herd before their removal. Thus, they have less opportunity of transmitting a high degree of susceptibility. This practice results in some automatic selection against the inheritance of susceptibilty. It should be remembered that this selection does not of itself lead to discarding the offspring the susceptible animals had produced before they were removed from the herd.

The automatic selection would not apply if eyes or lesions were treated or removed by surgery because the inherent susceptibility to the disease would still remain. Treatment or surgery can be used to prevent the spread of the disease and thereby increase the salvage value of an animal, or it can be used to allow an animal to remain in the herd until its calf is weaned.

Summary

A total of 2613 grade and purebred Hereford cattle were used to study (1) the relationship between amount of pigmentation on the skin of the eyelids and the occurence of cancer eye lesions; (2) the inheritance of amount of lid pigmentation, and (3) the inheritance of susceptibility to cancer eye.

A real relationship was found between lid pigmentation and lid lesions. Many more such lesions occurred on non-pigmented lids than would be expected if lesions and pigmentation were not related. Correspondingly fewer lesions occurred on partially pigmented lids than expected, while none was observed to develop on lids completely covered by pigment. No lid lesions were ever observed to develop on a pigmented area of the lids. There was little, if any, relationship between amount of lid pigmentation and cancer eye lesions occurring on the eyeball or area of the nictitating membrane.

Amount of lid pigmentation was found to be highly heritable. Selection for an increased amount of pigmentation would be expected to reduce the incidence of lid lesions, but would have little effect on the incidence of lesions on the eyeball or area of the nictitating membrane.

The general incidence of cancer eye lesions could be more effectively reduced by direct selection for increased resistance to the disease since susceptibility was found to have a genetic basis.

Radiographs of the Lumbar Vertebrae of Beef Calves and their Association with the Snorter Dwarf Gene

E. J. TURMAN, R. D. HUMPHREY, DOYLE CHAMBERS and DWIGHT STEPHENS

One of the important problems facing the beef cattle industry in recent years has been the occurence of dwarf calves among the progeny of phenotypically normal parents. Although conflicting opinions as to the cause of this condition have been advanced, it appears almost certain that it is hereditary.

Evidence collected to date indicates the inheritance of this abnormality is due to a single pair of autosomal recessive genes. Dwarf calves are homozygous for the recessive dwarf gene, while non-dwarf calves have at least one dominant non-dwarf gene. Thus normal calves may be either of two genotypes: homozygous for the dominant gene, and free of dwarfism: or heterozygous, and a carrier of dwarfism. The problem that faces the breeder in his efforts to eliminate dwarfism is to identify the normal animals that are carriers.

A large amount of research has been directed towards developing a method that will accurately distinguish carrier animals from clean. One such method was suggested by workers at Iowa State College, who observed marked differences in the lumbar vertebrae of dwarf and non-dwarf calves that were free of the dwarf gene. The abnormalities seen in dwarf vertebrae were also present, to a lesser degree, in the vertebrae of calves which were known to be carriers.

Examples of these characteristic differences, as seen in radiographs of the lumbar vertebrae, are presented in Figure I. The most noticeable differences are seen in the lateral profile of the body of the lumbar vertebrae. The vertebrae of animals believed to be free of the dwarf gene appear rectangular in outline and have a smooth ventral surface, which is arched dorsally (example C). In the dwarf (example A) there are marked undulations of the ventral profile, so that the ventral surface of the vertebrae protrudes downward. In addition the ventral edge of the lumbar vertebrae of the dwarf is usually shortened, resulting in a somewhat triangular, rather than rectangular, outline. The degree of abnormality observed in the vertebrae of dwarf-carrier calves varies considerably, from very slightly abnormal to very definitely abnormal. The radiograph labeled B in Figure I is a typical example of this type.

On the basis of these observations it was suggested that differences observed in the radiographs of the lumbar vertebrae of very young calves might permit the identification of animals that were carriers of the dwarf gene. Calves with normal vertebrae (C of Figure I) would be predicted clean, while calves with abnormal radiographs (similar to B of Figure I) would be predicted carriers of the dwarf gene.

To test this theory the present study was conducted at the Ft. Reno Station during 1955 and 1956. An x-ray machine was installed late in 1954, and a tester herd of approximately 100 cows known to be carriers of the dwarf gene were purchased to progeny test bulls whose genotypes for the dwarf gene were predicted on the basis of their x-rays.

Procedure

All calves produced in three projects in 1955 and 1956 at the Ft. Reno Station were x-rayed as soon as possible after birth. It is very

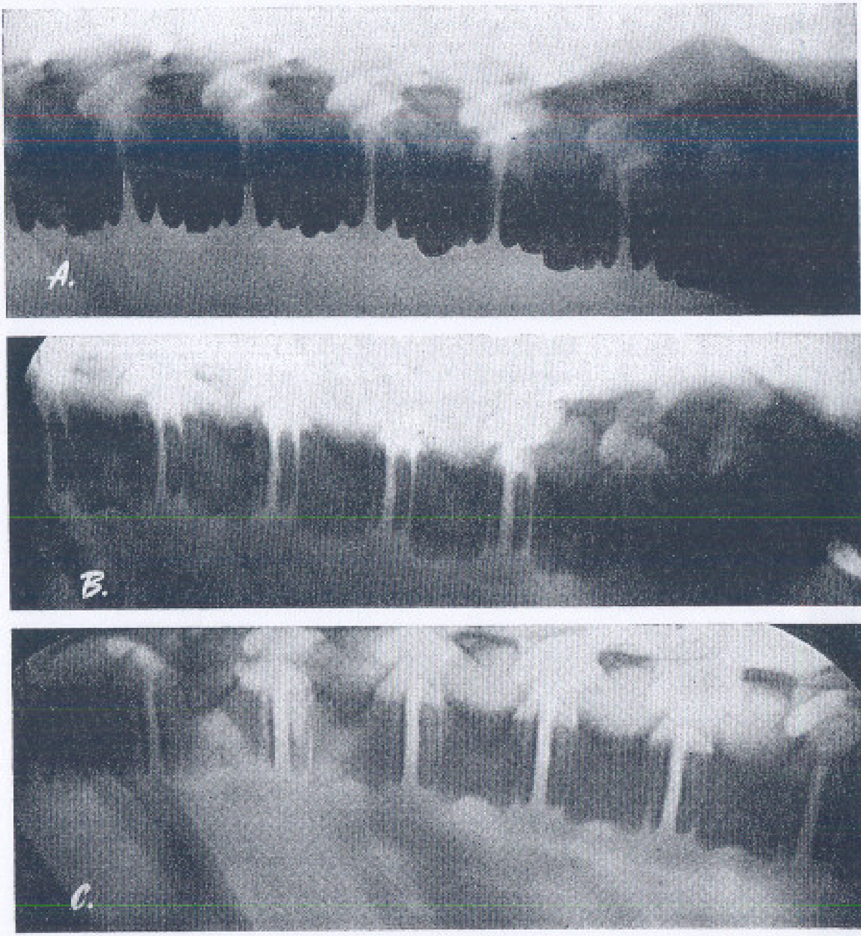

Fig. 1 Radiographs of the lumbar vertebrae, lateral view, of calves that are (A) a snorter dwarf, (B) predicted carrier of the dwarf gene, and (C) predicted free of the dwarf gene.

important that the calves be x-rayed by the time they are one week of age, primarily because the characteristic defects tend to be partially corrected as the animal grows older. There are also further advantages: the very young calves are easier to handle; their digestive tracts have not yet filled with gas and ingesta which tends to obscure the radiograph; and there is less tissue that the x-rays must penetrate.

On the basis of the radiographs of their lumbar vertebrae the calves were classified as A (dwarf), B (carrier), and C (clean) Calves with B x-rays were further classified as to degree of abnormality as MB (mild B, only slightly abnormal), IB (intermediate B, definitely abnormal), or

XB (extreme B, extremely abnormal). However, calves with any of these three classifications of B x-rays were predicted carriers.

The carrier cow herd now consists of 64 Herefords, 41 Angus and 1 Shorthorn. Except for 20 grade Herefords purchased in 1954, the cows were purchased in 1955 from cooperating breeders in four states. Many of the cows were with calf when purchased which prevented their immediate utilization in the progeny testing program.

Forty-three cows, bred to five half-brother pairs of bulls, calved in the Spring of 1956, and thirty-two cows bred to three pairs of bulls calved in the Fall of 1956. Except for one pair of bulls, both of which were predicted carriers, one bull of each pair was predicted clean, and the other a carrier. The bulls were selected from all of the purebred lines at the Ft. Reno Station as well as three pairs of Hereford bulls from the Iowa Experiment Station herd.

In the first test each bull was mated to six cows. In subsequent tests, each bull was mated to more than 6 cows to insure each bull siring at least 6 calves. Siring six calves would not test any individual bull to a very high level of probability, but 80% of the carrier bulls should sire at least one dwarf. The accuracy of the x-ray technique would be determined by whether dwarf calves were produced only by cows mated to bulls that were predicted to be carriers.

Results and Discussion

Data are presented on a total of 602 calves, of which 48 have a known genotype for the dwarf gene. Table 1 presents the x-ray classifications of all animals of known genotype.

Table 1.—Summary of x-ray classifications of animals of known genotype—data on all breeds combined

Description of Animals	No. Animals	No. Animals in Each X-Ray Classification				
		C	MB	IB	XB	A
Homozygous Recessive (Dwarf)	37	0	0	0	2	35
Heterozygous:						
By progeny test	4	1	0	1	2	0
One parent dwarf	7	1	1	3	2	0

All dwarf calves are known to be homozygous for the recessive dwarf gene. Ninety-five percent of the 37 dwarf calves x-rayed had the lumbar vertebral abnormalities that are characteristic of the dwarf. The two dwarf x-rays that were not classified A were classified as a very extreme B. Very few lumbar x-rays of non-dwarf calves have had abnormalities as extreme, and no x-ray from a non-dwarf calf has ever been classified as A. It should be noted that the two calves that were exceptions were of comprest breeding, although the calves were typical snorter dwarfs.

These data indicate that x-rays of the lumbar vertebrae are a very reliable means of identifying a dwarf calf. Although most breeders have very little trouble in recognizing a dwarf calf, there are some cases in which positive identification is difficult, especially when the calves are born dead or short term. In such cases an x-ray prediction could be extremely valuable to the owner of the sire of the doubtful calf.

Four animals, proven heterozygous on progeny test were x-rayed as baby calves. Three had the expected B type x-ray, but one bull with a C x-ray, and thus predicted clean, sired two dwarf calves in the comprest line. The bull was not of comprest breeding. Although there is evidence that animals of comprest breeding also carry a dwarf gene other than the snorter dwarf gene, these calves appeared to be of the typical snorter dwarf type.

Seven calves were known to be heterozygous because they were sired by a dwarf bull, and thus received a recessive dwarf gene from their sire. All were produced by Hereford heifers, one sired by a dwarf Hereford, and six sired by a dwarf Angus. Although all of the heterozygotes should have had x-rays with a B classification, one of the crossbred heterozygotes had a x-ray that was classified C.

The limited data available from known heterozygous animals indicates that the accuracy of the x-ray as a means of detecting carriers is not too high. Although it is dangerous to draw too many conclusions from the small number of animals in this study, 18% of the animals known to be heterozygous were, or would have been, predicted dwarf free on the basis of their x-rays. However, it may be very important to consider that the exceptions, in both the heterozygous and homozygous recessive groups involved either comprest breeding, or crossbred matings.

A summary of the offspring sired by 16 x-rayed bulls in the tester herd is presented in Table 2. Two of the nine bulls that were predicted carrier sired dwarf calves, while no dwarfs were sired by the seven bulls that were predicted clean. It will be noted in Table 2 that a number of the bulls were bred to fewer than six cows, largely due to the lack of knowledge about the cow herd. Most of the cows were purchased just prior to the start of, or during the breeding season. Many that were thought to be open, and which were allotted to bulls, were subsequently found to have been bred when purchased. There were a few instances in which the cows allotted to a bull were found to be non-breeders. In Table 2 the number of cows listed as having been bred to a bull include all open, fertile cows exposed to that bull. The number listed as having been settled by the bull were the cows bred to the bull that were diagnosed as pregnant by a veterinarian who examined the cows approximately three months after the end of the breeding season.

Although the progeny test data do not permit predictions as to the accuracy of the x-ray technique, the results are encouraging. Only bulls

Table 2.—Summary of x-ray classifications of calves sired by x-rayed bulls in tester herd

Sire	X-Ray of Sire	Dwarfism Status of Sire	Number of Cows: Bred	Settled	Calved	No. Calves in Each X-Ray Classification: C	MB	IB	XB	A
Hereford										
4-68	B	Predicted Carrier—Clean Pedigree	5	5	4	2	2	0	0	0
4-07	B	" " —Carrier Pedigree	6	4	3	0	0	2	1	0
I354	B	" " —Carrier Parent	3	3	2	0	0	1	1	0
I434	B	" " —Carrier Parent	4	4	2	1	0	0	0	1
I584	B	" " —Carrier Parent	6	6	6	0	0	2	1	3
I524	B	" " —Carrier Parent	6	4	4*	1	0	1	1	0
4-26	C	Predicted Clean —Clean Pedigree	6	6	6	2	0	1	3	0
4-38	C	" " —Carrier Pedigree	4	4	4	1	1	2	0	0
I044	C	" " —Carrier Parent	5	5	5	4	0	1	0	0
I154	C	" " —Carrier Parent	6	6	6	3	2	1	0	0
Angus										
304	B	Predicted Carrier—Carrier Pedigree	5	4	4	1	1	1	1	0
154	B	" " —Carrier Pedigree	6	4	2	1	0	1	0	0
455	B	" " —Carrier Pedigree	6	6	6	1	1	4	0	0
114	C	Predicted Clean —Carrier Pedigree	6	5	5*	4	0	0	0	0
104	C	" " —Carrier Parent	8	8	8	5	1	2	0	0
456	C	" " —Carrier Parent	8	8	8	6	1	1	0	0
Totals for 9 sires predicted carrier			47	40	33	7	4	12	5	4
Totals for 7 sires predicted clean			43	42	42	25	5	8	3	0

* Includes one calf for which x-ray classification was not made.

that were predicted to be carriers sired dwarf calves. It would be expected that if any carriers were included in the groups of bulls predicted clean, at least one would have sired a dwarf, since five of the seven bulls sired six or more calves. It is important to consider that four of these five bulls had a carrier parent, and by chance alone one-half of the sons of a carrier would also be expected to be a carrier. Thus the data obtained by the use of bulls with a C classification indicates the x-ray technique is fairly accurate. However, before any estimate of accuracy can be made many test matings such as this must be made. It will be important to know not only what percentage of the animals with C x-rays are carriers, but also, if possible, what percentage of the animals with B x-rays are clean.

It is very interesting to compare the breeding record of the two groups of bulls. The bulls predicted carrier settled 85% of the cows allotted to them, compared to 98% settled by the bulls that were predicted clean. Perhaps of even more importance is that all the cows calved that were diagnosed as settled to the predicted clean bulls, while only 83% of the cows diagnosed as settled by the predicted carrier bulls calved. In one instance a cow was known to have aborted, but the fetus was too premature to determine whether it was a dwarf. In the remainder of the cases the fetus either was resorbed or was aborted at a very early stage and was not detected. The significance of these observations is not known, but it seems more than coincidental that all cases of apparent fetal death occurred in matings involving bulls that were predicted carriers. It also suggests that care should be exercised in interpreting progeny test matings in which no dwarf calves were produced, but several cows bred to the bull under test aborted.

The Hereford heifers mated to the dwarf Angus bull provided some further progeny test information. Since the heifers were mated to a dwarf, one-half of the carrier heifers would be expected to produce a dwarf calf. Four of the seven heifers were predicted clean, and all produced normal calves. Three of the heifers were predicted carriers, and one heifer produced a crossbred dwarf. These results were as near the expected as could be obtained.

The data presented in Table 3 is a summary of the distribution of x-ray classifications among the calves produced in the three projects included in this study. Most of these calves were produced by animals whose genotype for the dwarf gene was not definitely known, but which could be predicted from pedigree and known breeding history. For example the animals in the grade Hereford herd of Project 650, and the purebred Herefords of Line 3 of Project 670 were believed to be clean on pedigree and no dwarf calves have been produced in these lines. The other purebred lines of Project 670 could be carriers on pedigree, but only a few dwarf calves have been produced, and the known carrier animals have been largely eliminated. All cows in the Project 873 herd are known to be carriers of the dwarf gene.

Table 3.—Summary of x-ray classifications of calves produced in three projects at Ft. Reno in 1955 and 1956.

Description of Cows	Dwarfism Status of Cows	No. Sires	No. Calves	No. Calves in Each X-Ray Classification				
				C	MB	IB	XB	A
Grade Hereford (Proj. 650)	Probably Clean	12	235	181	39	15	0	0
Purebred Hereford (Proj. 670)								
Line 2	Carriers in Pedigrees	7	64	34	12	16	1	0
Line 3	Pedigree Clean	3	54	39	4	11	0	0
Purebred Angus (Proj. 670)	Carriers in Pedigrees	4	64	41	11	8	2	2
Tester Hereford (Proj. 873)	Known Carriers	?	96	36	11	26	17	6
Tester Angus (Proj. 873)	Known Carriers	?	54	25	8	15	3	3

If a herd includes only clean animals, all calves should be dwarf-free and have x-rays classified as C. However, it will be noted in Table 3 that approximately one-fourth of the calves produced in the lines believed to be dwarf-free had B type x-rays, although none had extremely abnormal vertebrae. These observations suggest that these lines may include some dwarf carriers that have never been detected, or the abnormalities of the lumbar vertebrae are independent of the dwarf gene. However, this latter conclusion is not supported by the data from lines with a dwarfism history.

The two lines of Project 670 that have carriers in their pedigrees produced a higher percentage of x-rays classified as B than did the clean lines. Forty-seven percent of the Line 2 Herefords, and 33% of the purebred Angus calves were classified B and predicted heterozygous. Since the frequency of the gene in these lines is not known, although it is believed to be low, the expected percentages of each genotype cannot be determined.

If only the data from the known carrier cows of Project 873 are considered, the observed distribution of genotypes as predicted from the x-ray classifications closely fits the expected. If carrier cows were mated to clean bulls, 50% of the offspring should be clean and 50% should be carrier. If the carrier cows were mated to carrier bulls, 25% of the offspring should be clean, 50% carrier, and 25% dwarf. If both clean and carrier bulls were used the percentage of clean offspring would be somewhere between 25% and 50%, there would be 50% carriers, and less than 25% would be dwarf.

The genotypes of all the bulls to which the Project 873 cows were mated was not known, but it was evident that some were carriers and it was believed that some were clean. If the data for both breeds is combined, 40% of the calves had C x-rays, and thus were predicted clean, 54% had B, or predicted carrier, x-rays, and 6% were dwarf calves.

A comparison of the x-ray classifications of calves in Table 2 reveals striking differences in the progeny of the two groups of bulls. Sixty percent of the calves sired by the bulls predicted to be clean had x-rays classified as C, with 40% classified as B. In the group of calves sired by the bulls that were predicted carrier there were 22% classified C, 66% classified B, and 12% classified A. If we assume that the genotypes predicted for the sires on the basis of their x-rays were correct, these observed ratios were very close to what would be expected. It is evident, in any event, that bulls with B type x-rays sire a much higher percentage of calves with B x-rays, while bulls with C type x-rays sire a much higher percentage of calves with C x-rays.

While no definite conclusions as to the accuracy of the x-ray technique can be drawn from these distributions, the evidence suggests that the x-ray may be very useful in herds that have a dwarfism problem. It seems more than a coincidence that the observed distributions of enotypes as predicted by the x-ray fits so closely the expected distribu- ion of genotypes in the lines with known dwarfism history. However, he occurrence of calves which must be predicted carrier on the basis of heir x-ray in lines believed to be clean indicates that more study is ieeded.

The results obtained in this study to date are too inclusive to justify . critical evaluation of the technique at this time. Although it is ap- parent that occasionally an erroneous diagnosis is made, it may well pe that the technique may prove accurate enough to be of real value n problem herds. Certainly further study to attempt to determine the accuracy of the test is justified, and is under way at the present time. Recommendation as to the possible use of this technique by breeders cannot be made until further information has been obtained.

Summary

Data are presented on two years study of a technique for detecting beef calves that are carriers of the snorter dwarf gene, based on abnormalities observed in radiographs of the lumbar vertebrate of very young calves. Snorter dwarf calves have very characteristic abnormalities which have never been observed in x-rays of non-dwarf calves. Lumbar x-rays accurately identify a dwarf calf, and may be very useful to breeders in determining the dwarfism status of a doubtful calf.

The accuracy of the method as a means of detecting carriers of the dwarf gene could not be determined from the limited number of animals of known genotype included in the study. However, the results obtained to date are promising enough to justify further study.

Effect of Feeding Different Levels of Winter Supplement and Age of First Calving on the Performance of Range Beef Cows and Replacement Heifers

J. E. ZIMMERMAN, L. S. POPE, DWIGHT STEPHENS and GEORGE WALLER

The most common system of cow herd management in the southwest is to graze year-long and supplement during the winter to make up for the lack of protein, phosphorus or carotene in the weathered range forage. Previous tests have shown that this is the most economical and profitable method of maintaining brood cows, particularly under a spring calving program.

However, the question often raised is: How much supplemental feed should a cow receive during the winter months? Obviously, this may depend on several factors such as calving date or length of the lactation period before spring grass appears, the type and amount of native grass available, and the protein content of the supplement fed. Since supplemental feed during the winter represents the largest out-