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Effect of Forage Height Upon the Microtemperature of a Grass-Legume Pasture and a Comparison of Forage Composition

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EFFECT OF FORAGE HEIGHT UPON THE MICROTEMPERATURE OF A GRASS-LEGUME PASTURE AND A COMPARISON OF FORAGE COMPOSITION

by

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Robert E. Warnick

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INTRODUCTION

The use of pasture to provide low cost feed for dairy and other farm animals is an important factor in the success of livestock operations.

Some of the factors which influence the income from pasture land are: management, pasture mix, and climate. The management of a pasture can determine to a great extent the value of pasture in a farming enterprise. Irrigating the pasture at the right time, using the right fertilizer, and proper methods of harvesting are examples of some of the management problems facing the grassland farmer.

The development of pasture mixes that produce a high yielding, palatable and succulent feed has helped make pasture a profitable crop. It is important to understand the growth patterns of individual grasses and legumes when grown as single pasture components or as part of a pasture mix. The growth patterns of the grasses and legumes in the pasture mix help determine the best type of mix to furnish the type and quality of forage needed throughout the pasture season. There has been extensive research on pasture management and the development of pasture mixes.

Climate is a factor which affects most phases of pasture production. Climate has been studied in connection with management and the development of the pasture mixes. It has been noted that the weather conditions as reported by the weather stations do not always apply to an individual area such as a farm or a field. Limited studies in this type of research have shown appreciable climatic differences even within small fields.

Microclimate is a word used to describe the climate in a localized area such as a city, a hundred acre farm, or even a single blade of grass. Studies of the microclimate of forage crops are relatively new. Information obtained from studying microclimate of pasture may be very useful in obtaining the highest quality and yields of forage.

Temperature is one of the climatic factors of a microclimate. The term microtemperature is used to describe the temperature of the microclimate. Several studies have been conducted on the microtemperature of bare soil as related to air temperature. Temperature differences between plant forages and air can be studied in a similar way. Research on microtemperature of pasture is very limited.

A study of microtemperature of a high yielding grass-legume pasture was conducted to obtain information on the influence of forage height during a growing season on air temperatures within 24 inches of the soil. Yield and chemical composition data were collected for each harvest period and compared with temperature data.

REVIEW OF LITERATURE

A large portion of pasture research has been concerned with the development of pasture mixes that yield a relatively constant amount of high quality forage throughout the pasture season. Economical methods of forage harvesting also have been studied extensively.

Only in the last few years has attention been focused upon the microclimate of the pasture. Temperatures reported by most weather stations have been obtained from equipment located within shelters 4 to 6 feet above the ground, these temperatures can often be very misleading when relating them to plant growth. Sprague et al. (20) reported that during a three year period in Maryland, New Jersey, Pennsylvania, and Vermont, the mean daily temperatures were the same at 3 inches and at 5 feet above a Kentucky bluegrass sod. The highest maximum and the lowest minimum temperatures were obtained at the 3 inch level and the greatest differences between the extremes were found at the more southerly locations and during mid-summer.

Sward maintenance is a major concern of grassland farmers. It has been noted that severe losses of grasses and legumes in the sward during winter and summer may be reduced by maintaining a mulch cover thus reducing temperature extremes. Beil et al. (6) state that in direct sunlight during mid-summer, ladino clover stolons have been observed in Pennsylvania to reach 122 F. Shaded tissues seldom exceed 90 F. On one winter day, thermocouples placed inside ladino clover stolons, recorded temperatures of 4 F at 6:30 A.M. and 47 F at 2 P.M. A few inches away temperatures of stolons under a 3 inch mulch of orchard grass were 16 and 31 F at the same corresponding times. During a 4 hour period later the same day the temperatures of the uncovered stolons dropped to 16 F and the temperatures of stolons under the mulch dropped to 22 F. Air temperature 5 feet above ground level dropped from 22 to 20 F during the same 4 hour period. Subsequent laboratory studies showed that rapid cooling (7-10 F per hour) below freezing point resulted in far more severe cold injury to the plants than slow cooling (2 F per hour). Serious winter losses were also noted in the field among unprotected stolons.

The following table was presented by Champness (8) to show the influence of a 2 to 3 inch clover cover on ground and air temperatures. (The values have been converted to Fahrenheit.)

	white clover	bare ground
3 inches above ground	82°	83°
2 inches above ground	85°	84°
1 inch above ground	81°	87°
ground level	77°	95°

Davies (9) presents additional information concerning ground temperatures and forage cover which follow these same general temperature changes associated with forage cover. Champness (8) also presents a graph showing temperature variations with taller and mixed forages. The graph illustrates that with a forage cover, the highest temperature was recorded at the top of the most dense forage with a sharp decline to the ground level. These observations follow the same trends as information presented by Geiger (10).

Slope of the land also affects microclimate. In 1912 it was recognized that a 2^{o} slope to the land has much the same effect as changing the solar climate 140 miles in latitude (1). From such data it might be expected that the microclimate of a pasture in northern Utah with a 5^{o} southern slope will have many similarities to the microclimate of a pasture in southern Utah with a 5^{o} northern slope. Researchers studying microclimate generally agree that the more extreme temperature variations are found on the areas of land having a south or southeasterly slope and loss of soil moisture is least (on the same type of soil) on land with a northern slope (1, 16, 19, 21).

It has been shown that there is a relationship between temperature, light intensity, and plant growth. Gist and Mott (11) presented data showing the most growth of roots and above-ground forage of alfalfa, red clover, and birdsfoot trefoil at a temperature of 60 F with 1200 fc light. They indicate with an increase in light intensity that maximum growth would be obtained at a temperature above 60 F. An increase in temperature without an increase in light would result in slower growth. 1200 fc of light was the greatest light intensity used in their study.

Blackman (7) reported that there is little or no growth where soil temperature is below 42 F. When soil temperature was between 42 and 47 F there was a marked increase in growth rate of forage in the plots where nitrogen was added, but with temperature above 47 F the growth rate was similar in all plots. He also showed that addition of nitrogen resulted in a higher nitrogen content in the forage, but that increased growth due to nitrogen was directly associated with the length of time the soil temperature remained between 42 and 47 F.

The study of microclimate with forage crops is relatively new. Much helpful information for the grassland farmer can be obtained from the study of temperature variations in the microclimate caused by the amount and type of forage.

PROCEDURE AND EQUIPMENT

The pasture used in this study was a grass-legume mixture established in 1950 at the Utah State University Dairy Experimental Farm near Logan, Utah. During 1959 it was being used on a grazing versus green chop study. The pasture was managed for the grazing versus green chop study.

During 1957, the entire pasture was clipped and the forage hauled to the cows. Ten tons of barnyard manure were added per acre to the pasture during this year. In 1958 the pasture was subdivided into six equal plots with alternate plots grazed or clipped. Fifteen tons of barnyard manure and 135 pounds of phosphate per acre were added to all plots. The plots that were grazed received additional fertilizer of dung and urine from the cows during the grazing periods. During 1959 only the grazed plots received any form of fertilizer, and that included only the fertilizer from the cows while grazing.

The plots that were grazed were harvested five times while those clipped were harvested four times. Only the information obtained during the first four harvests was used for the comparisons in this study. The pastures were flood irrigated five times during the 1959 pasture season.

The temperature readings were obtained by the use of mercury thermometers which were compared before the trial for accuracy over the range of 50 F to 100 F. Five thermometers with the most uniform readings were used. (For standardization records see Table 2.)

Two large nails were partially driven into one end of a 1 inch by 6 inch by 3 foot board (Figure 1) and then the heads of the nails were cut off making prongs which would hold the board upright when placed in the ground. A one-half inch foam rubber sheet was tacked to one side of the board and the thermometers were held in place against the foam rubber by elastic bands. The foam rubber was removed from the area near the mercury bulb of each thermometer to allow air circulation around the bulb. The thermometers were placed at ground level and 6, 12, 18, and 24 inches above the ground.

Temperature readings were recorded at random times and at random locations in the pasture during the pasture season. The thermometer board was placed so that the thermometers were facing away from the direct sun. A period of 5 minutes was allowed for the thermometers to stabilize before the temperatures were recorded. The time of day and height of forage was noted each time the temperatures were recorded.

Forage samples were taken just prior to the clipping or grazing of each harvest. Samples were obtained by clipping two strips 36 inches by 20 feet in each plot with

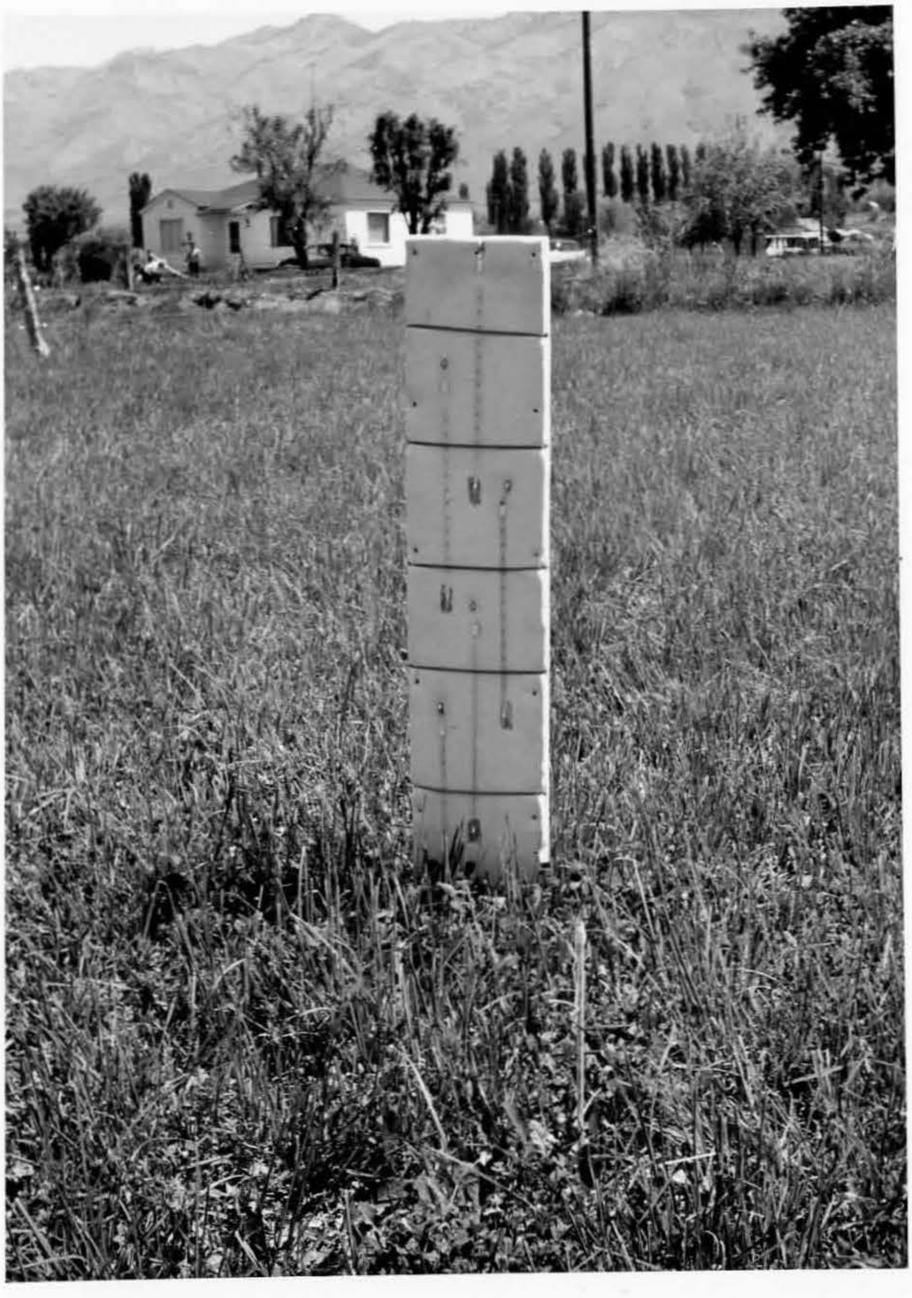


Figure 1. Equipment used for obtaining temperatures

a 36 inch Jerry power hand mower. The total weight of forage was recorded and a sample obtained from each 20 foot strip. After air drying, these samples were ground in a Wiley mill and composited to a single sample from each plot for each harvest. Samples were analyzed for moisture, ether extract, fiber, ash, nitrogen, and phosphorus, the values obtained were averaged for the whole pasture. Analytical procedures are outlined in AOAC (2) except for phosphorus, which was determined according to the procedure of Koenig and Johnson (15).

RESULTS AND DISCUSSION

Temperatures

The microtemperature for each harvest period are shown in Figures 2 and 3. Figure 2 includes average temperatures for each of the four harvest when the forage was less than 6 inches in height.

Temperatures obtained before the first harvest (May 15) indicate, where the forage is short, that the forage of this pasture had little effect on the temperature above ground level. The higher temperature at ground level might be expected, because the forage of the pasture mix at this height did not completely shade the ground. Heat from the sun warms the ground more than it does the air.

During the second, third, and fourth periods of growth, where the forage was less than 6 inches high (Figure 2), higher temperatures at the 6 inch level as compared with temperatures above 6 inches could possibly be due to reflection or radiation from the heated ground due to the warmer season. Warm air rising from the soil could help explain the fact that during the third and fourth harvest periods there was relatively little difference between temperature values at the ground and 6 inch levels with forage less than 6 inches high. It is possible that this movement of air could cause enough circulation to keep the

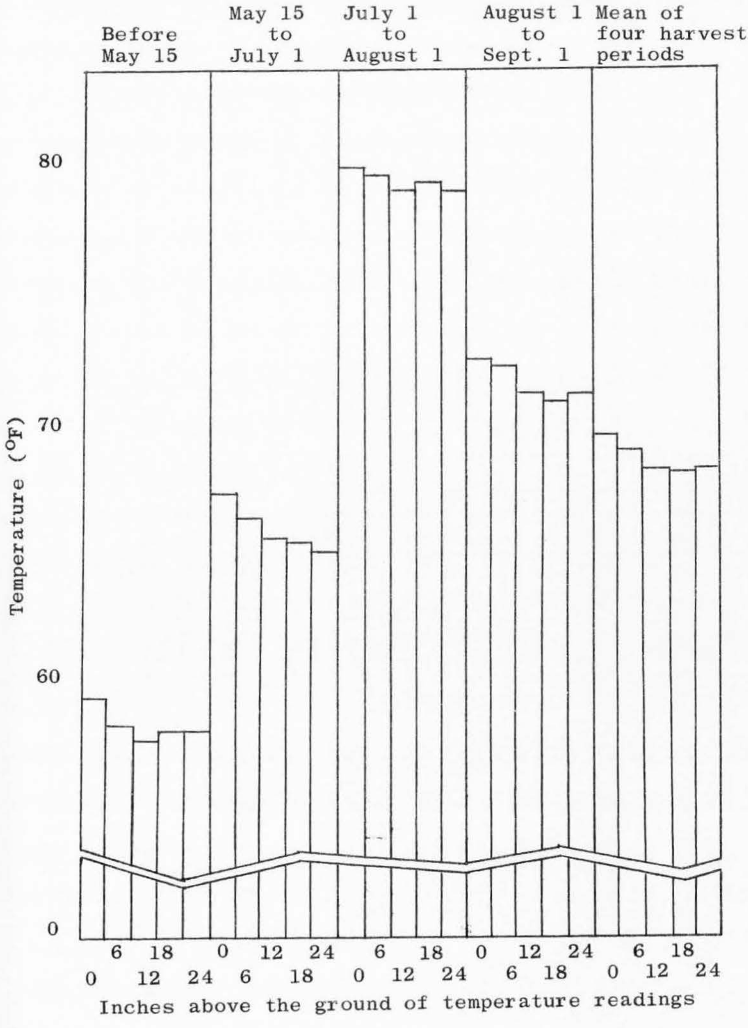


Figure 2. Temperature for four harvest periods during the time when forage was less than 6 inches high

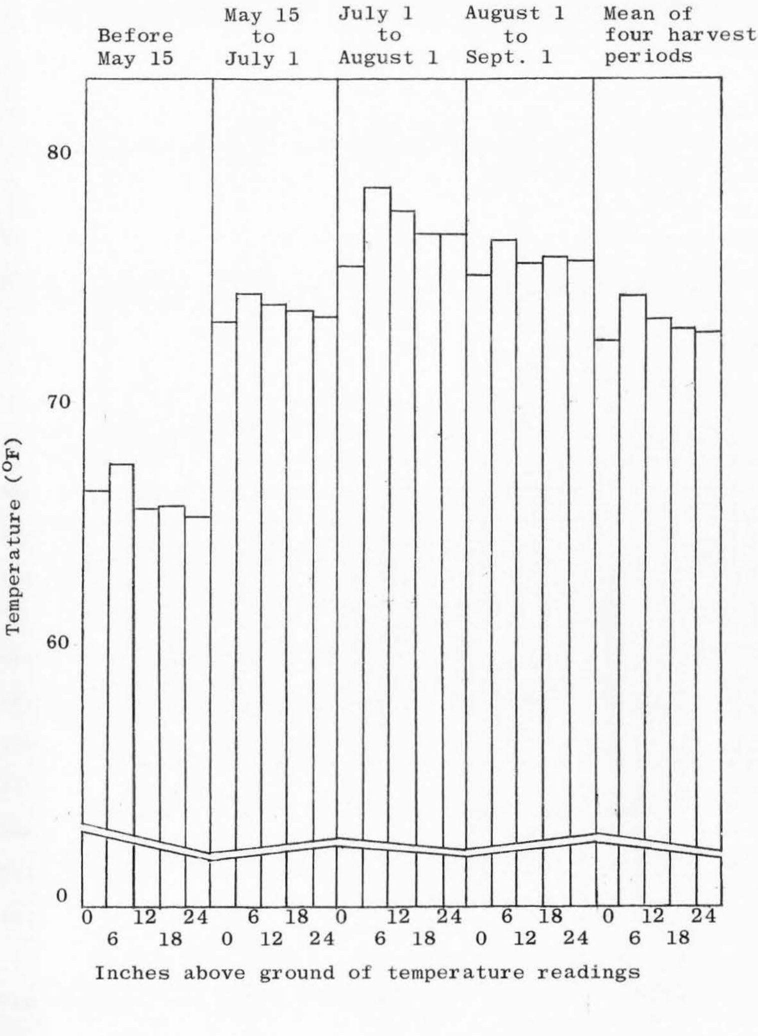


Figure 3. Temperatures for four harvest periods during the time when forage was greater than 6 inches high

temperature nearly the same at the ground and 6 inch temperature levels. Forage less than 6 inches high would not appreciably interfere with such air circulation. The mean value for each height of temperature readings where the forage was less than 6 inches high indicated that only those at the 6 inch and ground levels were different from atmospheric temperature.

The temperature pattern changed when the forage was high enough to shade the ground (Figure 3). During the first and fourth harvest periods the maximum forage height was about 12 inches. Temperature relationships during the two periods were similar. Temperatures at the 24, 18, and 12 inch levels were nearly the same, somewhat higher at the 6 inch level and cooler near the ground.

The forage grew to heights above 18 inches during the second and third harvest periods. Data for these periods (Figure 3) indicate that with the taller forage, temperatures at the 12 inch level are higher than at the 18 and 24 inch levels. Mean temperatures of the second and third harvest periods show a sharp increase from the ground to 6 inch level then decrease at each level from 6 to 24 inches.

It is interesting to note that during the last three harvest periods, which were the hottest of the season, that the temperature at the ground level was the lowest recorded during each period. Forage cover may have influenced these low temperatures by shading and interfering with air circulation. The highest temperatures were recorded near the area just above the dense forage of the pasture. In the more mature pasture forage this appeared to be near the top of the ladino clover.

Data were evaluated by an analysis of variance (Table 1). A large sampling error limited interpretation of harvest period and harvest period by forage height interaction. Assuming that the residual is a valid error term, the height of temperature measurement, forage height, and height of temperature by height of forage interaction are significant (P .01).

Table 1. Analysis of variance

Source	d.f.	s.s.	m.s.	F.
Harvest	3	138.89	462.96[a]	
Height of temp. measurement	4	5.72	1.43	7.15**
Harvest and height of temp. meas.	12	2.73	.23	1.15
Forage height	1	162.01	162.01	810.0**
Harvest and forage height	3	189.20	63.07[a]	
Height of temp. meas. and forage height	4	6.39	1.60	8.0**
Residual	12	2.37	.20	
Total	39	1757.32		

[a]Confounded with sampling error
**Significant at .01 level

Where forage is less than 6 inches high (Figure 2) temperatures are lower for the first two harvest periods than where the forage is greater than 6 inches high (Figure 3). The temperatures for the forage less than 6 inches high (Figure 2) were obtained during the first part of each harvest period and those for forage greater than 6 inches high (Figure 3) were obtained during the last of the harvest period. The differences in temperatures follow the trend of a warming season. Temperatures during the third harvest period for both forage heights should be similar. The difference noted could be due to the random method of sampling and daily temperature variations.

During the first 14 days of September the mean daily temperature was warmer than the last 14 days of August (See Figure 8e and 8f). The difference in seasonal temperature could account for the higher temperature values of the fourth harvest where forage is higher than 6 inches (Figure 3) than those of the fourth harvest where forage is less than 6 inches high (Figure 2).

Figures 4, 5, and 6 show the relationship between the heights at which the temperatures were obtained and the time of day for each of three heights of forage growth. The three figures were prepared using the averages of data collected during the entire pasture season and segregated according to time of day and height of forage. The data in Figures 4, 5, and 6 were not suitable for statistical analysis.

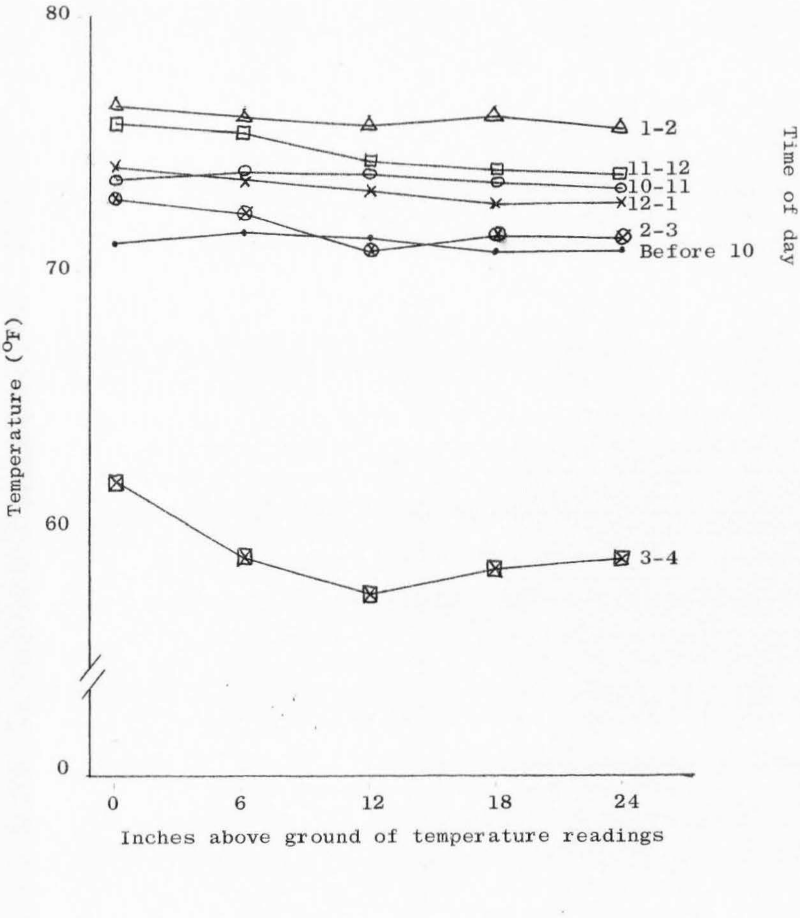


Figure 4. Temperature during the day with forage less than 6 inches high

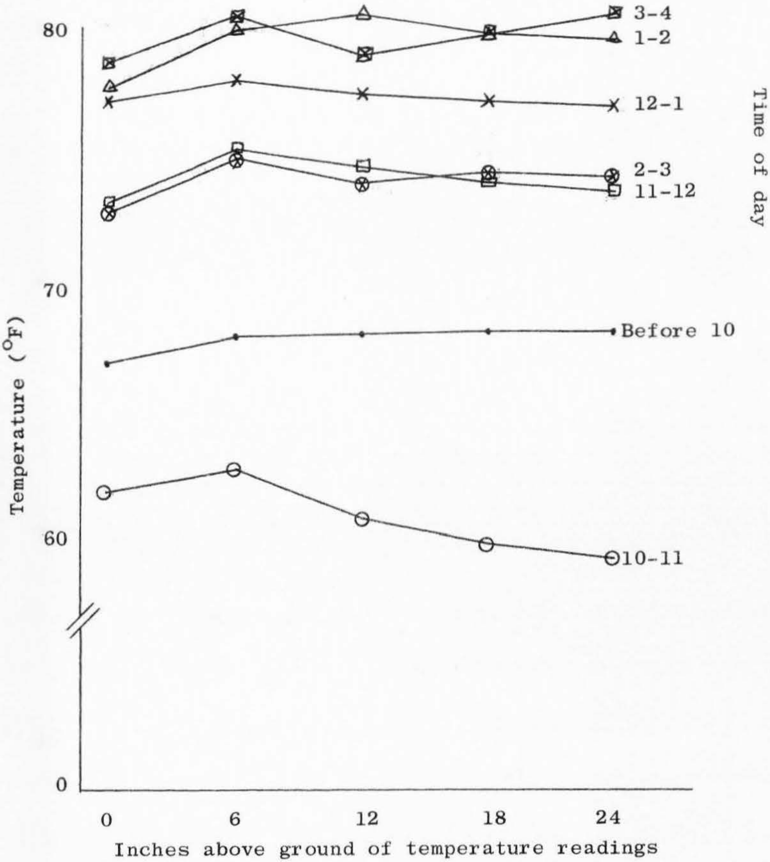


Figure 5. Temperature during the day with forage 6 to 12 inches high

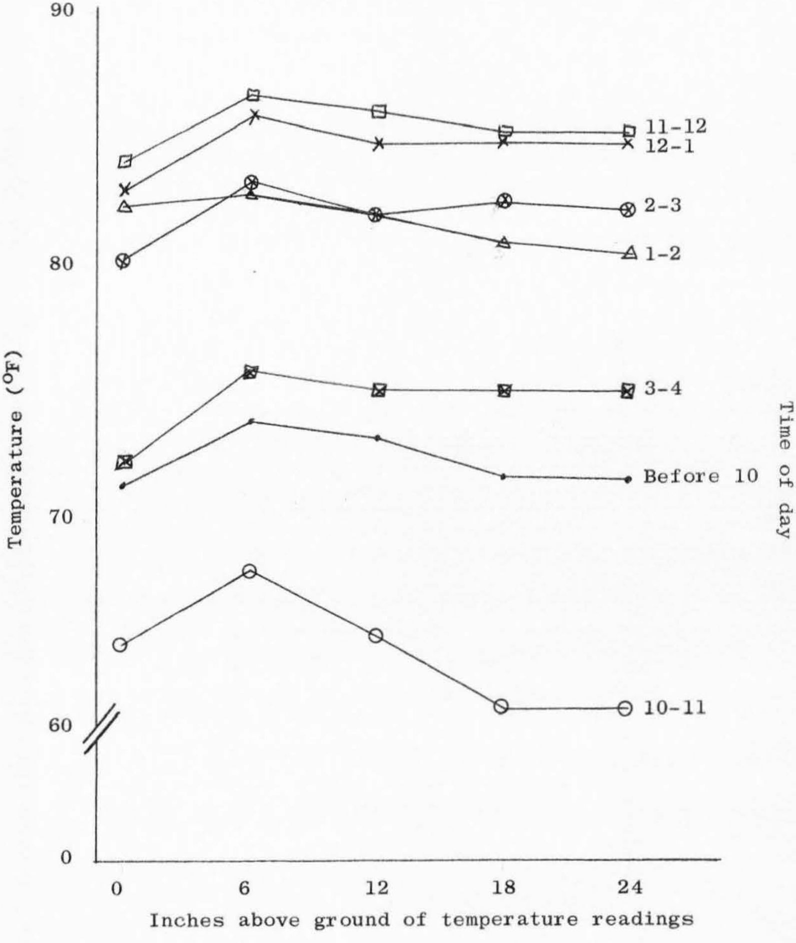


Figure 6. Temperature during the day with forage 12 to 18 inches high

For the period of time before 10 A.M. and from 10 A.M. to 11 A.M. where forage was less than 6 inches high (Figure 4) the temperature at ground level was lower than the temperature at the 6 inch level. After 11 A.M. the temperatures at ground level were increasingly warmer than at the 6 inch level. The effect of the sun of heating the soil during the day was evident when the forage cover was short.

Where the forage was taller (Figure 5) there were only small temperature differences at the different levels of measurement during the early part of the day. The temperature readings at ground level were lower throughout the day than at the 6 inch levels with forage 6 to 12 inches high. When the forage was from 12 to 18 inches high (Figure 6) the temperature pattern was similar to that noted for forage 6 to 12 inches high (Figure 5) but with a more marked temperature decline from the 6 inch level to ground level.

This study covers a type of research that is relatively new and needs more research especially on certain phases. Temperature data obtained at certain times during the day and at regular intervals during the growing season could be analyzed statistically. A complete record of weather conditions also might be helpful in a future study.

Yield and chemical composition

Yield and composition of forage are presented in Figure 7. The first harvest of the pasture yielded less than the second, as a result of early harvest date of first harvest.

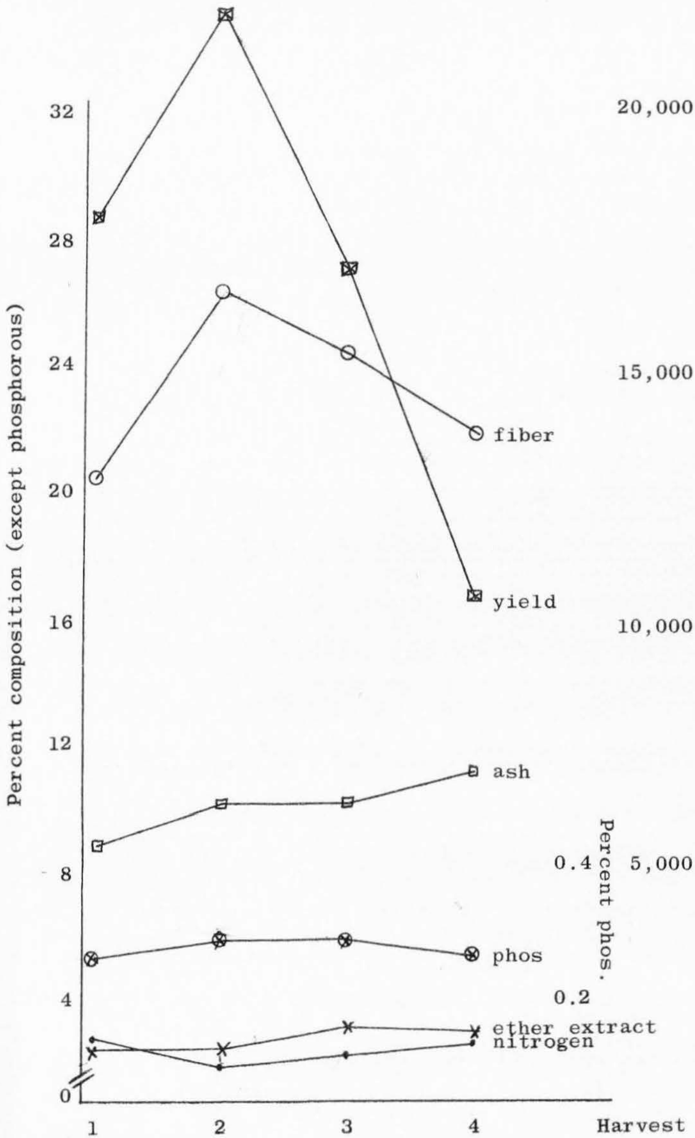


Figure 7. Yield, and composition of pasture forage (dry basis)

The early harvest date was part of routine pasture rotation harvest. The third and fourth harvests were progressively smaller than the second.

The first harvest of the pasture mix studied had relatively more grasses than legumes. The second harvest had about equal amounts of grass and legume, while the third had a higher percent legume, and the fourth more grass.

Fiber content of the forage followed a trend similar to yield during the four harvests with a higher fiber content in the second and third harvests. Phosphorus content was nearly constant throughout the four harvest periods, with a rise during the second and third harvests possible associated with the difference in the grass-legume ratio in the forage. Tables of feed composition (17) show that legumes usually have a higher phosphorus content than grasses.

The amount of nitrogen (or protein) in the forage appears inversely related to the yield and fiber content. The nitrogen content of the fourth harvest was slightly lower than expected, although no explanation is evident. The ash content appeared normal for the first three harvests. Ash content for the fourth harvest was higher than anticipated, although for the same pasture area in 1958 and 1960 ash content during the season was similar to that for 1959 (Figure 9).

Fat or ether extract content of the four harvests followed a slightly different pattern than expected from usual botanical composition. In composition tables (17) legumes have a lower ether extract content than grasses. In 1958, the content of ether extract followed the same trend for harvests as 1959, however, in 1960 the trend was reversed (Figure 9). A relationship may exist between temperature and fat content of the pasture forage since the curves follow similar trends (Figures 2, 6), although in this study there is insufficient information to evaluate such a relationship. Further study concerning the relationship of temperature and the ether extract content would be helpful.

SUMMARY

The effect of the height of forage of a high yielding grass-legume pasture upon the microtemperature of the pasture was studied. Yield and chemical composition of the forage were obtained and studied for each of the harvest periods. Because of the sampling method, a statistical analysis of the data was limited.

It was found that the temperature at selected levels above the soil was related to height of forage. Forage less than 6 inches in height affected the temperatures primarily in the area within 12 inches above the soil. With the short forage the highest temperature readings were recorded at ground level. When the forage was taller than 6 inches, the highest temperatures were noted at a height near the top of the most dense forage growth. With the taller forage the temperature at ground level remained cooler because of the forage cover.

Yield and chemical composition of the forage followed the trends which might be expected of a succulent, high yielding pasture. The second harvest yielded the most forage because of the rotational grazing system employed. The ash content of the fourth harvest was higher than expected but was similar to the preceeding and following years.

LITERATURE CITED

(1) Alter, J. Cecil. Crop safety on mountain slopes. Yearbook of Agriculture. United States Department of Agriculture, Washington, D.C. p. 309. 1912.

(2) Association of Official Agricultural Chemists. Official methods of analysis of the Association of Official Agricultural Chemists. Seventh Ed. Washington, D.C. 1950.

(3) Bateman, George Q., and Wesley Keller. Irrigated pastures in arid regions. Proc. Sixth International Grassland Congress. 1:404. 1952.

(4) Bateman, G. Q., G. E. Stoddard, and C. H. Mickelson. Self service or maid service. Farm and Home Science. Utah State University, Agr. Exp. Sta. Logan, Utah. 19:1. 1958.

(5) Bateman, G. Q., G. E. Stoddard, and C. H. Mickelson. Grazing versus feeding green chop in dry lot. Farm and Home Science. Utah State University Agr. Exp. Sta. 22:1. 1961.

(6) Biel, E. R., A. V. Havens, and M. A. Sprague. Some extreme temperature fluctuations experienced by living plant tissue. Bull. Am. Meterological Soc. 36:159. 1955.

(7) Blackman, G. E. The influence of temperature and available nitrogen supply on the growth of pasture in the spring. J. Agr. Sci. 26:620.

(8) Champness, S. S. Effect of microclimate on the establishment of timothy grass. Nature. 165:325. 1950.

(9) Davies, W. The grass crop. E. and F. N. Spon. Ltd., 22 Henrieta St., London, W. C. 2, England. 1954.

(10) Geiger, Rudolf. The climate near the ground. Harvard University Press, Cambridge, Mass. 1950.

(11) Gist, G. R., and G. O. Mott. Some effects of light intensity, temperature, and soil moisture on growth of alfalfa, red clover, and birdsfoot trefoil seedlings. Agron. J. 49:33. 1957.

(12) Harlan, Jack R. Theory and dynamics of grassland agriculture. D. Van Nostrand Co., Inc., Princeton, New Jersey. 1956.

(13) Jenson, Varon. Seasonal behavior of twelve pasture mixes and their components on irrigated land. Master of Science thesis; Logan, Utah. Utah State University Library. 1956.

(14) Keller, W., and M. L. Peterson. Irrigated pastures. Advances in Agronomy. 11:351. The Academic Press, New York. 1950.

(15) Koenig, R. A., and C. R. Johnson. Determination of phosphorus in biological materials. Industrial and Engineering Chemistry. 14:155. 1942.

(16) Molga, M. Agricultural Meteorology. Part II. Outline of Agrometeorologal problems (translated from Polish.) Published for Nat. Sci. Foundation and the Dept. of Agr. by Centralny Instytut Informacji Naukowo-Techniczne-l-Eronomicznej Warszawa. 1962.

(17) Morrison, F. B. Feeds and Feeding. 22nd Ed. The Morrison Publishing Co., Ithaca, New York. 1956.

(18) Pritchett, W. L., and L. B. Nelson. The effect of light intensity on the growth characteristics of alfalfa and bromegrass. Agron. J. 43:172. 1951.

(19) Sprague, H. B. Grasslands. Publication No. 53 of the American Association for the Advancement of Science. Washington, D. C. 1959.

(20) Sprague, V. G., A. V. Havens, A. M. Decker, and K. E. Varney. Air temperature in the microclimate at four latitudes in the north eastern United States. Agron. J. 47:42. 1955.

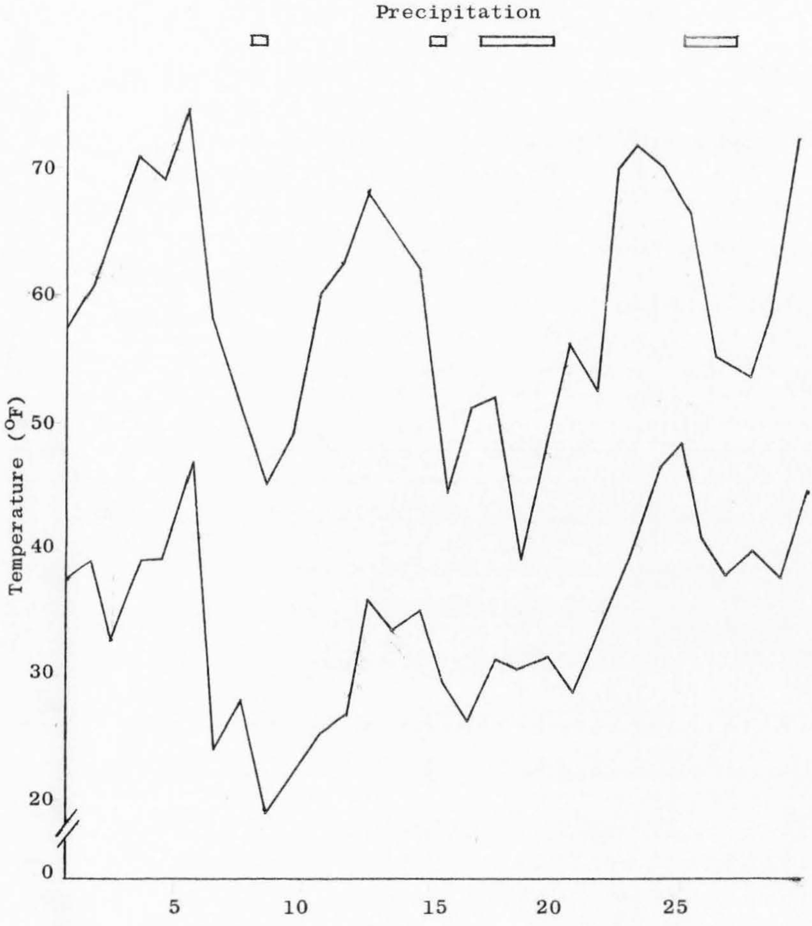
(21) Weaver, J. E., and F. E. Clements. Plant Eccology. Second Ed. McGraw-Hill Book Co., Inc., New York. 1938.

APPENDIX

Table 2. Thermometer calibration

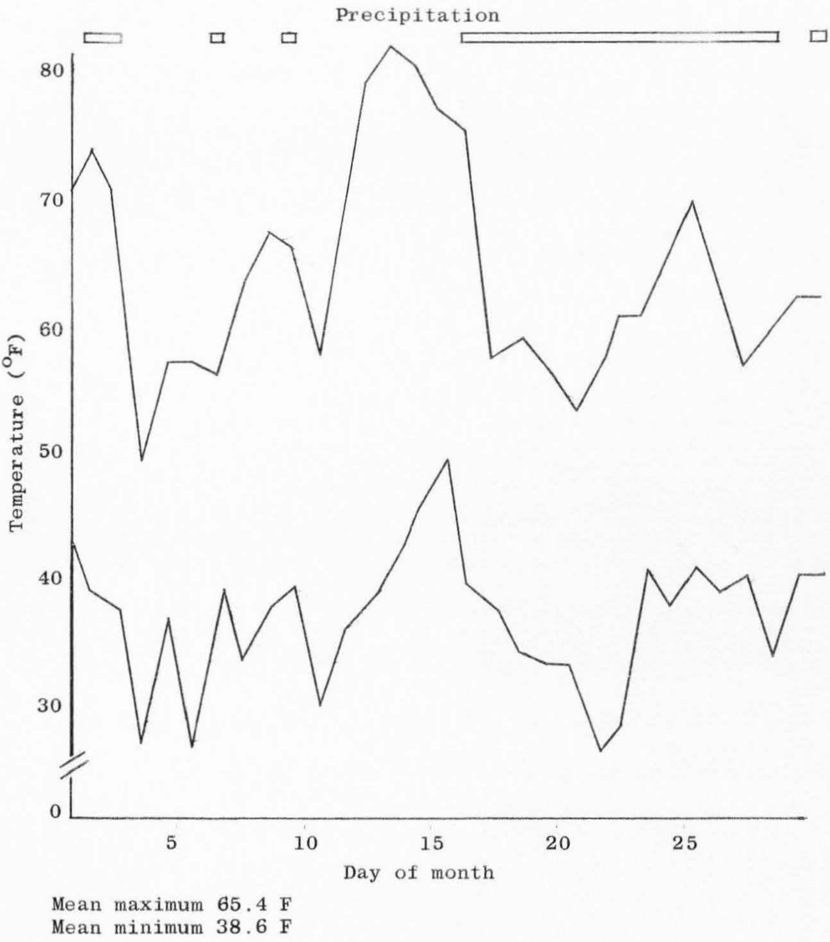
No.	Temperature in degrees fahrenheit					
			First calibration (April)			
1[a]	101	98	88	81	72	56
2	102	98.5	88.1	81.5	72.2	56
3	101.5	98	87.8	81	71.8	56.2
4	101	97.7	87.8	80.5	71.8	55.9
5	101.5	98	88	81	72	55.9
6	102	98.1	88.1	81	72	56.1
7	102	98.2	88.2	81.2	72.2	57
8[a]	101	98	88	80.5	72	56
9	102	98.2	89	81.5	73	57
10[a]	101	98	88	81	72	56
11[a]	101	98	88	81	72	56
12[a]	101	98	88	81	72	56
			Calibration check (July)			
1	100	96.5	85	78	68	50
8	100	96.5	85	77.8	68	50
10	100	96.5	85	78	68	50
11	100.1	96.5	85	78	68	50
12	100	96.5	85	78	68	50

[a]Thermometers used for collecting experimental data



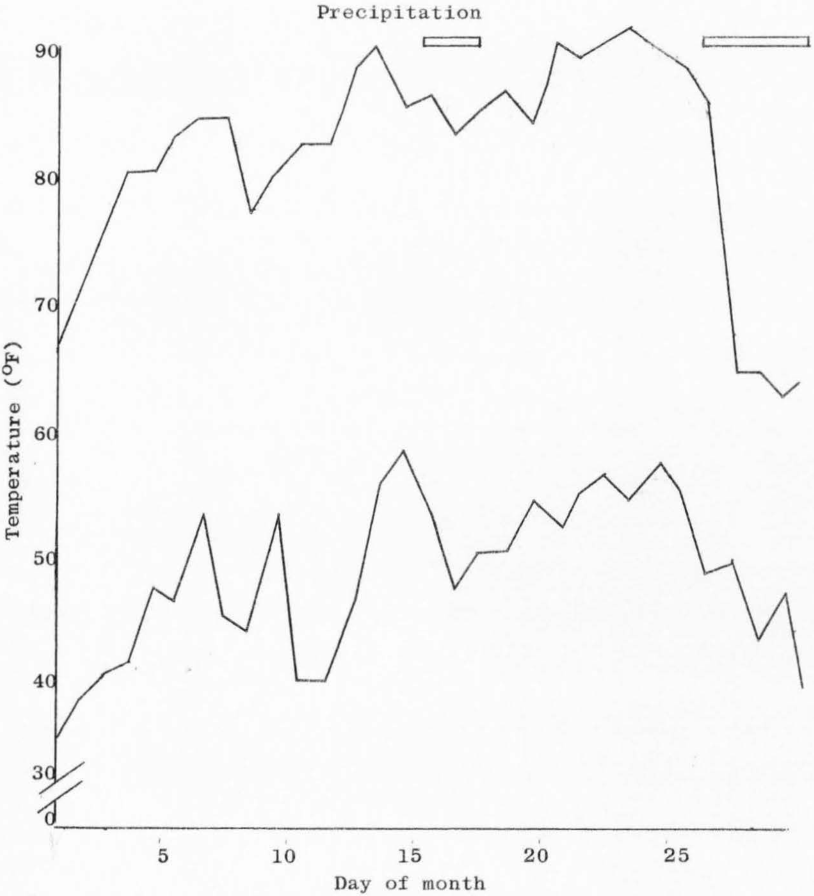
Mean maximum 60.5 F
Mean minimum 34.8 F

Figure 8a. Average daily maximum and minimum temperatures from three weather stations: KVNU, USU, Greenville Farm (April)



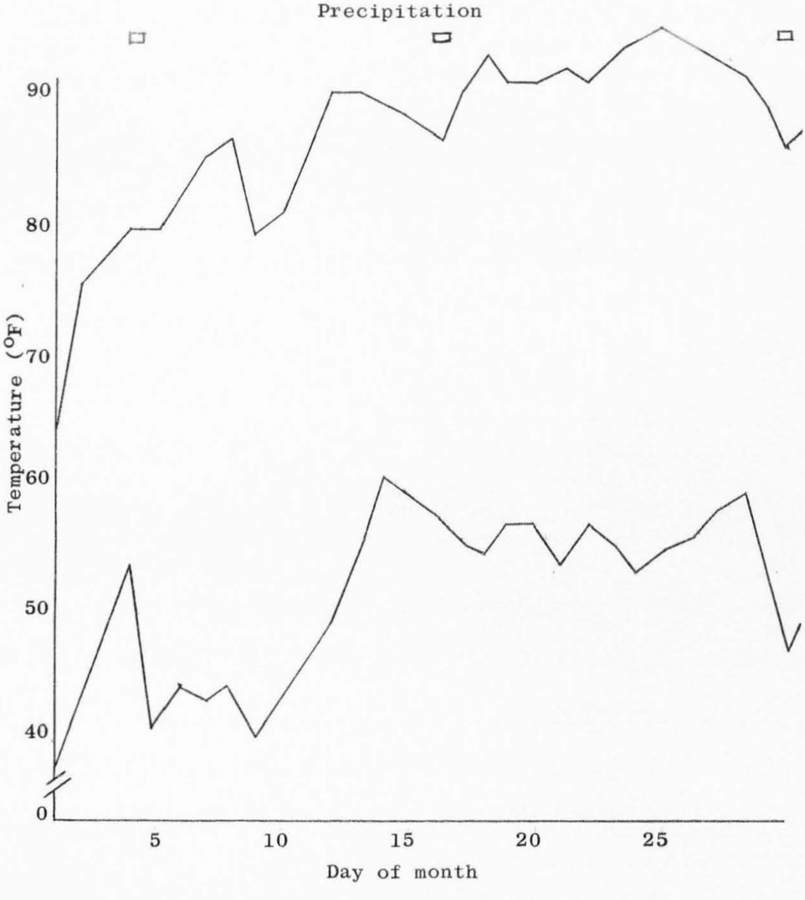
Mean maximum 65.4 F
Mean minimum 38.6 F

Figure 8b. Average daily maximum and minimum temperatures from three weather stations: KVNU, USU, Greenville Farm (May)



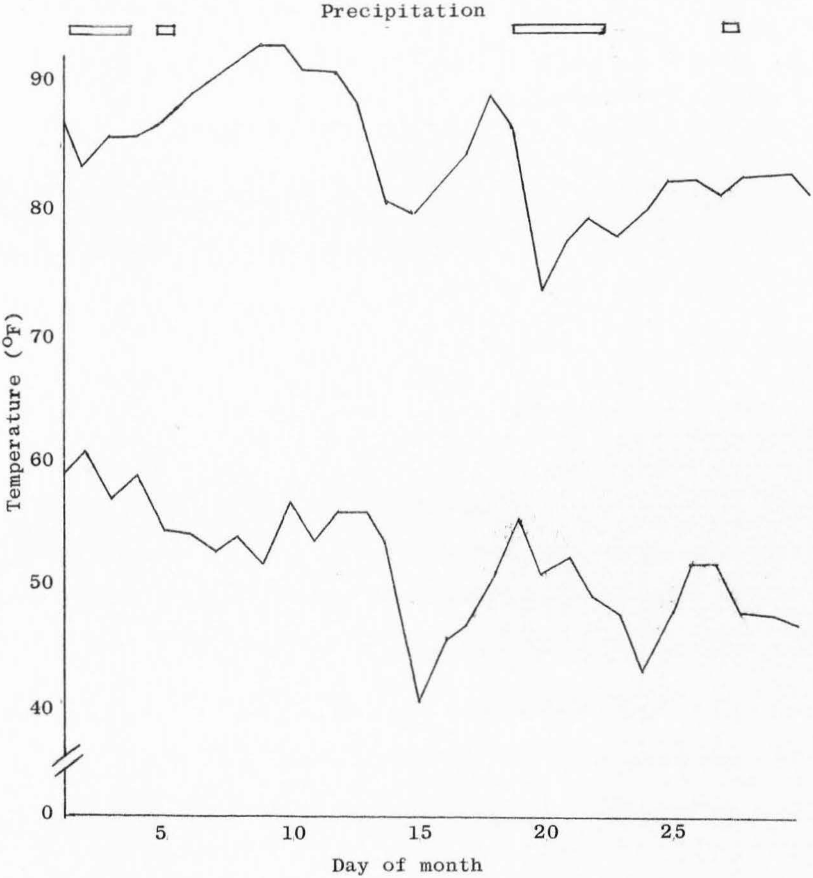
Mean maximum 82.8 F
Mean minimum 50.5 F

Figure 8c. Average daily maximum and minimum temperatures from three weather stations: KVNU, USU, Greenville Farm (June)



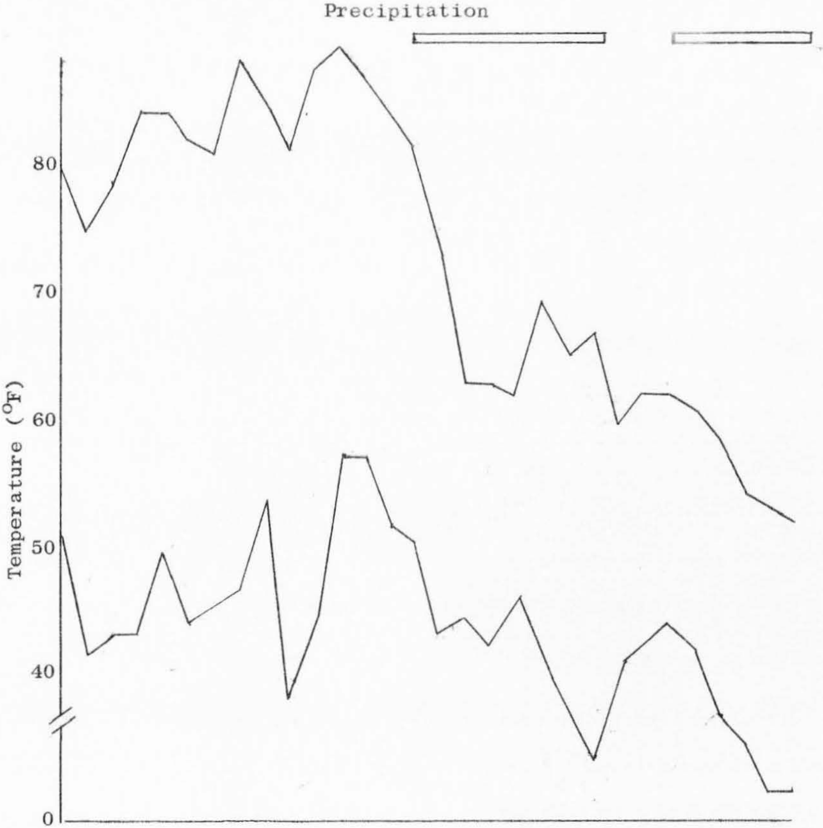
Mean maximum 89.3 F
Mean minimum 53.9 F

Figure 8d. Average daily maximum and minimum temperature from three weather stations: KVNU, USU, Greenville Farm (July)



Mean maximum 85.3 F
Mean minimum 52.7 F

Figure 8e. Average daily maximum and minimum temperatures from three weather stations: KVNU, USU, Greenville Farm (August)



Mean maximum 71.8 F
Mean minimum 44.2 F

Figure 8f. Average daily maximum and minimum temperatures from three weather stations: KVNU, USU, Greenville Farm (September)

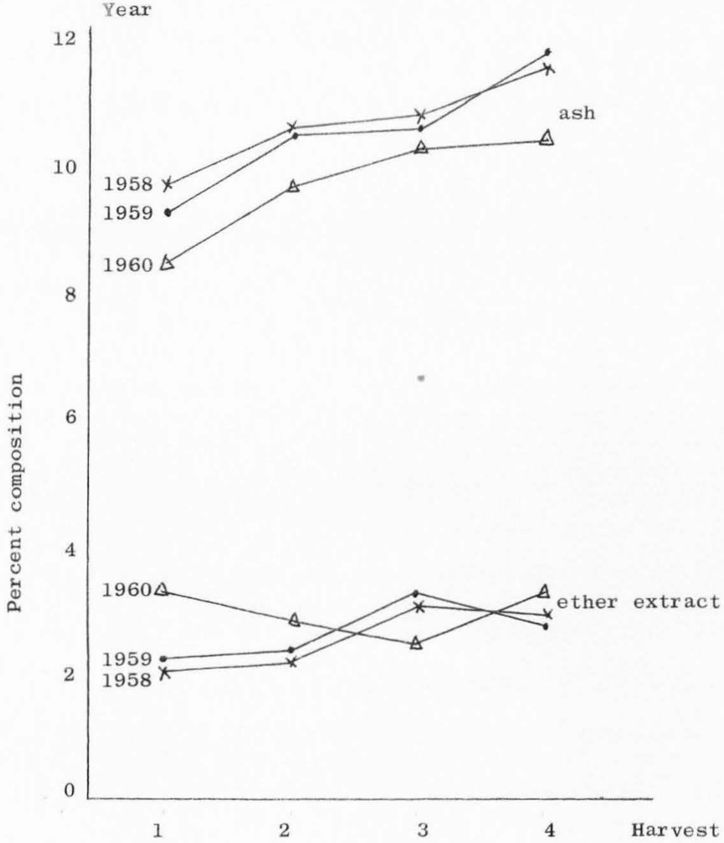


Figure 9. Ash and ether extract content of pasture forage (dry basis)