RELATION OF SHEEP TO CLIMATE

By Everett L. Johnson

Department of Animal Husbandry, University of Illinois

INTRODUCTION

For many years sheep breeders have contended that breeding, feeding, and management are the chief factors involved in the further selection and development of the various breeds of sheep. But evidence from literature, together with the records of the university flock of the University of Illinois (at Urbana, Ill.), indicates that climatic conditions should also be considered. The data here presented seem to support the following: (a) Sheep are limited to certain climatic conditions; (b) some breeds are better suited to certain climates than to others; (c) sheep are especially sensitive in lambing time and rutting seasons; (d) rutting season comes with falling temperature and varies from year to year; (e) high temperature with high humidity is detrimental to the growth of lambs; (f) some years are more favorable than others for lambing, growth of lambs, rutting season, and gestation period; (g) housing has extended the limits of sheep production; (h) some shelter types are more desirable than others. The climatic diagram methods used here were applied to tropical crops by Taylor (25). The writer is not aware of a previous application of this method to a critical period by months and to good and bad years.

WILD SHEEP

The ancestry of domestic sheep is not definitely known. It is most probable that the Moufflon, or European wild sheep, and one of the races of Asiatic urial (Ovis cycloceros) have formed the chief parent stocks (Lydekker, 17, p. 27). The Moufflon (Ovis musimon) is still found in Corsica and Sardinia. That at one time it had a wider distribution is evidenced by the remains of wild sheep in the superficial deposits of various parts of south Europe. The breeding or rutting season occurs in December and January. The gestation period is about 145 days, and the lambs (generally two) are born in April or May. The wild Moufflon interbreed with the domestic sheep and the offspring are fertile. The body covering of hair has to a minor degree the serrated scales which give to wool its felting property. The cry of the adult is a bleat very similar to that of domestic breeds (17, 18, 19). Sheep in the wild state are essentially mountain animals. They shun forests, live in the open, and feed upon the mountain grasses. The climatic conditions in such regions as the higher parts of Sardinia and Sicily are probably most suitable for sheep. The days are hot, the nights cool, the winters mild, with more or less rainfall; and the summers are dry (2). The sheep avoid the heat in the valleys by moving up the mountains, where it is cooler and where the grazing is less affected by the dry weather.

PRESENT DISTRIBUTION OF DOMESTIC SHEEP

Sheep are not uniformly distributed. There is dense sheep population in some localities and none in others (6). These areas of dense population have similar climates. The ideal climates here represented for sheep (fig. 1) are based upon these dense centers. The radical way in which such climates differ from others is emphasized by comparison with Taylor's 1919 diagrams. Each locality probably, though not necessarily, has the breeds which

1 Received for publication Apr. 2, 1924—issued February, 1925. Contribution from the Department of Animal Husbandry and from the Zoological Laboratory (No. 252) of the University of Illinois.
2 The writer desires to express his appreciation to Dean W. C. Coffey, of the University of Minnesota, for suggesting the problem. He is indebted to Prof. H. P. Rusk and to W. G. Kammade for many courtesies extended during the course of the investigation, especially in the securing of equipment and in giving access to the records of the university flock. The assistance from the graduate school research funds for the purchase of hygrothermographs to carry on a part of the work was invaluable. Thanks are especially due to Dr. V. E. Shelford for his encouragement and for suggesting and supervising the work with the graphic methods employed.
3 A summary of the more important literature reviewed is contained in a manuscript in the library of the University of Illinois (master's thesis), where important sections are quoted from the original sources and full citations given.
4 Reference is made by number (italic) to "Literature cited," p. 500.
thrive best, and best meet the needs of the people, as determined by time and varieties tried. Some breeds are suited to fertile valleys with damp climate and swampy soil; others are

In the new countries it was difficult to determine which sections were best suited to sheep and what breeds to select (7, 21, 23). Some were entirely unsuited; others proved suitable to

adapted to moorlands and mountains. Professor Wallace, of Edinburgh University, makes the following statement:

When local conditions of climate, soil, management, and markets are suitable, the breed is likely to enjoy a fixity of tenure (28).
The Romney Marsh and the Lincoln are found in large numbers, whereas the Merino is found only on the south island, where drier conditions prevail. The Romney Marsh breed comes from the county of Kent, in southeastern England, where the land is low and marshy. They are practically free from foot rot and can withstand cold wet weather. In New Zealand the conditions for the Romney Marsh are more favorable than in Kent, as evidenced by improved quality and length of the fleece. The Lincoln is quite similar to the Romney Marsh, although developed under somewhat different climatic conditions. In regard to moving sheep from one locality to another, Professor Wallace (28) states:

There is an invariable rule that brooks no breaking of the fleece, as the lambs must go from a poorer to a richer soil and more favorable climatic surroundings. For example, they must go from a humid into a drier district. It has been claimed that Oxford sheep coming from the cold, heavy clay of Oxfordshire and there subjected to the fogs and low temperatures do better in the drier and warmer localities. The long-wool and down breeds, if put on the mountain lands where the Cheviots, Blackfaces, and Welsh sheep thrive well, could not survive long enough to enable them to make the change. Lincolns, bred in Shropshire, do not attain the great size they do in their home country. The Kerry Hill (a Welsh breed), if removed to places where the soil is deep and the climate damp, get old and crocky or broken down in appearance and slack in their wool. It is claimed that the long wools thrive best on a light, dry soil, on account of the wool not getting so clogged in wet weather.

It has been assumed that sections having a dense sheep population have favorable climatic conditions for sheep production. Such dense world centers exist in South America (Uruguay and northeastern Argentina), South Africa (Basutoland), Australia (New South Wales), New Zealand, Great Britain, European Turkey, and Bulgaria. Russia and the United States also have a large sheep population.

**COMPARISON OF CLIMATES**

The climatic factors here considered are temperature, rainfall, and humidity. Comparisons were made by the use of the hythergraph (temperature-rainfall) (13, 14, 15, 24, 25) and the climograph (temperature-humidity) (1, 22). Graphs were made from the mean monthly temperature, rainfall, and humidity records for various meteorological stations located in sheep-growing sections. Each point on the hythergraph represents the mean of the temperature and the rainfall for a particular month. The points for each month in the year were plotted and then connected. For the climograph the mean monthly temperature and humidity were used. By this method
two factors and the months or critical periods can be shown at one time. In these graphs the temperatures are represented on the vertical scale to the left, and the tenths of inches of rainfall and the per cent of relative humidity on the horizontal scale at the top. (For a more detailed method of construction, see Taylor (25)). When graphs can thus be made of any section to compare with the composite.

A comparison of the graphs of the important sheep countries shows similarity in rainfall, temperature, and humidity (2, 5, 10, 11, 12, 20, 29). In general, the winters are mild and the summers cool, with a moderate amount of rainfall, sufficient to afford a good growth of forage; and the humidity is considerably lower in summer than in winter.

On the composite graph the rutting and lambing seasons have been plotted because sheep seem sensitive during these periods. The lambing season, which extends over three or four months, was obtained for each country and then plotted. The middle month (or months)
was taken as a mean because the bulk of the lambs are born at that time (figs. 1a, 1b, 2b, 3b). The rutting season was determined from the lambing season by counting back five months. The mean of the rutting season corresponds to the mean of the lambing season (figs. 1a, 1b, 2c, 3c).

The lambing and rutting seasons fall within comparatively narrow limits of temperature, rainfall, and humidity, and within narrower limits than does the composite graph for the whole year.

The graphs made from sections which have less dense population than those from which the composite was made show some variations—the climate may be hotter in summer, colder in winter; it may have more or less rainfall, a higher humidity, or a combination of these factors. The lambing or rutting seasons may not fall within the limits of those in the composite. For example, a hypergraph of Cedar Lake, King County, Wash. (fig. 14), for 1919 shows an excessive rainfall in the winter with 21½ inches in January, and a dry summer with 0.5 inch rainfall in July. There were no sheep recorded in this county, as the rainfall is too great in winter and too little in summer. Yet the temperature conditions are favorable, for the range is no greater than in some of the best sheep countries.

CRITICAL PERIOD

The periods in the life of a sheep during which it is more easily and more seriously affected by unfavorable conditions are the lambing and rutting seasons, which, as stated above, fall within narrower limits of temperature, rainfall, and humidity than the general conditions under which sheep live (figs. 1a, 1b, 2b, 3b, 3c). The first few months of the life of a lamb and to a less degree the time of pregnancy are also critical periods (fig. 4). A successful lambing season is often interfered with by cold, wet, or snowy weather, or by a shortage of feed. The newborn lamb is not able to withstand too rigorous climatic conditions. Likewise, the ewes, if exposed to excessive rainfall, or large amounts of snow, or if there is a shortage of feed, are liable to come to lambing time in unthrifty condition and give birth to weak lambs. According to Hammond (8), if conditions are extremely unfavorable, atrophy of the fetus, due to undernutrition, may occur. (This is much less frequent in sheep than in swine.)

The growth of the lamb during the first few months is readily retarded by hot, humid weather or by cold, wet weather. The extremely hot, humid weather also causes many lambs to lose weight (figs. 15 and 16). The late-born lambs are more severely affected than those born earlier. A breeder of purebred sheep in Illinois has found that clipping lambs in May has enabled them to withstand the summer conditions better.

According to Hammond (8), the rutting season comes with a falling temperature. It may be delayed by hot weather, particularly by warm nights (4). This becomes a serious problem in sections where the late summers and falls are hot, as it means that the ewes will not be bred until late in the fall, and the lambing season will be correspondingly late in the spring. Sections which have a warm fall usually have hot summers. In the West the ewes found unbred in the spring are gathered together and sent to the mountains, where a decreasing temperature is brought about by high elevation. Then they soon come in heat, and are bred for fall lambs. Conditions during the rutting season may have some effect upon the per cent of twins. According to Hammond (8), the number of ova produced by the ewes depends upon their condition at the rutting season. This is possibly the largest factor in the number of lambs born. (It is not true of swine, as many more ova are usually produced than can ever reach maturity.)

In Tennessee, where climatic conditions are generally favorable for lambing during the winter and early spring, the sheepmen find it difficult to get their ewes bred early enough in the fall for early spring lambs. If they do not market the lambs before hot weather, the lambs cease to make profitable gains. In Illinois, unfavorable weather conditions are often experienced at lambing time, but can usually be overcome by proper methods of housing (20). Yet the lambs do not thrive quite so well during long spells of cold, rainy weather, even though adequately housed. When winters are extremely cold and the snow is deep, weak lambs and trouble at lambing time usually follow. The difficulty of getting the ewes bred early enough is quite frequent. The year 1915 was an exception, as the summer was unusually cool (fig. 12). Ewes came in heat during all the summer months, and the first lambs came in November. The summer months are generally very trying on sheep, and the growth of lambs, particularly those born late in the spring, is retarded. In England it
appears that unfavorable conditions are most likely to occur during the lambing season and in the winter months. The cold, wet weather is very trying to the ewes and lambs; and frequent a cold, wet fall and winter are followed by a small fall of lambs (16).

GOOD AND BAD SHEEP YEARS

Since some years seem to be more favorable for sheep than others, a study was made of a number of years in south-central England and at Urbana, Ill. (20). Hammond (8) found the season to have considerable influence on the growth of sheep, particularly during their first year. He attributed most of this to rainfall, which he correlated with the weight at the end of the first nine months of the life of the lamb.

The years 1909 to 1921 (1912 no data) in England were studied, and the infor-
mation regarding the effect of each year upon the sheep was obtained (16). The years most favorable and unfavorable for the Southdown and Hampshire breeds were selected. Seasons unfavorable for these breeds were unfavorable for others in most districts in England. A number of meteorological stations were selected in south-central England, the native home of these breeds and the locality in which they are found in greatest numbers. Climographs and hythergraphs were made from the monthly means for the years 1909, 1910, 1911, 1914, 1915, 1917, 1918, 1919, and 1921. From the information compared with a composite containing the limits for April of a good year (fig. 4) it falls far below (fig. 8). A composite was made for the five months only, because they fall within narrower limits than some other months in the year, and come at more critical periods. The graphs for several years differ considerably, and do not always fall within the limits of a good sheep year for England. One critical month may be bad and others good. The graphs for 1909 at Reading, England, fall within the limits of the composite for a good year. That year was satisfactory for sheep (16), and in particular for the lambing season (fig. 5). The following selected case serves to illustrate bad years due to unfavorable critical months and to poor food and water supply. The summer of 1911 at Hastings was hot, and July was very dry; the humidity was high in July and August; and October, November, and December were very wet (fig. 6). This was noteworthy because of the small number of twin lambs, the failure of food crops, and the low price of mutton. From Figure 7 it appears that March, 1914, at Reading was too wet. Early lambs were weak and mortality was heavy. December of the same year was exceedingly wet, and ewes lost at hand, the best lambing seasons and the most favorable summers, autumns, and winters were selected. From these were made a composite hythergraph and climograph, which represents a good sheep year in England. The unfavorable years can be compared with this good year and the contrast noted (figs. 6, 7, 8, 9). As the critical months of a good year fall within narrow limits, a graph was made for February, March, April, May, and June of the good years (fig. 4). For example, too cold an April of any given year, when compared with the composite hythergraph and climograph, might fall within the limits of a good year; but when com-

![Graph](image-url)
weight. April, 1917, at Rounton, England was too cold, as were January, February, and March. There was a difficult lambing season with a small lamb crop, but the later months were better. August was too wet, with over 6 inches of rainfall, but the humidity was not high. In 1921 at Croyden the lambing season was favorable (fig. 9). The summer was particularly dry, accompanied by humidity a little above the limits. Water had to be carted for livestock for six months.

A comparison was made between the good and bad years at Urbana, Ill., from 1906 to 1922 (20). (The information obtainable was not so complete as that for England.) The rate of gains made by the lambs was taken as an indication of the effect of the summer conditions upon them. The mean weights of each breed—Southdowns, Shropshires, and Rambouilletswere plotted for the years 1907, 1911, 1913, 1915. The weights were taken each month, and twice a month during some years. The mean temperatures and humidity for two-week periods were also plotted. Hammond has shown the normal growth of lambs to be regular. Figures 15 and 16 show a comparison of the growth or increase in weight with the mean temperature and humidity. The irregularities indicate that a high mean temperature accompanied by high humidity is correlated with the retarded growth of the lambs. In some cases there was a loss in weight for a two to four week period. The graphs presented here (together with others on file at the University of Illinois) show that retarded growth follows high temperature and humidity regardless of the date or the age of the lambs. Curves drawn for 1913 (on file at the University of Illinois) show comparatively uniform growth of lambs (fig. 11). The difficulty in making use of the weights of the university flock grew out of the different dates of lambing, evidently influenced to some extent by the weather condition of the preceding mating season. Mean growth was rendered insignificant by this irregularity, and retardation in growth was noted at critical periods regardless of the age of the lambs.

A mean relative humidity higher than 80 per cent and a mean temperature higher than 70° F. seem to be detrimental. The sheep can stand a rather high mean temperature if the mean humidity is not over 60 or 65 per cent. The rate of growth was more uniform in 1913 than for the other three years plotted. The study has not been carried far enough to give definite limits of temperature and humidity. The Rambouillets, which come from a country where the temperature runs higher than it does in the section from which the Shropshire and Southdowns come, seem to be less affected by unfavorable conditions. The late-born lambs are more seriously affected by unfavorable conditions than the early-born lambs.

A good sheep year at Urbana, Ill., closely approximates the limits of a good sheep year in England, although it has a wider range, being warmer in summer and colder in winter. Figures 10, 11, 12, and 13 are hygrotherographs and climographs of the years 1912, 1913, 1915, and from June, 1920, to June, 1921, respectively, at Urbana, compared with the limits of a good sheep year at Urbana. It was found that summers unfavorable for the growth of the lamb are rather common. The high humidity during the summer of 1912 was thus detrimental (fig. 10). During the hot summer of 1913, which was accompanied by a comparatively low humidity, the lambs made a regular and satisfactory growth (fig. 11). Although the summer of 1915 was cool and wet, the comparatively high humidity retarded the growth of the lambs, particularly of those born late in the spring (fig. 12). The period from June, 1920, to June, 1921, was a favorable year for sheep, and falls almost entirely within the limits of a good sheep year (fig. 13).

HOUSING OR SHELTER FOR SHEEP

The climatic limits under which sheep can be successfully kept may be extended by providing shelter and extra food. In the important sheep countries the sheep are seldom housed, and depend largely upon grazing for their food supply, although in some sections some additional food is provided during the winter. Shelter or housing makes it possible to raise sheep successfully in sections which have low temperatures, heavy snowfall, or excessive cold winter rains. The types of shelter may vary from sheds, constructed to break the wind and protect them from the cold rains, to warm well-constructed barns. In comparing graphs of these sections with the composite graph for good sheep countries, one should make some corrections for housing and various kinds of shelter. But no data have been found on how much correction is advisable.

The sheep farm at the University of Illinois has two types of building—one a shed which is open to the south,
the other an inclosed barn with a loft above for hay and feed storage. In order to make corrections for temperature and humidity, a hygrothermograph was placed in each building, and one out of doors, making possible a comparison between the shed, barn, and outdoor conditions. These hygrothermographs were placed in the pens where the sheep were kept; the one out of doors was in a shelter about 60 rods south of the buildings. All of the instruments were placed 12 to 15 inches above the ground because this distance is approximately the mean of the center of the body of the sheep when standing and lying down. The records from the three instruments began February 1, 1922, and have been continued to the present time.

As yet there are not sufficient data to make accurate corrections for housing, but a marked difference is indicated by the records (fig. 17). The mean temperature was 3.4°F to 10.2°F higher in the barn than outside. The mean humidity was more variable, in some cases 13.6 per cent higher and others 6.7 per cent lower than outside. The differences between the shed and the outside were very small.

In the barn the temperature and humidity are more uniform with much less marked fluctuations than in the shed or out of doors (fig. 18). The barn is warmer than the shed in cold weather, but does not become warm so quickly on a mild sunny day in winter. The humidity runs higher in the barn, which frequently is steaming when opened in the morning. Some trouble from pneumonia and other respiratory diseases has been experienced with the sheep kept in the barn, but practically none with those kept in the shed. A study of the daily range and the maximum and minimum temperatures and humidities may also show a greater difference between the barn, shed, and outside. On many farms the housing is inadequate, with a resulting detrimental effect upon the ewes, especially where they are closely confined during very cold and snowy weather. After a winter of this kind, the lambs are usually born weak and as a consequence are less thrifty. This is possibly due also to a lack of exercise.

CONCLUSIONS

The dense centers of sheep population in the world are found within comparatively narrow limits of temperature, rainfall, and humidity. The mean temperature ranges between 28°F and 77°F; the rainfall between 0.3 and 4.5 inches per month; the relative humidity between 55 and 70 per cent at the higher temperatures and 65 and 91 per cent at the lower temperatures. Such conditions afford mild winters, cool summers, and sufficient rainfall to provide good grazing.

Climatic conditions must be favorable, especially during the critical periods of rutting season, pregnancy, lambing, and the growth of the lambs.
The lambing period generally comes in the spring, enabling the lamb to get a good start before hot weather sets in. In the spring there is also an abundance of forage for the suckling ewe. The growth of the lamb is retarded by high temperature and humidity, by excessive rainfall and cold weather. The rutting season comes with a falling temperature and possibly a rather wide range between the maximum and minimum temperatures. Unfavorable conditions at the rutting season or during the gestation period tend to produce a small fall of lambs, and often weak lambs. If these critical periods are greatly disturbed, sheep are not likely to be numerous or profitable.

In Illinois, conditions of good sheep years are found to resemble the average conditions prevalent in the best sheep countries. The bad years generally have unfavorable conditions at some of the critical periods. The most serious condition here is the hot summer with a high humidity. No practical methods of overcoming these conditions are known. At Urbana, Ill., a mean temperature of over 70° F., accompanied by a mean relative humidity over 80 per cent, retards the growth of lambs. A higher temperature can be tolerated if the humidity is lower.

More attention should be given to finding breeds best suited to a locality, since the Rambouillets seem to stand since the unfavorable conditions during the summer at Urbana, Ill., better than the Southdowns or Shropshires.

In some sections the limits of successful sheep production can be extended by proper methods of housing. The barn maintains a much more uniform and higher temperature and humidity than the shed or out of doors. But conditions in the barn are not entirely satisfactory for the health of sheep.

Sheep thrive best where cool summers and mild winters prevail and where sufficient rainfall is afforded to provide good grazing.

LITERATURE CITED

(11) 1906-11. HANDBUCH DER KLINOMATOS. Ausfl. 3 v., illus. Stuttgart.
(14) 1919. WORLD-POWER AND EVOLUTION. 287 p., illus. New Haven.