be able to select effectively for earlier calving cows. This would result in a more uniform group of calves so far as age is concerned and would perhaps be to the advantage of the breeder in the management of his cow herd and in the marketing of his calves.

These data were not suitable for a study of factors which might be responsible for "skip-breeders" because so few animals of that kind were available for observation. There is a real need for information of that type. Until suitable measures of reproductive efficiency are developed and until the importance of genetic and environmental factors has been determined, one cannot intelligently determine the amount of emphasis which should be placed upon reproductive performance in a selection program.

Genetic Aspects of Cancer Eye in Cattle[1,2]

DAVID E. ANDERSON[3] and DOYLE CHAMBERS

Cancer eye in cattle results in a significant economic loss each year to the livestock producer. The disease reduces productivity by shortening the life span of an animal. Diseased animals may die, may require treatment, or may need to be removed from the herd before their productive lives are completed, thus lowering the efficiency of production. It has been estimated that animals with cancer eye leave the herd about one year earlier than unaffected animals; and that in the southwestern states about 3 to 10 percent of the animals are removed from the herd each year because of the disease.

The salvage value of these culled animals and possibly of treated ones is reduced because entire carcasses or parts of carcasses may be condemned at slaughter, depending upon the extent of the disease and condition of the affected animal. The average annual loss from such condemnations alone is in excess of one million dollars. A reduction in the incidence of the disease obviously would be of economic concern to the livestock industry.

Materials and Methods

The animals included in this study were grade and purebred Hereford cattle from Oklahoma, Texas and New Mexico. A total of 2613 animals from seven herds were involved in the different phases of study.[4]

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The eyes of the animals in three of the herds were routinely examined in the spring and fall of each year. The period of observation for these three herds was from 1946 to 1954. One other herd has been examined twice each year since 1954. The remaining herds have been examined annually since 1954. Calves were observed for eyelid pigmentation. Animals in the breeding herds were observed for eyelid pigmentation and eye lesions. Any lesion on the eye which appeared to be cancer, or an advanced cancer precursor was usually removed by surgery. The practice in one of the herds was to dispose of such animals soon after the lesion was first observed.

Cancer may develop in any part of the eye and may develop simultaneously in both eyes. A common place for it is at the lateral portion of the eyeball where the white of the eye and dark cornea join. Other places where it is commonly seen include the inner or medial junction of the cornea and white of the eye, the region of the "third eyelid" or nictitating membrane, and the eyelids themselves. The disease usually develops after four or five years of age, and seems most frequent around eight years of age.

Some Herefords have brownish-red pigment on the skin of the eyelids which differs in shade of color, pattern, and amount between eyes on the same animal, and from animal to animal. In the present case, lid pigmentation was considered as an **amount**. The amount was measured as a percentage of the entire lid length covered by pigment; thus, the values could range from zero for complete lack of pigment to 100 percent for completely pigmented lids.

Results

Since the absence of eyelid pigmentation has been thought to be an important contributing factor in the occurrence of cancer eye in cattle, the first objective was to provide information on this relationship. All animals used in this particular phase of study were in the age range (over 4 years of age) in which the preponderance of cancer eye lesions occurs. Records of eyelid pigmentation were available on 842 animals, among which 338 had eye lesions which included cancer and other precursor lesions. The relationship between eye lesions and eyelid pigmentation is summarized in Table 1.

By comparing the expected values with the ones actually observed, the difference can be studied to determine the importance of the relationship between pigmentation and lesions. If there is little difference, it means there is probably little relationship between lesions and pigmentation. If the difference is large, the relationship is probably large.

There is little difference between the expected incidence and actual incidence of lesions on the eyeball within each of the pigmentation classes. There is only the slightest indication that more lesions occurred on the eyeball of eyes with zero lid pigmentation and correspondingly fewer lesions occurred in eyes completely surrounded by pigmentation than would be expected if there really were no relation between

Table 1.—The incidence[1] of cancer eye lesions among eyes with varying amounts of pigmentation on the lids.

Location of lesion		Percent pigmentation on the lids			
		Zero	Less than 50	50 or more	100
Eyeball	Observed	32	26	26	22
	Expected	(28)	(27)	(28)	(26)
Lids	Observed	18	9	5	0
	Expected	(10)	(10)	(10)	(10)
Nictitating Membrane	Observed	3	3	2	0
	Expected	(3)	(3)	(2)	(3)

[1] Each of the values represents the observed percentage of all animals within each of the pigmentation classes that had a lesion on the eyeball, lids, or area of the nictitating membrane. The numbers in parentheses are the values that would be expected *if* pigmentation and lesions were not related in any way.

lesions and pigmentation. The difference is small enough that it could easily have occurred by chance about 30 percent of the time. In other words, the incidence of lesions on the eyeball is about the same in eyes surrounded by a lot of lid pigmentation as it is in eyes surrounded by little or no lid pigmentation, meaning there is little, if any, relationship between lesions on the eyeball and lid pigmentation.

Likewise, there is little relationship between lesions developing in the area of the nictitating membrane and amount of lid pigmentation. In Table 1 the actual incidence of these lesions within the different pigmentation classes is almost identical to the expected incidence. Such a small difference would be expected by chance about 40 percent of the time.

There is, however, a highly significant relationship between cancer eye lesions on the lids and amount of lid pigmentation. In Table 1 the incidence of lid lesions in the zero pigmentation class exceeds the expected value by 8 percent. The incidence of lid lesions within each of the partially pigmented classes is correspondingly lower than expected, while no lesions were observed to develop on lids completely covered by pigment, although many more were expected. In fact, no lid lesions were ever observed to develop on any pigmented portion of the lids. It is evident that as the amount of lid pigmentation increases, the actual incidence of lid lesions decreases. Pigment on the skin of the lids seems to protect against the development of cancer eye lesions on the lids. Such differences as were found would occur by chance only once in a thousand times.

In view of this, the incidence of cancer eye lesions on the lids could be reduced by selection for an increased amount of pigmentation on the skin of the lids. The heritability of lid pigmentation was studied in a sample of 1117 animals. These were by 116 identifiable sires and from 513 dams.

Heritability is a measure of the extent to which the differences among animals are due to differences in the genes they have which act in an additive manner. Heritability can be determined from resemblances between relatives, that is, between mother and offspring, sire and offspring, paternal half-sibs, or maternal half-sibs. In the present case, the method amounts to dividing the parents into those which have pigmentation and those that do not, and then studying the pigmentation in the progeny of the two groups of parents. This method gives an estimate of the fraction of the differences in amount of pigmentation selected for in the parents that would be expected in the progeny. A low estimate of this fraction would mean that a selection program other than on the animal itself would be needed to change the average amount of pigmentation in the herd in succeeding generations. Information on the pigmentation of ancestors, parents, sibs or progeny would also be needed. On the other hand, a high fraction, or high heritability, would mean that direct selection for animals with large amounts of lid pigmentation would suffice in effectively increasing the average amount of pigmentation in the herd.

By studying resemblances in amount of pigmentation between mother and offspring, an estimate of heritability of .44 was found. This estimate is sufficiently high to indicate that the animal itself should be the most important criterion in selecting for an increased amount of pigmentation. Such selection, while increasing the average amount of lid pigmentation, would also be expected to reduce the incidence of lesions such as develop on the lids. It is unlikely that it would have much effect on the incidence of lesions on the eyeball or area of the nictitating membrane because the relationship between these lesions and eyelid pigmentation appears to be small. It is also unlikely that such selection would result in more than a slight reduction in the general incidence of cancer eye lesions because lesions on the lids are only a small proportion of the total number. Lesions on the eyeball and area of the nictitating membrane were about three times more frequent than those on the lids for animals in this study. Therefore, in a herd in which lid lesions account for a third of all eye lesions, selection for an increased amount of lid pigmentation might reduce the general incidence of lesions only about a third. The effect of selection for pigmentation on the general incidence of lesions will become smaller as the incidence of lid lesions becomes smaller. The general incidence of eye lesions might be more effectively reduced by selecting for increased resistance to the disease, since there appears to be a genetic basis for differences among animals in their susceptibility to cancer eye.

Table 2 shows the important effect inheritance has on the occurrence of the disease. The results are from a purebred herd in Oklahoma.

The incidence in the progeny of susceptible sires and resistant dams was 15 percent higher than the incidence in the progeny of two resistant parents. When the dam was the susceptible parent, the incidence was

Table 2.—The incidence of cancer eye in the progeny of susceptible parents with the disease and resistant parents without the disease.

Condition of parent Sire x Dam	Number of matings	Percent incidence in progeny (over 4 yrs. of age)
Resistant x Resistant	56	8.8
Susceptible x Resistant	13	23.7
Resistant x Susceptible	15	26.7
Susceptible x Susceptible	9	44.4

18 percent higher than that in the progeny of two resistant parents. The incidence in the progeny of two susceptible parents was 36 percent higher than that in the progeny of two resistant parents. Hence, one susceptible parent has increased the incidence about 17 percent and two susceptible parents have increased it 36 percent compared to resistant parents. This indicates the cumulative or additive effect of the genes affecting differences in cancer eye susceptibility.

Additional information on the importance of hereditary differences was had from study of mother-daughter resemblances in susceptibility to cancer eye. Susceptibility was determined by the age at which cancer eye lesions occurred. It was assumed that an animal developing the disease early in life is usually more susceptible than one developing the disease later in life. Among normal animals, the older ones are scored as being more resistant than the younger ones, because among the young ones some probably would have developed lesions if other causes had permitted them to remain in the herd to older ages. The heritability of susceptibility to cancer eye was .41, as measured by this age-score. This indicates that 41 percent of the differences in susceptibility selected for in the mothers would be expected in the progeny. Or, as the susceptibility score of the mothers increases, that is, the earlier they develop the disease, the susceptibility score of the progeny also increases, meaning they also tend to develop it earlier. Conversely this indicates again that resistant parents tend to have resistant progeny.

The incidence of cancer eye could be effectively reduced by selecting animals for the breeding herd from aged resistant animals. Since cancer eye appears in animals over four years of age and mostly in those about eight years of age, animals should be kept to 8, 9 or more years of age to be certain that they are resistant to cancer eye. If lid lesions are a problem, an increased amount of pigmentation on the skin of the lids should also serve as a criterion for some mild early selection.

Breeders are probably already practicing some selection against the disease, because animals with cancer eye are usually removed from the herd shortly after cancer is first recognized. Since an animal with cancer early in life is considered more susceptible than one in which it occurs later, the more susceptible animals leave fewer offspring in the 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