EFFECT OF SOME ENVIRONMENTAL FACTORS ON REPRODUCTION AND GROWTH IN SHEEP

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EFFECT OF SOME ENVIRONMENTAL FACTORS ON REPRODUCTION AND GROWTH IN SHEEP

By

ONKAR NATH SINGH

A THESIS

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INTRODUCTION

Long ago, livestock improvement was made by a small number of resourceful, practical stockmen who had no definite rule to follow except that "Like begets like" and "Breed the best to the best". This, however, when applied by many average breeders frequently proved very disappointing. The explanation for such mysterious happenings or failures was supplied by the Mendelian findings of 1866, which were rediscovered in 1900. Reference is made to the two laws or fundamental principles of heredity, namely: (1) the Law of Segregation and (ii) the Law of Independent Assortment.

In the light of present knowledge of Genetics and Animal Breeding, an animal is said to be the result of heritable genotype and non-heritable environment. Therefore, characters of an animal, viz., reproduction and growth, are partly inherent and partly dependent on the environment, and the expression of the characters can be changed by appropriate alterations either in its heredity or its environment.

That environment has an important bearing on characters--altering them in one way or another--has been observed from time immemorial. It is known that the great philosopher Aristotle observed that fertility in sheep was increased when these animals were exposed to favorable environment. More recently, Darwin, the great English naturalist reported that there was a tendency for domestic animals to breed at more frequent periods and to produce a greater number of offspring than wild animals of the same species. Heap (1899) also reported that environmental factors such as season, nutrition and management greatly influenced the breeding and fertility of sheep. Observations since the turn of the present century removes all doubt that environmental factors do influence numerous processes--be they of a physiological nature or otherwise.

The seasonal breeding nature of sheep was observed long ago, and it seems conceivable that the factors responsible for this periodic breeding activity probably also govern, to some extent, fecundity and multiple birth in ewes.

Heap (1900) and Marshall (1903, 1922) observed that ewes of British breeds came into estrus in the autumn and early winter months. Following their reports, a number of investigations on the duration of breeding season were made and reported. These investigations were made by studying the normal cycle in ewes (Cole and Miller 1933, Grant 1934, Roux 1936, McKenzie and Terril 1937, Kelley and Shaw 1943, Hammond Jr. 1944, Phillips, Schott and Simmons 1947 and others). In general these investigators have shown that most of the breeds of sheep, especially those produced above the tropic of Cancer, have a marked restricted breeding season at a definite time of the year--this being fall and winter (September to February). However, sheep with long breeding seasons have also been reported. They are primarily those which have been produced in a tropical country such as India, (Smith and Hussain 1935).

Reproductive periodicity in sheep and its varying duration in the different latitudes is convincing evidence that some environmental factors operate directly or indirectly on the endocrine glands, thus influencing the sexual cycle. Based on many significant findings, the concensus of opinion is that many valuable quantitative characters depend on optimum hormone levels for their full expression. These hormone levels are in turn influenced by environment. It is apparent, therefore, that there is a chain reaction, relating environmental climate, successively to nervous system, to the endocrine system, and finally to the metabolic and reproductive processes.

In sheep production in addition to prolificacy, which is very important in determining economy of production, the breeders are also interested in the factors which influence a second economic character--growth of lambs. The rate of growth in the early post natal period is mainly governed by the amount of milk secreted by the dam, but later the quality and quantity of pasture or the plane of nutrition gradually assumes more importance. It seems, therefore, of prime interest to study the factors which might produce marked effects on the nutrition of growing lambs.

It should be pointed out that although it is known that environmental factors, light and temperature among others, affect seasonal rhythmicity of reproduction in such a way that estrus in ewes is manifested coincidentally with decreasing light and temperature, there is still no precise information on the effects of these factors on prolificacy and actual lamb yields in sheep. While there is good reason to believe that rainfall can influence the said reproductive phenomena, in this also there is a dearth of information. This study was, therefore, undertaken in an endeavor to remove some of the deficiencies in our knowledge.

REVIEW OF LITERATURE

Factors Regulating Gonadal Function

(a) Effect of Photoperiodism

Varying exposure to light has been shown experimentally in many cases to influence the onset of the sexual season. Investigations made on avians, like juncos, crows, starlings, ducks, and others show that the daily period of light is a factor in conditioning sexual activity (Rowan 1925, 1930, Bissonnette 1931, Benoit 1936, and others). In mammals, Bissonnette (1932) was the first to show the similar response of ferret gonads to light. He reported that in female ferrets, full estrus was induced some months earlier than normal by subjecting them in the winter to 6 - $6\frac{1}{2}$ hours of artificial (electric) light, in addition to daylight hours.

Response to light by ruminating ungulates, e.g., deer, sheep, goat, ets., has also been reported. Marshall (1937) has pointed out that when sheep and red deer are transferred from one hemisphere to the other, they soon adjust their habit to the reversed seasons and breed at different times of the year but in the right season. He further stated that autumn is the sexual season for the majority of ruminants, both in the Northern and Southern hemispheres, so that if these animals react to the light it must be to diminution and not to increase. Effect of light on goats was studied by Bissonnette (1941) who has pointed out that the breeding cycle in goats is controlled by light in such a way that diminution in light induces breeding cycles, while increases inhibit them.

Sykes and Cole (1944) observed the effect of light on reproduction in ewes. They conducted their experiment on 8 ewes, five of which were yearlings (4 Rambouillet x Cotswold crossbreds and 1 Rambouillet), and the other three (1 Southdown, 1 Rambouillet and 1 Hampshire were mature ewes.

They artificially increased the duration of light during March until three hours of light were added to the normal day. The light was then decreased at intervals in one hour steps until early May, when it was decreased by six hours of daylight. The ram was kept with the ewes during the summer. Five of the ewes gave birth to normal healthy lambs between November 1 and November 5, four to five months previous to the usual time. The Hampshire ewe did not lamb. One of the Rambouillet ewes which failed to lamb was suspected of having aborted. It is not uncommon for Rambouillets and their cross-ewes to breed in the month of May, but it is certainly unusual for a Southdown to conceive during that period. Hence, they concluded that the alteration in the sexual cycle was a result of light treatment. It may be pointed out, however, that the number of animals in this experiment was small, and no clear cut comparison was afforded since control ewes were not used.

An extensive investigation on the effect of light on the sexual activity of sheep was conducted by Yeates in England (1949). By subjecting a group of ewes to gradual increases of light during shortening days and decreases of light during lengthening days of the year, he observed changes in the breeding and lambing time of the year. The experimental ewes conceived in mid-summer (May and June) and lambed the following October, which is the usual time of mating. He, therefore, advanced his hypothesis that the sexual season in sheep can be modified or reversed at will by suitable artificial alteration in the duration of daily light.

More recently, Hart (1950) induced estrus in Suffolk ewes by subjecting them to a daily light/dark ratio, in hours of 4 light, 2 dark, 4 light, 14 dark. From this he suggested that splitting the long summer days into two short periods may induce breeding activity.

All the above reports indicate fairly conclusively that decreasing light is correlated with sexual activity. Attention should be called to the fact that much emphasis has been put on increasing or decreasing light as the causative factor in varying reproductive states. Yet, in the literature it is most evident that despite the control accorded light, temperature is not seen to be controlled. Contrasting reports have also been presented. For instance, Terry (1951) reported results in which 4 ewes out of 8 under constant light lambed earlier than those in normal light, and those, with the exception of one, in constant darkness. With but eight ewes in each of the three groups one would hesitate to base conclusions on the results.

(b) Effect of Environmental Temperature

Many experiments have shown that temperature exerts an influence on the reproduction of various species. Some species are stimulated to sex activity by increasing temperature, others by decreasing. A survey of such work was made for this study.

The reproductive cycle as well as spermatogenesis in the fish, three-spined stickleback, was shown by Craig-Bennet (1931) to be conditioned by changes in temperature. He observed a rise of temperature to have a stimulating effect upon the testis of this fish.

Wells (1935) studied the sexual periodicity in the male ground squirrel. He concluded that sexual periodicity was due to the seasonal variation in the sex-stimulating potentiality of the anterior pituitary, which was probably influenced by the environmental temperature. Moreover, in 1940 Wells and Zalesky observed the association of testicular regression of the ground squirrel with rising summer temperature, and its reactivation with diminishing temperature of fall and winter. Breeding males kept in a cold room (40° F.) for a year maintained their breeding condition throughout the period.

Among the farm animals, the most marked seasonal changes in the physiology of reproduction occur in sheep and goats. Fertility in the rams of some breeds is practically lost during those months of the year when the temperature is at the highest. A study of ram fertility was made by McKenzie and Berliner (1937) at the Missouri Agriculture Experiment Station. They stated that the decreased sperm concentration and increase in number of abnormal sperms in the semen of rams during summer was due to the effect of high temperature, since they also observed similar changes during winter in the semen of rams placed in rooms maintained at high temperatures.

At the Kentucky Agriculture Experiment Station (1951) using Hampshire cross western ewes, 20 were subjected to 45 - 48° F. with relative humidity 70 to 80 percent on May 26, another 20 ewes were kept as control under the prevailing temperature and relative humidity. Estrus and conception in the experimental ewes were initiated 8 weeks earlier than in the control group.

Thyroid Activity

For a long time, the pituitary has been regarded as the only endocrine gland exerting a marked effect on gonadal activity. The gonadotrophins have been cited as the possible route. Within recent years however, the thyroid hormone has been found to be related also to the gonadal functioning. It has been demonstrated that the level of thyroid secretion is influenced by seasonal variation. There is good evidence, as will be shown, to indicate that gonadal activity is dependent in part on the optimum levels of thyroid hormone.

Thyroidectomy has been found to result in reduced sperm concentration and in general, impaired fertility. In rams, Berliner and Warbitton (1937) observed marked decrease in sperm concentration and volume of semen with a relatively increased number of abnormal spermatazoa. Other adverse effects as sloughing of semineferous tubules, increase in glandular interstitial cells and edematous exudates were also observed by the same workers. On administration of thyroxine, spermatogenesis was improved in these animals. Rams with low fertility in summer also showed marked improvement when treated with thyroxine. Working with chickens, Winchester (1939) and Taylor and Burmester (1940) observed marked decline in egg production following thyroidectomy. By replacement therapy egg production was found to be increased.

Turner, Kempster, Hall and Reineke (1945) found that egg production was maintained on a more uniform level when the thyroid hormone was maintained at a uniform level in the feed and possibly in the body. This observation was made on a group of 24 two-year old White Leghorns and two groups of 12 Rhode Island Red pullets fed for one year on a ration containing thyroprotein in comparison with a control group of each breed. These workers concluded that thyroid secretion was one of the most important factors influencing gonadotrophins and egg production. Furthermore, they interpreted their results as indicating that seasonal cycle of egg production was in part due to reduced secretion of thyroid hormone during summer months.

Reineke (1946) reported that thyroprotein will correct certain types of infertility in bulls. Of thirteen bulls treated with thyroprotein definite improvement in vigour and libido was observed in ten. Evidence was also obtained indicating improvement in spermatogenesis as a result of thyroid administration.

Shuffner and Andrews (1948) found reduced semen quality in fowls as a result of hypothyroidism. They concluded that thiouracil impaired the ability of the gonads to produce viable sperms which were capable of surviving normal lengths of time in the oviduct of the hen.

Turner (1948) found that when egg production began to decline in May the secretion of thyroxine also declined by fifteen percent. During the cooler months, between January and March, no decline in thyroxine nor egg production was observed. These findings are in agreement with seasonal egg production data; egg production normally begins to decline in the latter part of April or the beginning of May.

Henneman (1953) observed significantly low levels of thyroid secretion in sheep during summer as against high levels during other periods of the year. This seems to furnish further evidence in support of the seasonal control of thyroid secretion and relating it to seasonal breeding activity of sheep.

On the basis of the above experimental evidences, varying levels of thyroid secretion seem to be clearly correlated with reproductive activity. Though these reports have demonstrated the seasonal variation in the activity of thyroid they do not identify which of the climatic conditions is responsible for this cyclic change. Some other workers have stated that environmental temperature plays a role.

Dempsey and Astwood (1943) treated rats with thiouracil and thyroxine and found that the rate of thyroid enlargement as a result of thiouracil was low in a hot environment and high at cold temperatures. They also found that 100 gram rats produced about five times as much thyroxine at a temperature of 1° C. as at 35° C. (9.5 ug. vs. 1.7 ug.).

Bogart and Mayer (1946) stated that high summer temperature caused a decline in spermatogenesis and breeding capacity in the ram which could be restored to near normal level by the administration of thyroprotein or thyroxine.

In summary, it is evident that reproductive activity is affected, but whether the effects are traceable to light or to temperature or to both is controversial.

(c) Mode of Action of Light and Temperature on Reproduction

It is a common observation that some mammals breed at all times of the year, whereas others like sheep and goats breed only during a particular season of the year. This periodic gonadal activity in these species has been stated by many workers to be influenced by environmental factors viz. light, temperature and nutrition. While much is known about the influence of nutrition on reproductive activity as a whole, the mechanism by which light and temperature affect seasonal reproduction is still obscure. Within recent years much has been revealed however, and consideration will now be given to the most plausible reports.

It has been suggested that seasonal breeding behavior is due to variation in the secretion of gonadotrophins by the pituitary (Warbritten and McKenzie 1937, Robinson 1951, and others). It appears that the sexual cycle is influenced by certain environmental factors, which stimulate and/or inhibit the functional activity of the anterior pituitary.

Hill and Parkes (1933) have demonstrated that in wild mice and various species of birds, response to illumination is not possible after hypophysectomy, and it is much impaired after division of the optic nerves (Bissonette 1935 a, b, 1936). Marshall and Bowden (1934) have adduced further conclusive evidence that activation of the gonads is principally dependent on retinal stimulation and on the effects which such stimulation exerts upon the pituitary. A ferret blinded by cataract failed to come in heat at any time between December 23, 1932 and July 10, 1935 notwithstanding successive periods of artificial illumination (Marshall and Bowden 1934, 1936). When birds were hooded and simultaneously exposed to light, normal sexual rhythmicity was not observed. On the other hand, when the eyes were removed from ducks, sexual activity was not inhibited (Benoit and Ott, 1944). These workers also demonstrated that by transmitting light directly on the anterior pituitary, they could induce the development of the testis is ducks. The best available evidence indicates that light impulses are received by the eyes. They are then passed by way of the optic nerves to the hypothalmus, the pituitary stalk and finally to the pituitary itself, where they produce their effects on the release of gonadotrophic hormones which serve to stimulate the respective target organ-ovary or testes. (Figure 1).

Though the influence of temperature on the sexual cycle of certain species has been suggested as resulting from the release of pituitary hormones, the mode of stimulation is still unknown. According to Turner (1948) it has been observed that hypertrophy of the thyroid does not ensue on exposure to cold if the infundibulum is severed. This is probably because the anterior pituitary cannot respond directly to cold with increased output of thyrotrophic hormone. This indicates that the nervous mechanism is involved in the action of temperature. The evidences indicate that temperature has its effect on the secretory activity of hypophysis, but the pathway of this action is not yet known. Regarding its pathway, it is generally suggested that it first acts on the cutaneous nerve endings of the body and that stimulation is carried to the brain after which the pathway is the same as that of light (Figure I).

Cyclic variation in the activity of thyroid as related to the functioning of gonads has been observed from time to time. It is believed that the thyroid activity is under the direct control of anterior pituitary and environmental factors, and therefore, that it can influence the thyroid function only by the way of the pituitary. Besides this, the function of the gonad is also said to be under the control of the anterior pituitary. Hence, if the thyroid has any action on the gonads, as has been suggested because of their apparent relationship during different times of the year, it is quite logically through the pituitary. However, some workers have suggested the possibility of a direct action on the function of gonads.

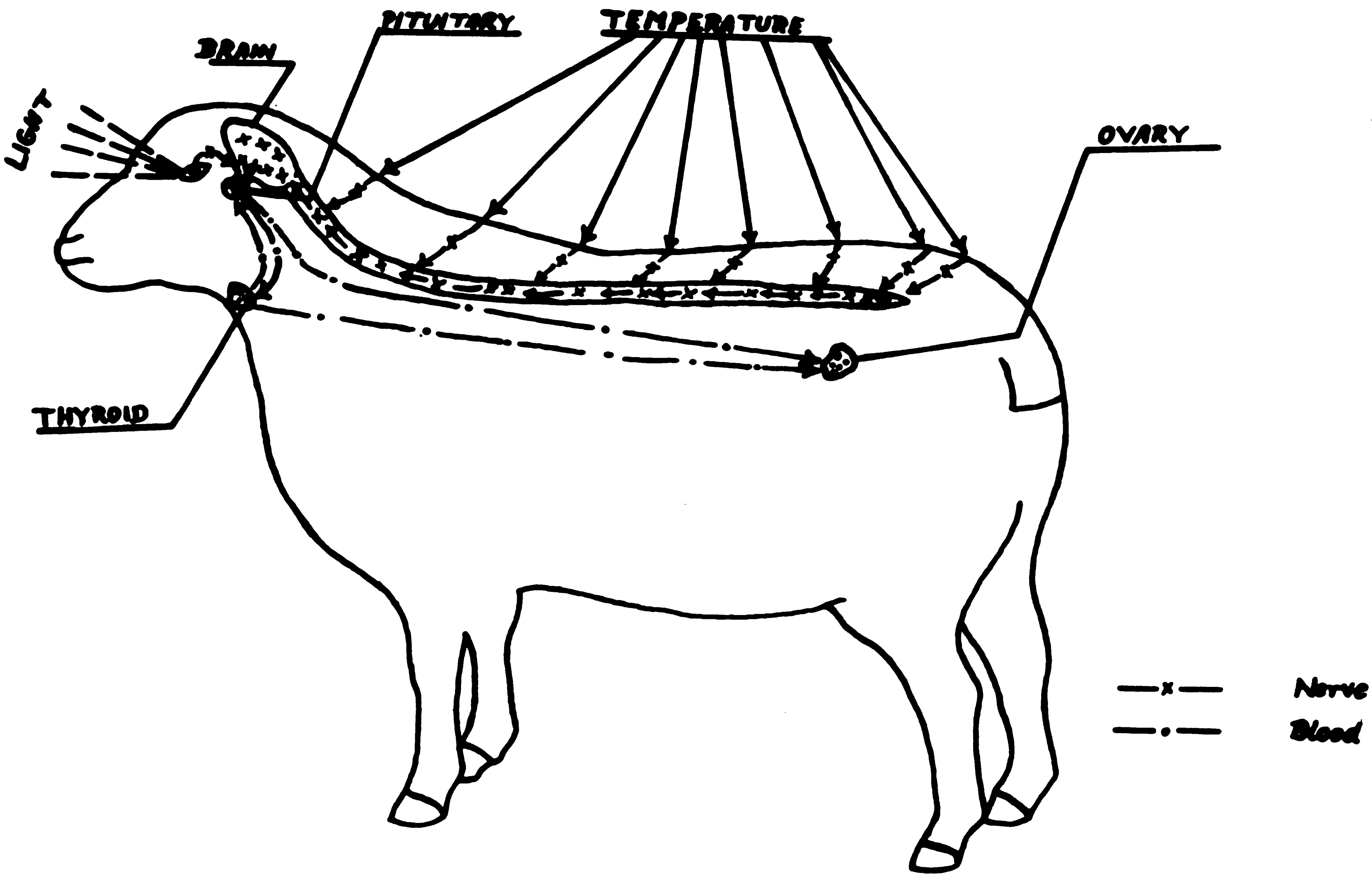

Figure 1. Probable Modes of Action of Light and Temperature on the Gonad of the Ewe.

(d) Effect of Rainfall

The belief that raising the plane of nutrition or extra feeding of ewes at the time they are bred will result in larger crop of lambs has long been held by sheepmen. The evidence for this is the widespread practice of "flushing" before tupping (sexual season). As pointed out by various workers varying the length of exposure to light and differences in temperature are responsbile to some extent for differences in the time of reproduction in ewes. The nutritive changes on pasture alone may sometime give a satisfactory explanation for the variation observed in the size of lamb crop.

Marshall (1908) studied data on the effect of flushing, and stated that flushing at about tupping time generally resulted in a larger crop of lambs at the subsequent lambing. He further suggested that the stimulation afforded by the extra feeding or flushing probably induces a general increase in ovarian metabolism.

Hammond (1914) reported that fertility in domestic animals is governed by factors which control the number of ova shed at each estrus period and the number of embryos which survive to birth. He was also of the opinion that the number of ova shed can be modified to a certain extent by improving the nutrition furnished to the ovary.

Marshall (1922), Marshall and Potts (1924), Nichols (1924, 1926), Clark (1934), and Underwood and Shier (1941) have all presented reports substantiating the favorable effect of flushing on fertility, but the results obtained by many other workers--Briggs, Darlow, Hawkins, Wilham and Hauser (1942) and others do not support this view.

SOURCE OF DATA

The data used in this study were obtained from the flock of sheep at Michigan State College. The breeds of sheep studied were Shropshire, Hampshire, Southdown and Oxford. The records of these breeds, dating back to 1919 were used for the studies on reproduction, and to 1945 on the growth of lambs. The figure used for the studies on reproduction was the percent of multiple births in the year, and for growth, weaning (120-day) weight of lambs in pounds. The data for the climatic conditions for the years 1918-1952 were obtained from the East Lansing Weather Bureau for this study.

ENVIRONMENTAL EFFECTS ON REPRODUCTION

(A) Methods and Procedure

(a) Biometrics Used

Correlation and Regression Coefficients: Correlation coefficients and regression coefficients were used extensively in this study to measure the effects of environmental factors on the two characters investigated. Therefore, it seems reasonable to the writer to briefly define these terms.

The correlation coefficient measures mathematically the closeness of the relationship between independent (X) and dependent (Y) variables. It is universally symbolized by *r* and is measured in terms of the variation of the two distributions and their covariation. Specifically, it is the ratio between the covariation and the geometric mean of the variations of the two distributions.

$$\text{Coefficient of correlation} = r_{xy} = \frac{S\,(X-\overline{X})\,(Y-\overline{Y})}{\sqrt{S\,(X-\overline{X})^2\,S\,(Y-\overline{Y})^2}}$$

$$= \frac{Sxy}{\sqrt{Sx^2Sy^2}}$$

where $S =$ the sum

X and Y are the independent and dependent variables

$x = X-\overline{X}$

$y = Y-\overline{Y}$

The coefficient of correlation must lie between -1 and 1, and the two limits, -1 and 1, result from a perfect relationship between the two variables. Negative values occur when Y decreases as X increases and positive values when Y increases as X increases.

The regression coefficient expresses the average change in the dependent variable for each unit increase in the independent variable. It is ordinarily symbolized by b and is computed by the following formula:

$$b_{yx} = \frac{S_{xy}}{Sx^2}$$

The regression or predicting equations were also computed in this study to determine the nature of association between the two characteristics. The equation is

$$Y = a + bX$$

The formula for determining the value of b has already been shown above, and that for computing a is:

$$a = \frac{SY - bSX}{N} = \overline{Y} - b\overline{X}$$

To test the statistical significance of the regression coefficients the analysis of variance method was applied. The F value was determined by the following formula:

$$F = \frac{\text{M.S. of regression}}{\text{M.S. of error}}$$

Sum of squares (S.S.) of regression = b.Sxy

$$\text{Mean squares (M.S.) of regression} = \frac{\text{S.S. of regression}}{\text{D.F. of regression}}$$

Total S.S. = Sy^2

S.S. of error = Total S.S. - S.S. of regression

$$\text{M.S. of error} = \frac{\text{S.S. of error}}{\text{D.F. of error}}$$

For a more detailed discussion of these statistics see Snedecor (1950).

(b) Analysis of Data

Data to study the reproduction in ewes were divided into two groups: (A) 1919 to 1929, 1939 to 1952 and (B) 1930 to 1938. The years of group "B" were studied separately because the figure for the per cent of lambs dropped was not available. Instead the available data, the per cent of live lambs born, were used. For each of the years, the lambing per cent was figured out separately for each breed, and then combined into a weighted average for all breeds. For example, if the average per cent of multiple births from 25 Southdown ewes was 53.5, and from 35 Hampshire ewes was 45.5, the over-all average for the year was calculated as follows:

$$\frac{(53.5 \times 25) + (45.5 \times 35)}{25 + 35} = 48.8 \text{ per cent.}$$

The environmental condition during the breeding season (previous to year of lambing) was studied for its effect on the lamb crop. For example, the environmental conditions during the breeding season of 1951 were studied for their effect on the lambing percentage of 1952. Breeding dates were calculated back from lambing dates. As most of the ewes were found to settle during the first 30 days of the breeding season

(Sayed, 1951), the average daily temperature and hours of sunshine for that period were used for the years 1939 - 1952. For the rest of the years, due to unavailability of the accurate dates of lambing and because the first 30 days of the breeding season usually came in the months of October, the average daily figures for that month were used. The total monthly rainfall for the months of August and September were studied separately, considering the possibility of an indirect effect on reproduction through the pasture.

Table I contains the summarized data, showing the number of ewes lambed, per cent of multiple births, average daily temperature sunshine, total August and September rainfall for the years 1919 to 1952.

TABLE I

SUMMARY OF DATA USED IN REPRODUCTION STUDY

Year	Number of Ewes Lambed	Percent of Multiple Births	Av. Daily Sunshine During First 30 Days (hours)	Av. Daily Temperature During First 30 Days (Fahrenheit)	Total Aug. Rain (inches)	Total Sept. Rain (inches)
1919	42	40.5	6.7	52.6	1.44	2.88
1920	36	52.8	6.1	53.3	4.03	2.61
1921	38	36.8	7.0	57.8	2.00	1.26
1922	60	53.3	6.4	50.5	5.18	2.64
1923	48	50.0	6.1	51.8	2.42	2.93
1924	46	43.5	6.0	48.5	1.27	5.61
1925	37	48.6	8.8	54.6	2.01	2.58
1926	43	67.4	3.0	41.4	2.15	3.88
1927	40	47.5	3.6	48.0	2.61	3.71
1928	47	42.6	7.0	54.0	0.21	4.67
1929	59	40.7	6.4	52.0	2.19	2.14
1930	62	29.0*	5.3	47.6	0.29	1.23
1931	62	22.6*	5.1	48.0	0.18	1.42
1932	56	21.4*	6.1	53.4	1.70	3.33
1933	68	44.1*	3.3	50.0	3.71	3.04
1934	59	37.3*	6.0	47.4	2.14	5.37
1935	67	44.8*	5.9	49.6	1.51	2.21
1936	68	25.0*	4.7	49.0	2.69	2.49
1937	82	28.0*	5.4	48.1	2.42	7.76
1938	86	36.0*	4.6	46.7	4.42	1.28
1939	91	46.2	6.6	55.2	4.24	1.64
1940	84	60.7	5.2	51.2	1.97	1.41
1941	79	48.1	7.5	57.5	9.21	1.42
1942	78	52.6	3.5	47.8	2.86	2.96
1943	84	53.6	5.8	53.9	2.36	2.16
1944	85	49.4	5.3	48.6	2.68	3.45
1945	76	57.9	6.7	54.0	2.39	2.50
1946	88	48.9	5.8	47.7	6.31	6.58
1947	88	43.2	6.6	52.4	0.88	1.76
1948	96	49.0	6.1	56.7	3.86	4.75
1949	105	43.8	4.7	48.6	1.86	1.62
1950	89	45.0	7.0	57.1	1.61	1.91
1951	105	49.1	6.0	54.9	2.45	3.02
1952	97	61.9	6.1	53.3	2.84	2.59

*Per cent multiple live-lamb births.

(B) Results

(a) Estimates of the Effect of Photoperiodism

Estimates of the influence of sunlight were obtained separately for group A and group B. The average daily hours of sunshine for the first 30 days of the breeding season for the years 1939-52 and for the month of October for years 1919-36 was used as the independent variable (X), and the per cent of multiple births as the dependent variable (Y). The computed correlation and regression coefficients are shown in Tables IV and VII.

A correlation of -.428 was obtained between the hours of sunlight and the per cent of the following lamb crop in group A. This is statistically significant at the 5 per cent level. This shows that in this flock there was a definite tendency for larger lamb crops in the years following low average daily sunshine during the breeding season.

The regression of size of lamb crop on hours of sunlight was -2.4. By the F test, this regression coefficient is significant. The lamb crop for a given year would be estimated from this regression coefficient as follows: multiphy the hours of daily sunshine during the breeding season by "b", the regression coefficient; this is then added to "a", which is 63.7 (Figure 3).

The correlation and regression coefficients of per cent of multiple-live-lamb births on the hours of sunlight for group B were -.295 and -2.97 respectively. Although these values are not significant, they do give added support to the figures obtained above.

The effect of hours of sunlight on lambing percentage was analyzed by a second method. The average daily hours of sunshine for group A are grouped into eight classes and presented in Table II. The

TABLE II

RELATIONSHIP BETWEEN THE HOURS OF DAILY SUNSHINE (X) DURING THE FIRST MONTH OF BREEDING SEASON AND PER CENT OF LAMB CROP (Y)

Y X	3.0 - 3.7	3.8 - 4.5	4.6 - 5.3	5.4 - 6.1	6.2 - 6.9	7.0 - 7.7	7.8 - 8.5	8.6 - 9.3
Per Cent of Lamb Crop	167.4		160.7	152.8	140.5	136.8		148.6
	147.5		149.4	150.0	153.3	142.6		
	152.6		143.8	143.5	140.7	148.1		
				153.6	146.2	145.0		
				148.9	157.9			
				149.0	143.2			
				149.1				
				161.9				
Ave.	155.8		151.3	151.1	147.0	143.1		148.6

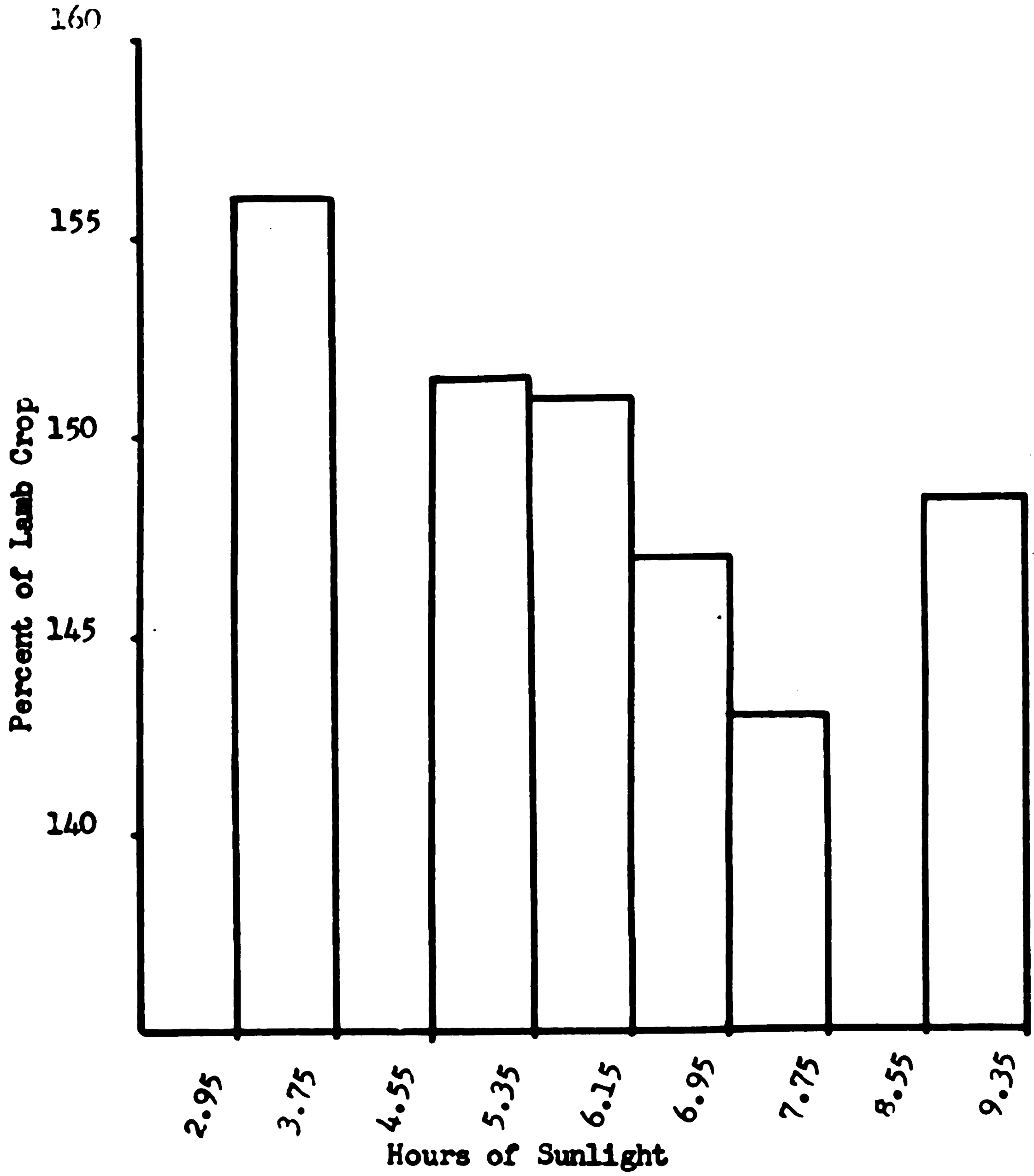

Figure 2. The Relation Between Hours of Sunlight During Breeding Season and Subsequent Lamb Crop.

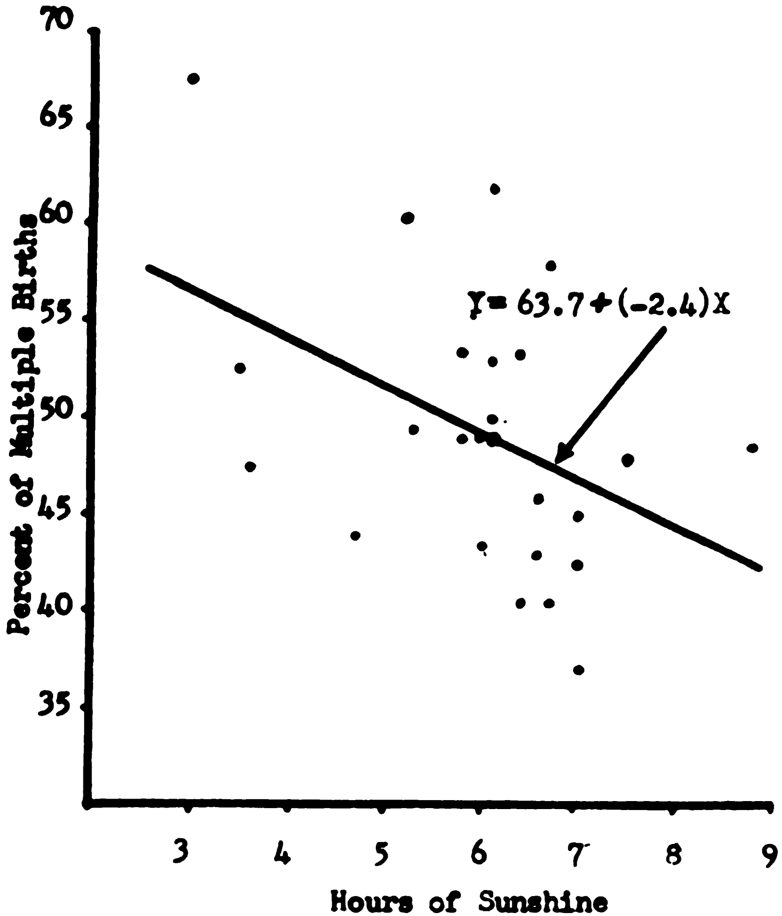

Fig.3. Regression Line of Percent Multiple Births on Photoperiodicity. (Group A)

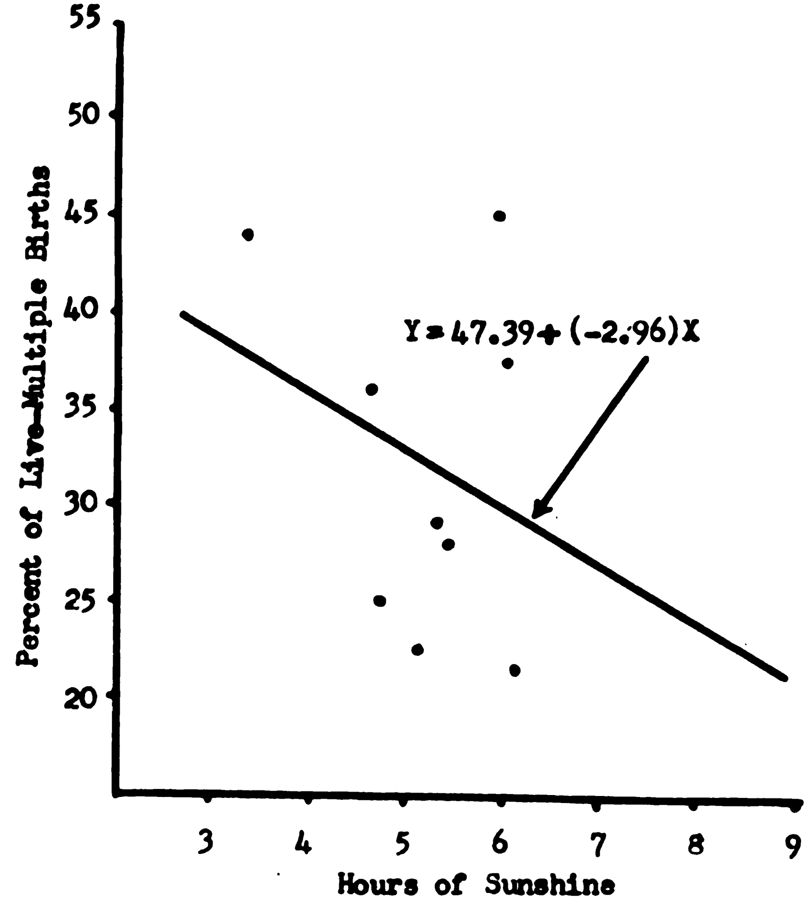

Fig.4. Regression Line of Percent Live-Multiple Births on Photoperiodicity. (Group B)

per cent of lambs dropped are entered in the appropriate columns, and the averages for the eight respective columns computed. Figure 2 is the graphical representation of these data. It can be seen that with an increase in daily sunlight there is a decrease in rate of lamb production. There is one exception, however, in the range 8.6 to 9.3 hours of sunshine. This may be attributed to the fact that it is based on only one observation.

(b) Estimates of the Effect of Temperature

The effects of environmental temperature on fertility in ewes have been studied in the two groups, as were the data on the effects of sunshine. For group A, the coefficients of correlation and regression between the environmental temperature and fertility were found to be -.397 and -.74 (Table IV). These coefficients are significant and show that as environmental temperature increased the fertility of ewes tended to decrease. For the years 1930-1938, group B, the coefficients of correlation and regression between the environmental temperature and fertility were found to be -.192 and -.85 (Table VII). These values are not significant but the fact that they also were negative values should be countenanced. These results show that in this flock fertility was associated with environmental temperature, and supports the well known phenomenon of seasonal periodicity in sheep.

The data were also analyzed to determine the per cent of lambs born in the different temperature ranges (Table III). The lowest temperature range for which data were available was 41.4° to 43.4° F. and the mean per cent of lambs dropped for the temperature was 167.4. This was the highest for the 25-year period. At the highest range of temperature, 56.1° to 58.1° F., the lowest average lamb crop (144.7 per cent) was obtained. These data do not show an uniform effect of temperature on size of lamb crop. In the second lowest temperature range for which data were available the yield of lambs was lower than in all but the highest temperature range. Not enough data were available for the years when temperatures were low. However, in these data in the temperature range from 49.8° to 58.1° F. the percentage lamb

TABLE III

RELATIONSHIP BETWEEN THE AVERAGE DAILY TEMPERATURE (X) DURING THE FIRST MONTH OF BREEDING SEASON AND PER CENT OF LAMB CROP (Y)

Y X	41.4- 43.4	43.5 - 45.5	45.6 - 47.6	47.7 - 49.7	49.8 - 51.8	51.9 - 53.9	54.0 - 56.0	56.1 - 58.1
Per Cent of Lamb Crop	167.4			143.5	153.3	140.5	148.6	136.8
				147.5	150.0	152.8	142.6	148.1
				152.6	160.7	140.7	146.2	149.0
				149.4		153.6	157.9	145.0
				148.9		143.2	149.1	
				143.8		161.9		
Ave.	167.4			147.6	154.7	148.8	148.9	144.7

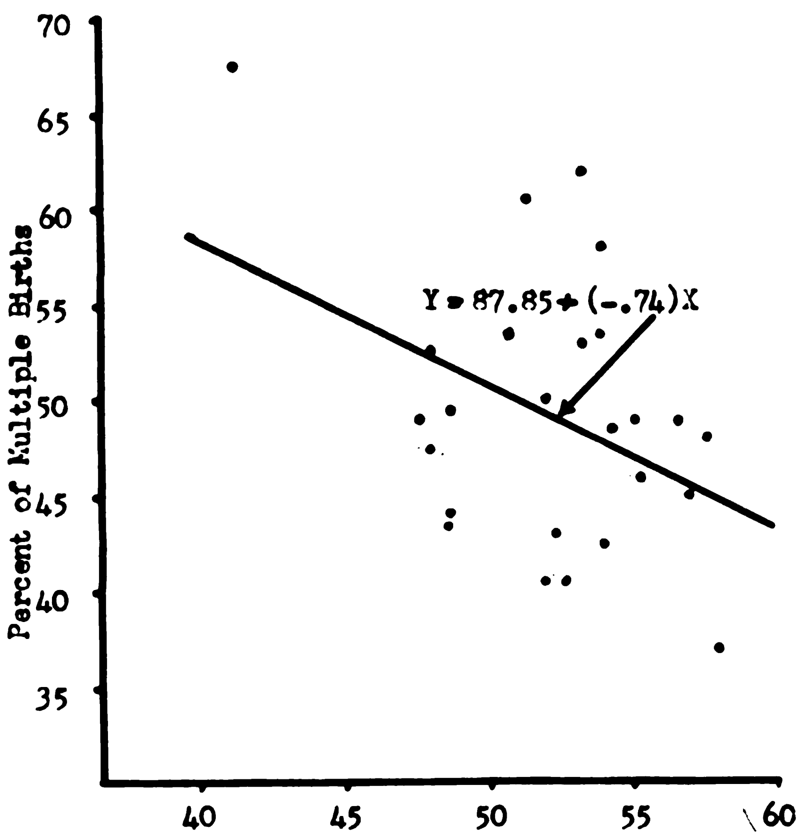

Fig.5. Regression Line of Percent Multiple Births on Temperature. (Group A)

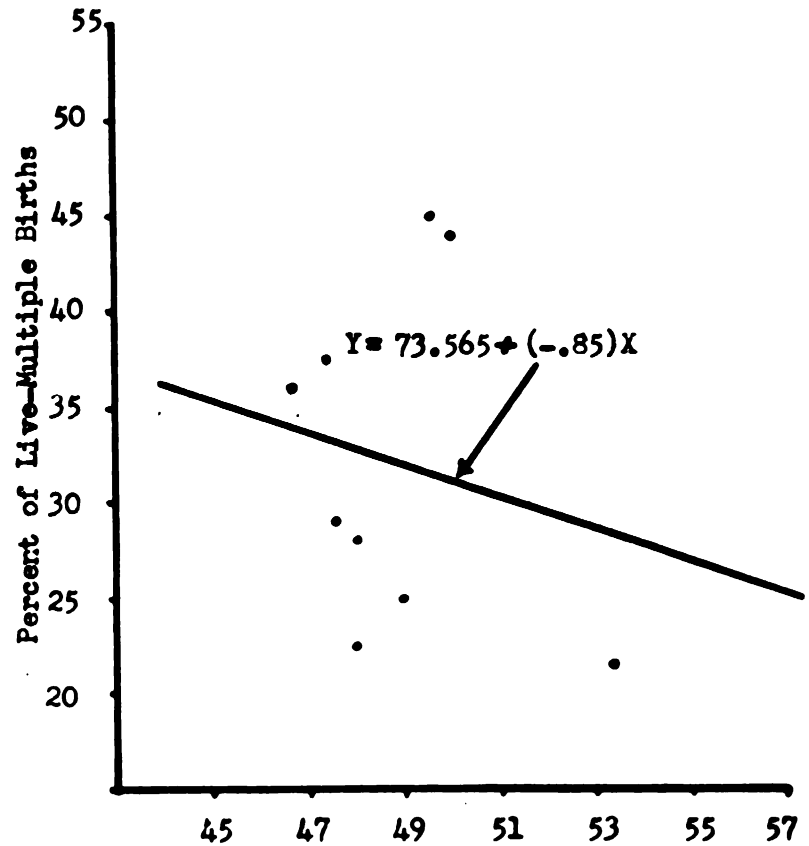

Fig.6. Regression Line of Percent Live-Multiple Births on Temperature. (Group B)

yields ($\overline{X}$) declined from 154.7 to 144.7. Despite insufficient data to give conclusive support there was a tendency in this flock for decreasing temperatures during breeding season to be associated with a higher percentage of twins the following spring.

(c) Estimates of the Effect of Rainfall

The influence of rainfall om lamb crop was measured by the computation of correlation and regression coefficients. These coefficients are presented in Tables IV and VII. Again it was found expedient to study the data in two periods, that is, one period for the years 1919 to 1952, excluding 1930 to 1938, with these being studied as a separate group.

August rainfall as correlated with the per cent of multiple births for the first period yielded a value of .156. The regression coefficient between the two variables was .60. These values are not statistically significant. Although a trend is indicated, it could not be concluded that August rainfall had a definite effect on lamb yield during this period. The correlation coefficient between August rainfall and per cent of live-multiple births during 1930 to 1938 was .038 with regression value of .20. These values being below the level of statistical significance suggest little relationship between August rainfall and size of lamb crop in this period also.

Correlation values of September rainfall on the first and second periods were found to be .437 and -.018, and regression coefficients were 2.75 and -.07 respectively. These coefficients are not statistically significant.

As a result of the evidence presented in this study from somewhat insufficient data, it is apparent that rainfall during the months of August and September had little influence on reproduction in this flock as expressed by per cent multiple births.

TABLE IV

CORRELATION AND REGRESSION COEFFICIENTS BETWEEN ENVIRONMENTAL FACTORS AND THE PER CENT LAMB CROP (GROUP A)

X	D.F.	Sum of Squares and Products			r	b
		Sx^2	Sxy	Sy^2		
Sun light	24	39.2	-94.2	1235.7	-0.428*	-2.40*
Temperature	24	355.5	-263.2	1235.7	-0.397*	-0.74*
August rain	24	84.07	50.12	1235.7	0.156	0.60
September rain	24	43.65	8.73	1235.7	0.033	0.20

*Significant at 5 per cent level

TABLE V

ANALYSIS OF VARIANCE OF REGRESSION COEFFICIENT OF PER CENT OF LAMBS BORN (GROUP A) ON SUNLIGHT

Source of Variation	D.F.	Sum of Squares	Mean Square
Total	24	1235.7	
Regression	1	226.1	226.1
Error	23	1009.6	43.9

$F = \frac{226.1}{43.9} = 5.15$ (Significant at 5 per cent level)

TABLE VI

ANALYSIS OF VARIANCE OF REGRESSION COEFFICIENT OF PER CENT OF LAMBS BORN (GROUP A) ON TEMPERATURE

Source of Variation	D.F.	Sum of Squares	Mean Square
Total	24	1235.7	
Regression	1	194.8	194.8
Error	23	1040.9	45.3

$F = \frac{194.8}{45.3} = 4.30$ (Significant at 5 per cent level)

TABLE VII

CORRELATION AND REGRESSION COEFFICIENTS BETWEEN ENVIRONMENTAL FACTORS AND THE PER CENT OF LIVE-LAMBS BORN (GROUP B)

X	D.F.	Sum of Squares and Products			r	b
		Sx^2	Sxy	Sy^2		
Sun light	8	6.2	-18.4	629.1	-0.295	-2.97
Temperature	8	32.2	-27.3	629.1	-0.192	-0.85
August rain	8	15.9	43.72	629.1	0.437	2.75
September rain	8	37.72	- 2.79	629.1	-0.018	-0.07

ENVIRONMENTAL EFFECTS ON GROWTH OF LAMBS

(a) Procedures

Weaning Weight: There are various ways to measure growth in sheep, but the most accepted method is by weight. Growth in lambs is generally first measured by weighing them at about four months of age when they are weaned. On the basis of this weight, some of the lambs are selected and retained in the flock for breeding purposes, while the rest are marketed. For this study, the weaning weight (120-day) of lambs was considered the index of their growth.

Growth of lambs is influenced to a considerable extent by nutrition. As lambs get older the quality and quantity of the pasture gradually becomes more important than its mother's milk. A good pasture of short succulent grass is desirable for the fastest growth of the young lambs. Therefore, factors which affect the pasture will also indirectly influence the growth of lambs.

Conversion Factors for Standardizing Weaning Weights: The purpose of a conversion factor is to eliminate as best possible certain phenotypic differences arising from varying environmental conditions. It is well known that even two animals with very similar genotypes can show marked differences in observable characteristics. The use of a conversion factor has been used to good advantage by other workers and will be used here. One example which is very much related to this study is to be found in a study made by Venkatachalam (1949) of the Michigan State College flock of sheep. He corrected the weaning weights of Hampshire, Oxford, Rambouillet, Shropshire, and Southdown lambs using the common correction factors of 1.168 for the type of rearing, 1.046 for the age of dam and 1.063 for sex. The marked differences observed in the effect of age between the breeds in this study, probably due to differences in environmental effects, indicated the need of working out separate conversion factors for each breed.

To compute the conversion factors, the data were first grouped for the age of the dam under two main headings: (a) 2-year old dam (b) mature dam (dam above 2 years old). Each of the groups was further divided for the type of rearing, viz: (a) single (b) multiple, which were subdivided for sex--male and female. If both members of a pair of twins were raised on the dam's milk for more than 30 days, they were considered as twin or multiple raised. If one of them had died or was separated for any reason during that period, the other was considered as a twin raised singly. The average figures for all the different groups are given in Tables IX and X. The conversion factor was made by the straight average method. As an illustration, the conversion factor for the age of dam was the average of the following two obtained figures: (a) the average 120-day weight of single lambs from mature dams divided by those from two-year old dams (b) average 120-day weight of the multiples from mature dams divided by those from two-year old dams. The obtained conversion factors shown in Table VIII were used to convert all the weaning weights (120-day) to single reared, mature dam, and male basis.

TABLE VIII

CONVERSION FACTORS FOR AGE, SEX, AND TYPE OF REARING FOR THE LAMBS OF FOUR BREEDS

Breed	Conversion Factors		
	Age of Dam	Sex	Type of Rearing
Hampshire	1.025	1.045	1.220
Oxford	1.135	1.040	1.189
Shropshire	1.068	1.055	1.196
Southdown	0.986	1.100	1.232

TABLE IX

120-DAY WEIGHT OF LAMBS FROM 2-YEAR-OLD EWES CLASSIFIED BY BREED, TYPE OF REARING, AND SEX

Breed	Single Reared				Twin Reared			
	Males		Females		Males		Females	
	No.	Ave. Weight (lbs.)	No.	Ave. Weight (lbs.)	No.	Ave. Weight (lbs.)	No.	Ave. Weight (lbs.)
Hampshire	13	79.3	16	74.6	10	62.6	10	62.2
Oxford	6	69.2	8	69.6	8	56.5	11	57.5
Shropshire	17	63.8	36	57.1	11	50.5	12	45.2
Southdown	8	61.9	5	50.8	4	45.3	5	47.1

TABLE X

120-DAY WEIGHT OF LAMBS FROM MATURE EWES CLASSIFIED BY BREED, TYPE OF REARING, AND SEX

Breed	Single Reared				Twin Reared			
	Males		Females		Males		Females	
	No.	Ave. Weight (lbs.)	No.	Ave. Weight (lbs.)	No.	Ave. Weight (lbs.)	No.	Ave. Weight (lbs.)
Hampshire	26	80.8	26	75.6	37	64.5	37	62.8
Oxford	13	82.2	20	73.6	12	68.9	16	64.3
Shropshire	61	63.6	67	58.3	81	52.5	71	53.3
Southdown	15	57.9	15	54.6	21	46.1	36	46.1

(b) Results

Estimates of the Effect of Rainfall

The effect of rainfall on growth as expressed by weaning weight was determined. It would be expected that rainfall, especially in the months of May, June and July could influence growth rate indirectly through pasture.

The degree of relationship between the two variables--rainfall and weaning weight--was computed first for each breed and then combined into one estimate. The coefficients of correlation and regression between rainfall of May and growth for each breed are presented in Table XI. In the Hampshire breed a statistically significant correlation coefficient of -.757 was found between rainfall and growth. For the Oxford breed, a significant value of -.687 was obtained. Correlation values of -.174 and -.327 obtained for the Shropshire and Southdown breeds respectively are not significant, suggesting that increased rainfall did not affect growth rate to as great an extent in these two breeds.

The coefficients of correlation and regression as computed between the average weaning weight of the four breeds and the mean rainfall of May for the years 1945 to 1952 were -.496 and -1.619 respectively. These values are statistically highly significant.

The data in Table XII show the correlation and regression coefficients between June rainfall and weaning weight. The Hampshire breed shows a significant value of .719 for correlation and 3.148 for regression coefficient. In this breed greater gains were associated with heavy June rainfall. The Oxford, Shropshire and Southdown with their correlation coefficients of .198, .125, .274

TABLE XI

CORRELATION AND REGRESSION COEFFICIENTS OF WEANING WEIGHT ON MAY RAINFALL

Breed	D.F.	Sum of Squares & Products Sx^2	Sxy	Sy^2	r	b
Hampshire	7	23.04	-50.68	194.48	-0.757*	-2.20
Oxford	6	22.50	-62.38	366.05	-0.687*	-2.772
Shropshire	7	23.04	-11.16	178.69	-0.174	-0.484
Southdown	7	23.04	-24.07	234.75	-0.327	-1.045
	30	91.62	-148.29	973.97	-0.496	-1.619

*Significant at 5 per cent level

TABLE XII

CORRELATION AND REGRESSION COEFFICIENTS OF WEANING WEIGHT ON JUNE RAINFALL

Breed	D.F.	Sum of Squares & Products Sx^2	Sxy	Sy^2	r	b
Hampshire	7	10.14	31.92	194.48	0.719*	3.148
Oxford	6	5.57	8.92	366.05	0.198	1.601
Shropshire	7	10.14	5.33	178.69	0.125	0.526
Southdown	7	10.14	13.39	234.75	0.274	1.321

*Significant at 5 per cent level

respectively and regression coefficients of 1.601, 0.526 and 1.321 respectively do not show this relationship at any significant level. These values although not statistically significant need not be disregarded. That they are all positive values shows that in this flock there was a tendency for increased June rainfall to result in heavier weaning weights.

The coefficients of correlation and regression between the mean weaning weights of the four breeds and the mean rainfall of June for the years 1945 to 1952 were .318 and 1.655 respectively. These are not statistically significant.

In Table XIII are summarized the correlation and regression coefficients between the weaning weight of lambs and July rainfall for the four breeds. None of these values are statistically significant. Since half of them are positive and the other half negative, there was apparently no uniform influence of July rainfall on the 120-day (weaning) weight.

TABLE XIII

CORRELATION AND REGRESSION COEFFICIENTS OF WEANING WEIGHT ON JULY RAINFALL

Breed	D.F.	Sum of Squares & Products			r	b
		Sx^2	Sxy	Sy^2		
Hampshire	7	17.43	14.32	194.48	0.246	0.822
Oxford	6	16.88	12.29	366.05	0.156	0.728
Shropshire	7	17.43	- 5.54	178.69	-0.099	-0.318
Southdown	7	17.43	- 0.24	234.75	-0.004	-0.014
	30	69.17	20.83	973.97	0.080	0.301

DISCUSSION

One of the primary objectives of this study was to determine if natural occurring differences in temperature and amount of light during the breeding season of sheep had any marked effect on reproduction in ewes. The best data from flock records for determining this is the ratio of the total number of lambs born (dead or alive) to the total number of ewes in the flock. This is a more valid figure to use than the ratio of the number of live lambs born to the total number of ewes because of the higher mortaility at birth among twin lambs. Data of the first type were available for 25 years and of the second type for 9 years. Since the first is a more accurate measure of the character being studied and since it covers a greater number of years, conclusions will be based largely upon its relationship with the environmental factors studied.

Correlating the per cent of lambs born (dead or alive) with the two environmental factors--light and temperature--resulted in the significant values of -.428 and -.397. These being significant in the negative direction, it is logical to conclude that increased light and temperature during the breeding season led to subsequent decreased lamb production. The association of increased photoperiodicity and temperature with decreased reproductive efficiency as observed in this study also serves to confirm the findings of many in which marked alteration of the sexual cycle followed experimental changes of light and temperature. These reports have been presented in the appropriate section.

Statistical interpretation of these correlation coefficients leads one to suggest that increase or decrease in lamb production is not entirely controlled by light and temperature, but that there are many things to be taken into consideration. Light and temperature are not the only factors in the environment. Whatever the others might be one would also expect interactions between some of them. In addition, genetic differences among animals certainly existed from year to year. However, the values obtained indicate convincingly the inverse association of reproduction with environmental light and temperature.

Correlating the per cent of live-multiple-lamb births with the same two factors--light and temperature--estimated correlation coefficients were -.295 and -.192 respectively. These values though not statistically significant do show the same tendency as those reported above.

Because under natural conditions, the effect of temperature on ewes is difficult to separate from the usually accompanying sunlight, it is not possible by this study to give any sound answer to the question: which of the two factors governs the per cent of lamb crop production in ewes? However, there are some indications that photoperiodicity may be given priority over temperature for its effect on reproduction. (1) Tables IV and VII show a higher relationship with light than with temperature during the breeding season and the following lamb yield. (2) It will be observed in Table II that there is a gradual trend of low reproduction associated with the rise in hours of daily sunshine with only one exception, no doubt due to the small amount of data in that class (one year). Such a uniform relationship is not observed in Table III showing the influence of temperature on reproduction. Description of the association between the two independent characters and the per cent lamb crop afforded by the scatter plot in Figures 3, 4, 5 and 6 also supports the statement.

Another environmental factor considered for its effect on reproduction was the amount of rainfall during the month of August and September. None of the coefficients between the two variables were significant. Therefore, it appears that the rainfall during those months has no effect on the following lamb yield. This statement can not be made with complete confidence because of the small amount of information used for this study. Because the effect of rainfall on reproduction as stated before is through pasture and nutrition, it seems logical to presume that all the factors producing changes in the quality and quantity of feed available to the ewes need consideration. On account of this presumption, many new variables or factors seem worth studying, some of which are as follows: (1) amount of land under pasture for each year (2) kind of pasture (3) grain or supplementary ration fed at this period (4) period and duration of flushing. Information on these factors for a study on reproduction is very essential. For example, the low rainfall during August and September in a certain year would not produce adverse effects on reproduction if the ewes were given some supplementary grain ration or sufficient acreage of pasture was available. Such information was not available in these records.

The influence of difference environmental factors on reproductive efficiency can yield valuable information if data are obtained on large flocks kept under ideal and uniform conditions. Of utmost importance is the fact that extensive records must be kept on all animals. As a rule the above conditions are not met by the average farmer, since they are not compatible with maximum profits. Where emphasis is not on profits but rather on research, as is the case with college experiment stations, data emanating therefrom cannot but be valid. In view of this, it is recommended that copious records, i.e., on the said factors be kept on the state farms. This would no doubt contribute to the greatest amount of accuracy in assessing the influence of environmental factors on various economical characters.

Amount of rain during the month of May, June and July appears to exercise some influence on the growth of lambs measured in terms of 120-day weight. The highly significant negative relationship which has turned up in this study between May rain and weaning weight indicates that in the years of high rainfall in the month of May, the weaning weight decreases. This is difficult to explain. It can be interpreted that in the year of high May rainfall the days are colder, as observed in data ($r = -.889$), and the young lambs are not comfortable and do not eat well. Besides this, pneumonia becomes a problem while the lambs are in the barn and in general the lambs get off to a poor start. By the month of June, the lambs are older and stronger, and practically no relationship was found between the June rain and temperature ($r = .035$). Therefore, the heavy rainfall in the month of June mainly has its effect on the growth of pasture and produces more feed for the ewes and lambs in June and July. Moreover, the larger lambs develop resistance to the climatic conditions and become better foragers.

The variable and insignificant relationship observed between the different breeds and July rain can be explained as due to the fact that on the average the lambs are born in the middle of March and are weaned about the middle of July. Therefore, the lambs are kept on pasture before weaning on the average up to the first half of July and rain in the later part is unimportant. Besides this, the rain during the first half of July has not much to do with the growth of pasture during the same period, but the rain during the last half of June has greater influence on early July pastures. Therefore, this is a possible explanation for the non-significant relationship which has been obtained.

APPLICATION

Of necessity, what should be of the greatest importance in a study of this nature would be the contributions to the sheep breeder. These are presented as follows:

(1) The result of this study would seem to indicate that the early prediction of subsequent lamb yield might be made by sheepmen by observing photoperiodicity and temperature during breeding season. Statistically, the estimated regression coefficient of 2.44 between photoperiodicity and lamb crop indicates that if the average daily sunshine during breeding season was one hour less in a given year than that of the previous year, then the average gain in the following lamb crop would be predicted to be 2.44 per cent above the mean of the last year. Stated in other words the production of lamb crop (Y) may be estimated by taking the product of hours of average daily sunshine and the computed value of regression -2.4 (b), and adding this to 63.7 (a). In a similar way, by the available information on the temperature during the breeding season, the subsequent lamb yield may also be estimated. The regression coefficient (b) obtained between the two was -.74. In both instances the data are fitted to the regression equation: $Y = a + bX$ (Figures 3 and 5). It must be emphasized however that biological data do not invariably fit a straight line or any other mathematical concept. Hence, the sheepman should expect no more than trends from the above.

(2) In addition to the early prediction of lamb crop, the findings of this study might serve to favor greater reproductive efficiency. Evidence has been presented--and literature has been reviewed--

to demonstrate the importance of light and temperature in the regulation of reproduction. On the basis of the conclusion drawn, a high lamb yield should be obtained by decreasing the photoperiodicity and temperature during breeding season. These results may well serve as a plank in the much-sought-for, two lamb crops per year. But the sheep breeder who would implement these findings in the endeavor to increase reproductive performance should be aware that a great deal of information is still needed. More studies must be directed to the end whereby it will be clearly known whether light and/or temperature must be invoked as the responsible agent. He must realize that this calls for designing experiments in such a way that interrelationships between light and temperature are definitely obviated. Setting up such experiments and conducting them on large flocks, constitutes one of the most practical applications of this study.

(3) In most kinds of livestock data, a certain refinement of the data is necessary. Conversion factors are therefore used. Growth performance measured in terms of weaning weights is the means by which sheep breeders select their lambs for the breeding flock. The need for eliminating environmental effects has already been recognized. It has been met by the computation of certain correction factors. The method for computation has been shown on page 35. In this study all the differences in the weaning (120-day) records were corrected to a common basis (single reared, mature dam, and male basis).

It is believed that these factors can be of utility to sheep breeders. Of the four correction factors for the different breeds, those for Oxfords and Southdowns cannot be recommended for use in other flocks due to the small volume of data on which they are based, but the application of the factors obtained for Hampshire and Shropshire may enable the breeder to select lambs on comparatively more genetic merit of the individuals than has been possible in the past.

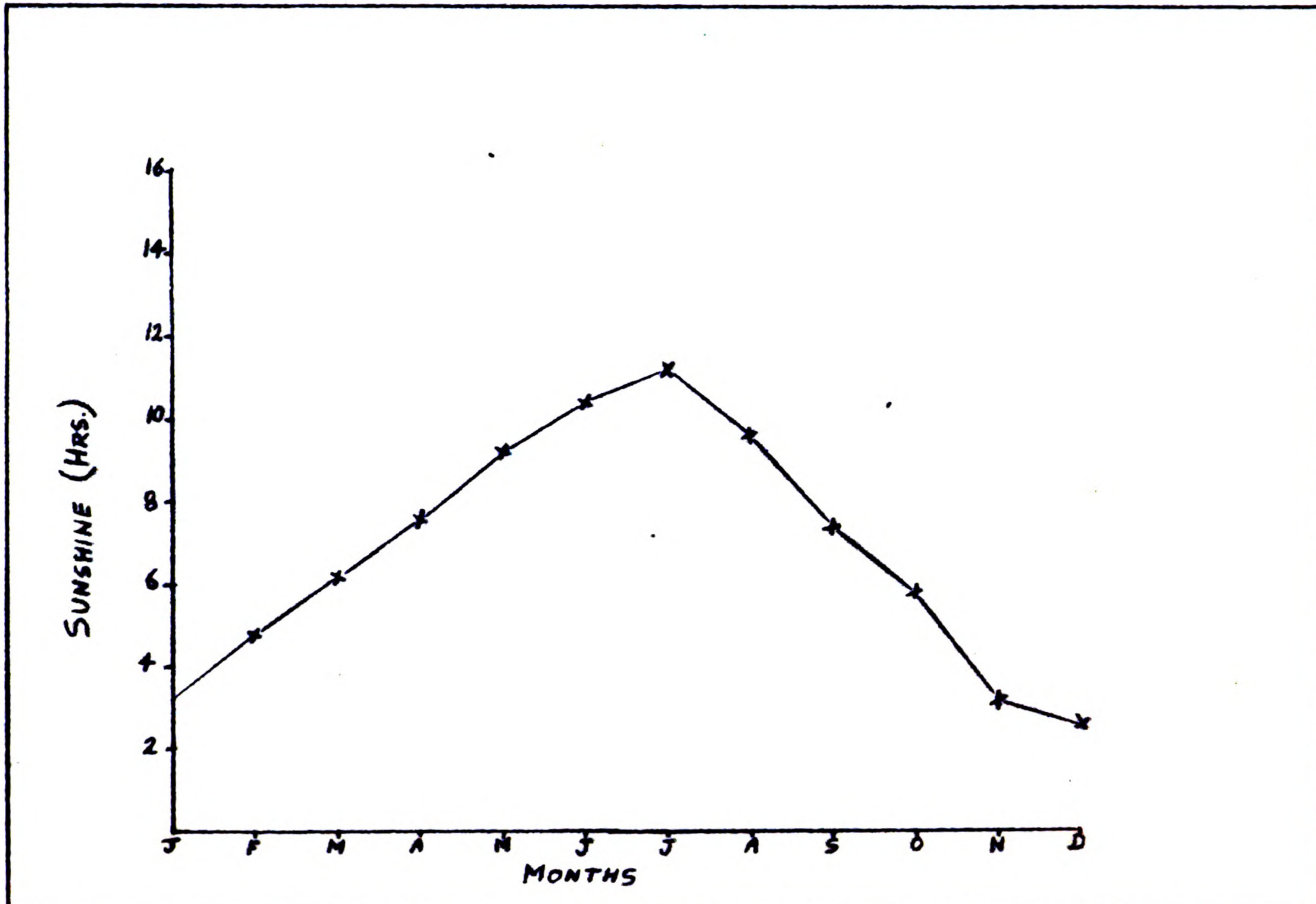

Figure 7. Average Length of Daily Sunshine from January to December at East Lansing.

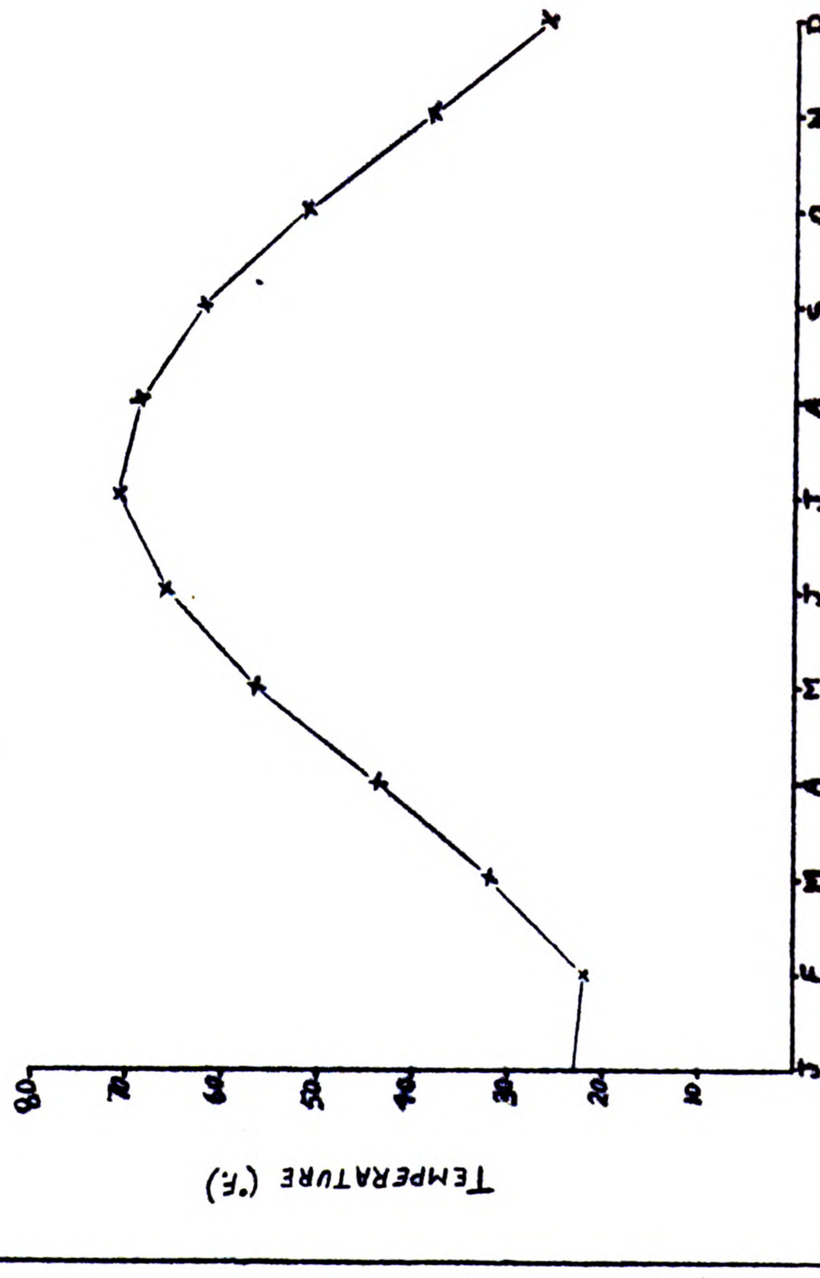

Figure 8. Average Monthly Temperature at East Lansing.

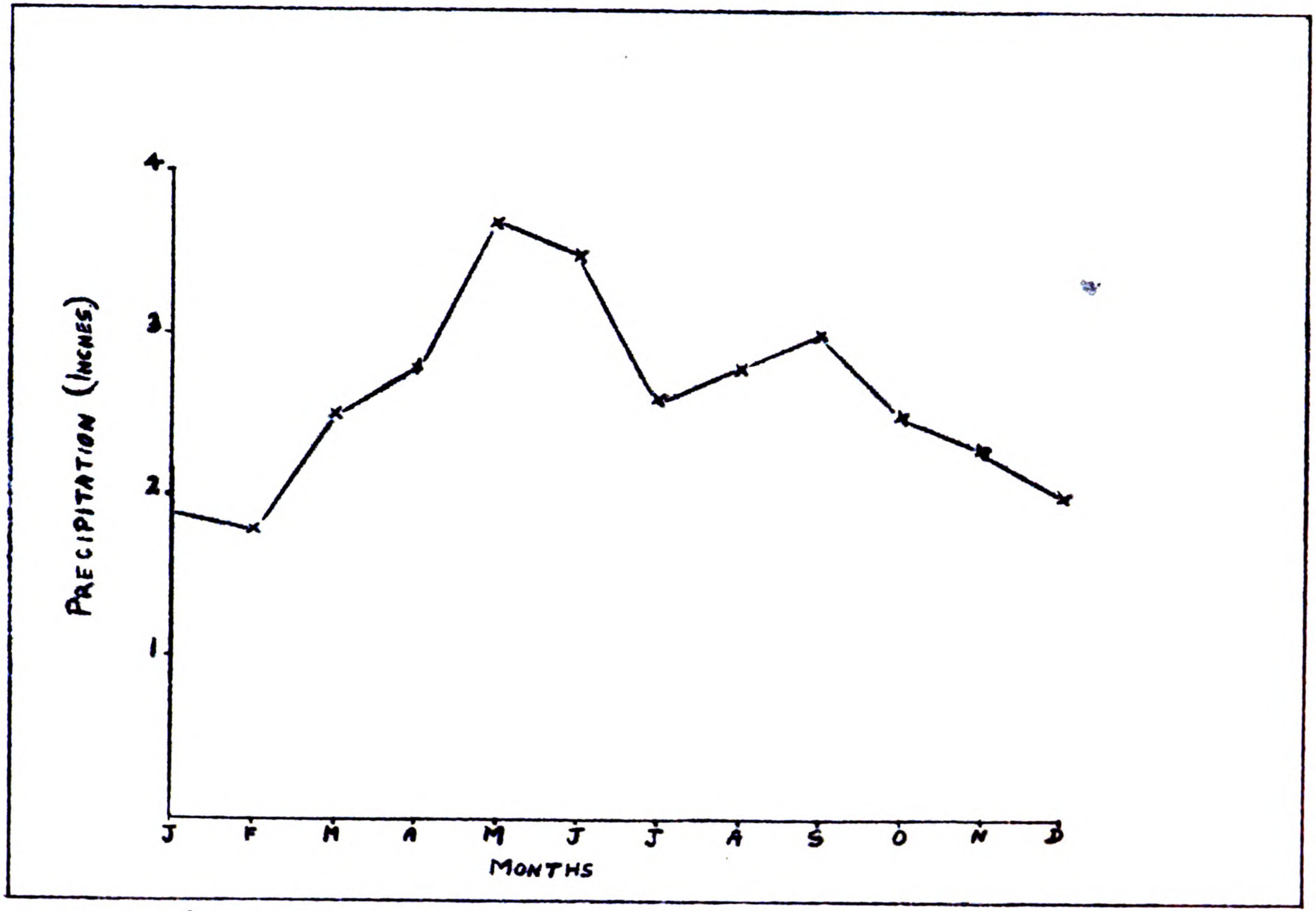

Figure 9. Average Total Monthly Precipitation at East Lansing.

SUMMARY AND CONCLUSIONS

1. A study was made of the effect of some environmental factors on the growth and reproduction in sheep. For this, the reproduction records of four breeds--Hampshire, Oxford, Shropshire and Southdown were used. These records covered the period from 1919 to 1952. The growth records (120-day weight) of lambs of the same breeds from 1945 to 1952 were also used. These sheep were in the Michigan State College flock and the records were studied in relation to the existing climatic conditions in the same period.

2. The data were organized to determine the effect of: (a) photoperiodicity and temperature during the first month of breeding season on reproductive performance, (b) rainfall during the month of August and September on the following lamb crop, (c) rainfall during the month of May, June, and July on growth of lambs.

3. The coefficient of correlation between photoperiodicity during the breeding season and the subsequent multiple birth* was -.428 and the regression coefficient was -2.40, both significant. The coefficients for the per cent of live-multiple births for the years 1930-1938 were -.295 and -2.97 respectively (not significant).

4. The peak lamb crop was found following the year of fewest hours of average daily sunshine during the previous breeding season with a tendency to decrease as the hours of sunshine increased. In

* Per cent multiple birth refers to data of 1919 to 1929, 1939 to 1952. It differs from per cent live-multiple birth (1930-1938) in that it includes the total per cent of dead and live lambs born.

general, a decrease in photoperiodicity was associated with an increase in the lamb crop.

5. The coefficients of correlation and regression obtained between temperature during the breeding season and the per cent of multiple births were -.397 and -.74, which are significant. Between temperature and per cent of live-multiple births these values were -.192 and -.85 respectively. These are not significant.

6. Using per cent multiple births as a measure of reproductive efficiently there was good evidence that increases in light and temperature during the breeding season would lead to decreased subsequent lamb crop.

7. The results of this study indicate that rainfall during August and September has little if any effect on reproduction.

8. It is suggested that the non-significant estimates of relationship between August and September rainfall and size of lamb crop, with no definite trend could have arisen from year to year variations in the following: (i) amount of land under pasture, (ii) kind of pasture, (iii) supplementary rations fed, (iv) duration of flushing. These factors were not included in this study.

9. Growth of lambs (weaning weights) as correlated with May rainfall gave a highly significant correlation value of -.496. This value shows that in years of high rainfall there was a tendency in flock for growth to be decreased.

10. The correlation coefficients between June and July rainfall and weight of lambs at weaning (120-day) were found to be .318 and .080 respectively. These coefficients are not significant, and indicate that rainfall during these months did not have a marked influence

on weaning weights. However, June rainfall did show more of a tendency in this direction than did July rainfall.

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