig 4. Herbage mass and plant component yields for undefoliated wheat in 1982-1983.

LITERATURE CITED

Fraser, J., C. T. Dougherty and R. H. M. Langer. 1982. Dynamics of tiller populations of standard height and semi-dwarf wheats. N. Z. J. Agric. Res. 25:321-328.

Friend, D. J. C. 1965. Tillering and leaf production in wheat as affected by temperature and light intensity. Can. J. Bot. 43:1063-1076.

Gifford, R. M. and C. Marshall. 1973. Photosynthesis and assimilate distribution in Lolium multiflorum Lam. following differential tiller defoliation. Aust. J. Biol. Sci. 26:517-526.

Hay, R.K.M. 1978. Seasonal changes in the position of the shoot apex of winter wheat and spring barley in relation to the soil surface. J. Agric. Sci., Camb. 91:245-248.

Holliday, R. 1956. Fodder production from winter-sown cereals and its effect upon grain yield. Field Crop Abstracts. 9:129-135; concluded 9:207-213.

Hubbard, V.C., and H.J. Harper. 1949. Effect of clipping small grains on composition and yield of forage and grain. Agron. J. 41:85-92.

Morris, H.D., and F.P. Gardner. 1958. The effect of nitrogen fertilization and duration of clipping period on forage and grain yields of oats, wheat, and rye. Agron. J. 50:454-457.

Ong, C.K. 1978. The physiology of tiller death in grasses. 1. The influence of tiller age, size and position. J. Brit. Grassland Soc. 33:197-203.

Ong, C.K., C. Marshall, and G.R. Sagar. 1978. The physiology of tiller death in grasses. 2. Causes of tiller death in a grass sward. J. Brit. Grassland Soc. 33:205-211.

Quinlan, J.D., and G. R. Sagar. 1962. An autoradiographic study of the movement of 14-C-labelled assimilates in the developing wheat plant. Weed Res. 4:264-273.

Sprague, M.A. 1954. The effect of grazing management on forage and grain production from rye, wheat and oats. Agron. J. 46:29-33.

Swanson, A.F. 1935. Pasturing winter wheat in Kansas. Kansas State Agric. Exp. Sta. Bull. 271. 29 pp.

Washko, J. B. 1947. The effects of grazing winter small grains. J. Am. Soc. Agron. 39:659-666.