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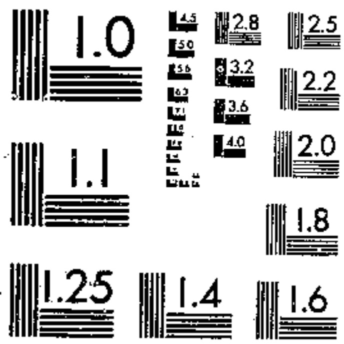

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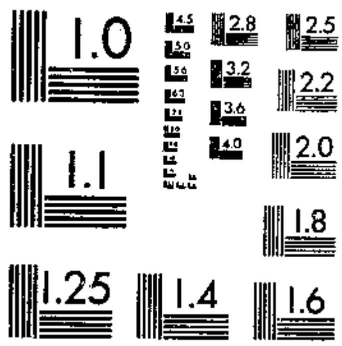

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Experiments With Annual Crops and Permanent Pastures to Provide Grazing for Dairy Cows in the Sandhill Region of the Southeast[1]

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United States Department of Agriculture, Bureau of Dairy Industry, in cooperation with the South Carolina Agricultural Experiment Station

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[1] Received for publication June 26, 1941.

[2] Prof. J. H. Mitchell and Mr. D. B. Roderick, of the Chemistry Department, South Carolina Agricultural Experiment Station, made the chemical analyses referred to in this bulletin.

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INTRODUCTION

The Sandhill region of the Southeast is an area of approximately 3,432,000 acres in a rather narrow strip that extends southwesterly from south-central North Carolina for approximately 400 miles into the eastern border of Alabama. The main area includes all or part of each of 39 counties in North Carolina, South Carolina, and Georgia. The outstanding characteristic of this region, from a farming standpoint, is the sandy nature of the soil. The soil for the most part is open, porous, and low in organic matter, and is considered of low value for growing feed crops and pastures. In general, however, the response to applications of fertilizer is favorable though temporary, and the climatic conditions are favorable for growing feed crops.

The Sandhill Experiment Station, located near Columbia, S. C., in the heart of the region, was established by the South Carolina Agricultural Experiment Station and the United States Department of Agriculture in 1927. This station is carrying on investigations of dairy-farming problems on typical Sandhill land. Among the problems of most importance are those of raising low-cost feeds for milk production, especially in the form of good roughages, and the development of a grazing system that would supply adequate pasturage throughout most of the year. Heretofore there has been little published information on the production of feed crops in this region.

PURPOSE AND PLAN OF THE EXPERIMENTS

The experiments reported in this bulletin were conducted at the station farm to determine the extent to which annual crops, and also permanent pastures, could be used to provide grazing for dairy cattle, and to determine also the relative economy of the two systems of producing the nutrients required for milk production.

For the experiment with annual crops, eight 2-acre plots were fenced and seeded to a succession of annual crops to provide grazing for the summer, fall, winter, and early spring months. During the 5-year period 1933–37 the plots were grazed in rotation by dairy cattle, and records were kept of the number of days of grazing obtained, the seasonal distribution of the grazing, the amount of nutrients produced by the crops, and other pertinent data, including all costs.

For the permanent-pasture experiment, a 6-acre representative area in a pasture that had been seeded in 1928 was enclosed for grazing. Data comparable to those for the annual crops were recorded for this experimental pasture plot. The grazing experiments, both with the permanent pasture and the annual crops, were repeated for several years to minimize yearly variations in the results.

Details of the methods used in carrying out the experiments are given in the appropriate sections in the following pages.

TOPOGRAPHY, SOIL TYPE, AND CLIMATE OF THE SANDHILL REGION

The Sandhill region, sometimes referred to as the Carolina Land of Longleaf Pines, lies between the Piedmont region on the north and west and the Coastal Plains region on the south and east. The general location is shown in figure 1.

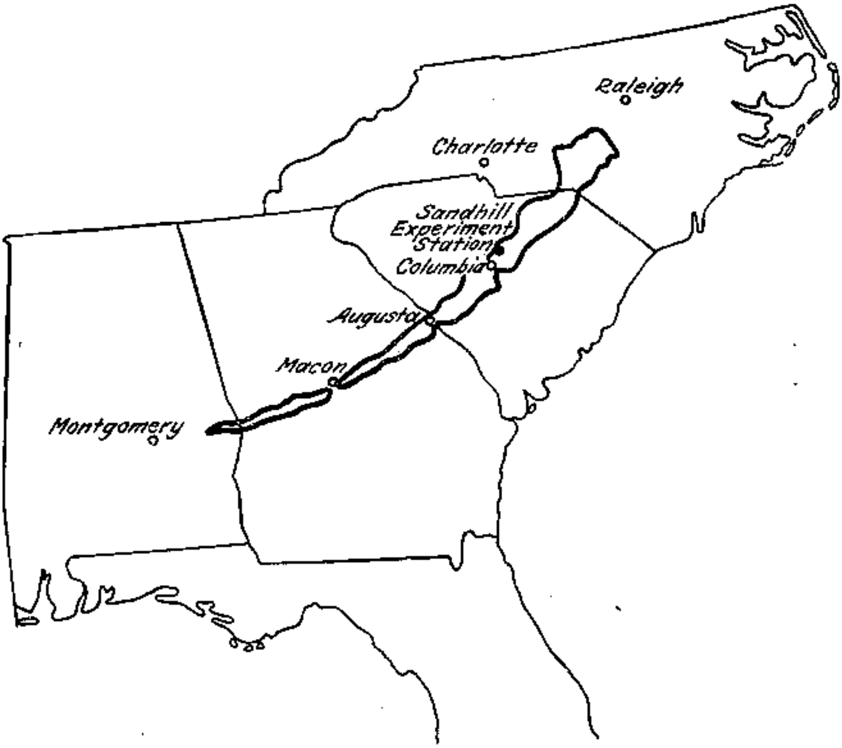

FIGURE 1.—Location of the Sandhill region of the Southeastern States (after W. E. Hearn).

Topographically it is a land of low-lying, dune-shaped hills and ridges, among which are plateaulike areas and bottom land through which many small fresh-water streams flow. These streams usually originate from numerous springs, many of which do not have centralized water heads but seep through the sand and spread over considerable areas. The water from these areas finally congregates to form rivulets which in turn converge to form larger streams.

Though the hills and ridges are sometimes used for agricultural purposes, the scattered plateaulike areas and the land adjacent to small streams are preferable.

The typical soils are the coarse phases of Norfolk sand and other similar types. The soil, generally, is open and porous. As a consequence of this physical nature, moisture retention is low and leaching is excessive, resulting in a deficiency of organic matter. Thus the soil in its natural state is unsatisfactory for optimum plant growth.

In contrast to soil conditions, the climate is well adapted for plant growth. The winters are relatively mild and short and the summers are long. As shown in table 1, the winter temperature rarely drops below 15° F. and that of the summer seldom rises above 100°. Normal annual precipitation is about 44 inches (table 2), of which approximately 32 inches fall during the growing season, a period averaging between 240 and 246 days (table 1).

TABLE 1.—*Monthly range of temperatures at Columbia, S. C., date of last killing frost in spring and first killing frost in fall, 1933–37, and average monthly temperature for the 10-year period 1928–37* [1]

TEMPERATURE DATA

Month	1933		1934		1935		1936		1937		10-year average 1928–37
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.
January	76	26	74	14	76	16	72	15	78	35	40
February	75	17	70	14	72	20	76	16	76	25	48
March	84	29	80	26	89	30	87	35	77	29	55
April	83	45	88	35	87	39	89	32	89	35	63
May	96	58	89	50	92	52	94	50	95	50	72
June	100	55	90	63	98	63	103	60	98	64	79
July	96	62	101	69	96	66	101	63	100	62	81
August	99	66	98	61	101	62	97	61	93	65	80
September	96	61	91	58	93	55	92	61	92	52	76
October	88	40	83	38	87	40	84	43	89	33	65
November	78	27	81	29	80	25	80	22	76	21	54
December	78	26	69	19	66	17	72	30	71	15	47

DATA ON KILLING FROSTS

Item	1933	1934	1935	1936	1937
Date of last killing frost in spring	Mar. 11	Mar. 15	Mar. 1	Mar. 19	Mar. 29
Date of first killing frost in fall	Nov. 9	Nov. 12	Nov. 24	Nov. 16	Nov. 5
	Days	*Days*	*Days*	*Days*	*Days*
Frost-free period	243	242	268	242	221

[1] These data are from the Weather Bureau station at Columbia, S. C., 15 miles from the Sandhill Experiment Station.

The ranges of temperature by months and the dates of first and last killing frosts for each season of the 5-year period, 1933–37, are shown in table 1. With the exception of the minimum temperatures of January and February 1934, the ranges of the temperature during the period of these experiments were normal. The intervals between killing frosts were normal in 1933, 1934, and 1936, but abnormal in 1935, when the interval was longer than normal by 25 days, and in 1937, when the interval was shorter by 22 days.

The record of the total annual rainfall at the Sandhill Experiment Station during the period of the experiments is shown in table 2.

The range was from 29.92 inches, 14.13 inches below the 10-year average, in 1933 to 56.57 inches, 12.52 inches above, in 1936. With the exception of these 2 years, the annual rainfall deviated very litte from the 10-year average.

TABLE 2.—*Actual monthly precipitation, 1933–37, compared with 10-year average and total for the growing season* [1]

Month	1933	1934	1935	1936	1937	5-year average, 1933–37	10-year average 1928–37
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	1.96	1.19	1.64	7.10	5.60	3.50	3.22
February	4.73	3.63	2.40	4.37	4.32	3.89	3.42
March	2.98	3.45	2.02	5.11	3.06	3.32	3.34
April	1.01	1.82	3.92	10.21	6.49	4.69	4.19
May	3.76	4.92	1.19	.16	1.90	2.39	3.19
June	2.69	2.09	2.99	2.21	8.65	3.73	4.13
July	4.77	3.44	5.60	4.08	4.69	4.50	4.61
August	3.89	6.46	7.53	4.63	7.50	6.00	5.44
September	1.70	4.42	5.76	2.08	1.98	3.19	4.36
October	1.16	2.79	.99	8.89	2.52	3.27	2.81
November	.42	3.49	2.88	2.97	2.99	2.55	2.22
December	.85	3.46	2.47	4.76	2.48	2.80	3.11
Total yearly precipitation	29.92	41.16	39.29	56.57	52.18	43.83	44.05
Precipitation for growing season only (March through October)	21.96	29.39	29.90	37.37	36.79	31.09	32.07
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Percentage that the precipitation in growing season is of the total yearly precipitation	73.4	71.4	76.1	66.1	70.5	70.9	72.8

[1] These data obtained from the Office of Soil Fertility Investigations, Bureau of Plant Industry. Rain gage located at Columbia, S. C., (Sandhill) Experiment Station.

More important than the annual precipitation is the periodic distribution. Plants growing in the open porous soil, the prevailing type, need frequent rains for optimum growth. During the growing season, a span of several days without rain tends to retard the growth of the crops. Obviously then, the monthly distribution as given in table 2 covers too long a period to indicate fully the effect of distribution on pasture yields. The uniform distribution during 1935 rendered this the most satisfactory year of the experimental period for crop production. Though the annual rainfall was low for 1933, the distribution was good until late in the year. In contrast, the total rainfall for 1936 was high but the distribution was poor, being very dry during late spring.

EXPERIMENTAL PROCEDURE WITH ANNUAL CROPS FOR GRAZING

DESCRIPTION OF THE PLOTS

A 16-acre field was selected at the Sandhill station for use in the grazing experiment with annual crops and subdivided into eight fenced plots of 2 acres each as shown in figure 2. The land was typical of the Sandhill region, and the plots were similar in type of soil and general topography. Figure 3 shows the general topography of the experimental area.

Prior to the fall of 1931 the area in plots 1, 2, 3, 7, and 8 had been used for routine crop production, the area in plot 4 was a peach orchard, and plots 5 and 6 were in virgin growth of dwarf oaks. In the winter of 1931–32 the entire 16-acre area was seeded to rye, which was grazed late that winter and in the following spring. The rye was followed during the summer of 1932 with corn for silage. Immediately preceding the last cultivation of the corn the area was seeded to cowpeas by broadcasting. The crop was turned under that fall just before the first crop was seeded for the grazing experiment, which began in the spring of 1933.

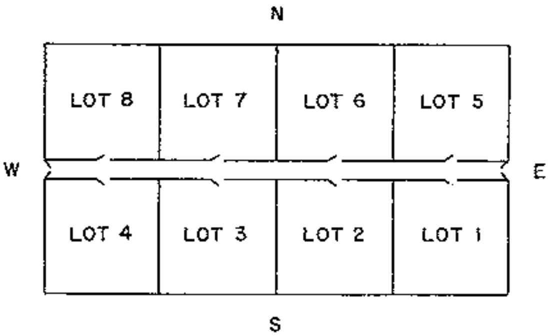

FIGURE 2.—Arrangement of the plots used in the grazing experiment with annual crops.

FIGURE 3.—General view showing topography of the area used for the grazing experiment with annual crops. The crop being grazed is soybeans and pearl millet.

FERTILIZER AND MANURE TREATMENTS

The fertilizer nutrients that were added to the soil were in the form of pulverized limestone, commercial fertilizers, and barn manure. The manure was that collected daily from the box stalls of dairy cows, and it contained considerable quantities of straw bedding.

Early in the fall of 1932 dolomitic limestone was applied to the entire 16-acre area at the rate of 2,000 pounds per acre. In addition, an application of 10 tons of manure per acre was made on plots 1, 2, and 3, prior to seeding the first experimental grazing crop (oats, barley, rye, and vetch) in late September, 1932, and on plots 4, 5, 6, 7, and 8 in the spring of 1933. Before the spring crop was seeded in 1933, basic slag was applied to all plots at the rate of 500 pounds per acre.

After the initial manurial treatments in 1932 and 1933, annual applications of 5 tons of manure per acre were made on all plots. In 1934, and also in 1935, the manure was applied at two different periods, 2½ tons per acre before the fall seeding and a like amount before the spring seeding. In 1936 and 1937 the total yearly amount (5 tons) was applied just before either the spring or the fall seeding.

The original plan of applying commercial fertilizers, which was continued through 1934, consisted in the application of 400 pounds of 4–8–4 (N–P–K) fertilizer per acre to a plot when a crop was seeded, and of subsequent applications of sodium nitrate at intervals during the growth of the crop. The time and rate of the nitrogen treatments were governed by climatic conditions and by the apparent need of the plants.

This system was changed after 1934, as recommended by the Office of Soil Fertility Investigations, Bureau of Plant Industry. Since the annual applications of manure probably provided enough available phosphorus and potash for maximum plant growth, it was suggested that additional amounts of these two elements were unnecessary. Investigations at the Sandhill station, where four lysimeter tanks were subjected to the same cropping system and soil management as the experimental grazing plots, had shown that the amount of available nitrogen present in the soil and the amount and distribution of rainfall were the major factors determining the degree of utilization of this element by the plants. Excessive rainfall removed the nitrogen before it could be assimilated; whereas insufficient moisture obviously prevented its utilization. This was the reason for the recommendation to reduce the total amount of phosphorus, potash, and nitrogen applied in the form of a commercial fertilizer at seeding time and to make frequent applications of sodium nitrate during the growing season.

Beginning with the seeding of the spring crop in 1935, and continuing throughout the remainder of the experiment, the quantity of commercial fertilizer applied to a plot when seeding a crop was reduced from 400 pounds to 200 pounds per acre and the formula changed from 4–8–4 to 2–8–4. Applications of nitrogenous fertilizer during the growing season for the crop were made immediately after the grazing cows were removed from the plot. Since the amount applied each time was constant (50 pounds per acre) the total quantity depended upon the number of rotational grazings made on any crop and was from 100 to 150 pounds per acre. After the third grazing and the subsequent application of nitrogenous fertilizer, no further applications were made during the growth of the crop.

System of Crops Used

Different annual crops were planted in succession, in an effort to provide continuous grazing throughout the year.

The principal crop planted for summer grazing was a combination of Biloxi soybeans and pearl millet.

The principal crop planted for fall, winter, and early spring grazing was a combination of frostproof oats, beardless barley, Abruzzes rye, and hairy vetch. Two unit seed mixtures of these crops were tried, as follows:

Mixture 1 consisted of oats, 32; barley, 48; rye, 56; and vetch, 30 pounds per acre.

Mixture 2 consisted of oats, 96; rye, 56; and vetch, 20 pounds per acre.

These rates of seeding probably would be considered excessive in most localities. The need for a thick growth (more plants per unit area) for grazing was the principal reason for heavy seeding.

Mixture 1 was planted for every winter-grazing season except the second. The poor growth of the barley in comparison with the oats during the first season (1932–33) and the low palatability of the vetch had made it seem advisable to omit the barley, increase the amount of oats, and reduce the amount of vetch, so mixture 2 was used the second season (1933–34). The use of mixture 2 did not prove very successful, however, because there was considerable winter-killing of the oats during the severe cold of 1934, and the use of mixture 1 was resumed.

In addition to the foregoing crops, other plants or combination of plants, designated as trial crops, were tried in an effort to find crops more suitable for grazing under the Sandhill conditions or that might be used as supplementary crops to span the interval between the major summer- and winter-grazing crops. The trial crops included a combination of Italian ryegrass and crimson clover for late-spring grazing; pearl millet for summer; lespedeza (common, Tennessee 76, Kobe, and Korean) for late summer; alfalfa for summer and late fall; and corn interplanted with velvetbeans for late fall and early winter. The fertilizer treatments for these crops were the same as already described for the major crops. The results from only the following trial crops are included in this report: Italian ryegrass and crimson clover; pearl millet; and corn interplanted with velvetbeans. The alfalfa and the lespedeza failed to develop proper stands.

Seeding and Cultivation

The nature of the soil in the Sandhill region is such that the preparation of land for a seedbed is usually a minor problem. In this experiment, however, the relatively heavy applications of barn manure, which contain a high percentage of straw, and the stubble remaining on the area after grazing increased the operations necessary to get the soil in a satisfactory condition for seeding.

The general procedure for seedbed preparation was as follows: After the final grazing of any crop, barn manure was spread over the area. The manure and the stubble on the land were cut by means of a disk harrow. The cut material was plowed under and the land redisked, which left the soil in excellent condition for seeding. Immediately before the crops were planted, commercial fertilizer was applied on the area, either by broadcasting it over the land or drilling it in rows, depending on the individual crop. Soybeans and the combination of corn and velvetbeans were the only crops cultivated. The soybeans were cultivated twice, usually within the first month of growth. The rate, time, and method of seeding the crops are shown in table 3.

TABLE 3.—*The rate, time, and method of seeding various crops used in the experiment with annual crops grazed by dairy cattle at the Columbia, S. C. (Sandhill) station, 1933–37* [1]

Class of crop	Average rate of seeding		Time of seeding	Method of seeding
	Seed	Quantity per acre		
		Pounds		
Primary, winter: Combination of oats, barley, rye, and vetch.	Oats	41.6	Late September to early November.	All seeds were mixed and sown as a unit, with a grain drill.
	Barley	48.1		
	Rye	50.0		
	Vetch	22.0		
Trial, winter: Combination of Italian ryegrass and crimson clover.	Ryegrass	40.0	Late October and early November.	Sown independently. The clover seed was broadcast by hand seeder, and immediately followed with ryegrass sown by drill.
	Clover	6.0		
Corn interplanted with velvetbeans	Corn [2]	10.0	Apr. 15 to May 15	Both corn and beans were planted simultaneously in same drill, by means of single row seeder.
	Velvetbeans	30.0		
Primary, summer: Soybeans interplanted with pearl millet.	Soybeans	60.0	Late March to early May.	Planted by means of single-row seeder in rows 2 feet apart. The millet seed was broadcast by hand immediately preceding last cultivation of the soybean plants, except in 1937 when it was seeded in rows.
	Millet	30.0	30 days later	
Trial, summer: Pearl millet alone	Millet	30.0	Early April to late May.	By means of a drill designed for small seeds.

[1] For years and dates each crop was seeded, see table 5.
[2] The corn crop was grazed as uncut stover.

Selection, Management, and Feeding of Grazing Animals

All animals used to graze the annual crops were selected from the registered Guernsey herd maintained at the station. The selection of satisfactory individuals presented a difficult problem throughout, because of the fluctuation in the numbers required on the plots and the relatively few animals available. Usually the cows selected were in moderate to heavy production, and were at least 6 weeks advanced in lactation yet not too far advanced to prevent their completing the grazing season. However, in order that all crops might be grazed to capacity, it was sometimes necessary to use cows well advanced in lactation. Whenever possible the same individuals were used throughout the grazing season.

The grazing of the trial crops was conducted with a mixed group of cattle consisting of cows well advanced in lactation, dry cows, virgin heifers, and bred heifers.

Prior to being placed on the experimental plots, all animals were allowed to graze for several days on crops similar to those in the experiment. During the experimental grazing, cattle were rotated from one plot to another as frequently as was considered necessary to obtain optimum yields. Insofar as possible, available growing material was grazed to capacity, that is, cows were added or removed as the quantity of available grazing varied. This system, of course, could not be followed with the corn and velvetbeans, which were mature before grazing was started.

All experimental animals were driven from the grazing plots to the barn, a distance of 300 yards, and returned at least once daily. The grazing day for all lactating animals averaged about 7 hours, which was divided into two periods—from 7 a. m. to 10:30 a. m. and from 3 p. m. to about 6:30 p. m. These cows were milked three times daily by means of mechanical milkers. At night the milking cows in winter were confined in small individual pens in a pen barn, but in summer they were turned into a dry lot where salt and water were available. All dry cows and heifers were also retained in the same dry lot at night.

The only feed provided in addition to that obtained from the grazing was a concentrate. An experimental mixture with a digestible-protein content of 12.6 percent and a total-digestible-nutrient content of 76.6 percent, was fed until the summer of 1934. After this the regular herd mixture was fed, which averaged 17.7 percent in digestible protein and 72.9 percent in total digestible nutrients. The object was to feed enough grain to the milking cows to maintain their body weight and to prevent an abnormal decline in milk production, and enough to dry cows to maintain their weight or to produce slight gains, and enough to the heifers to promote continuous growth. The lactating cows were fed the supplementary concentrate at the rate of 1 pound daily for each 4 pounds of milk produced. The feed adjustments were made each week. Dry cows and heifers either were fed 2 pounds of grain daily or were restricted to the nutrients obtained from grazing.

ESTIMATING THE RETURNS FROM THE ANNUAL-CROP PLOTS

ESTIMATING THE COMPOSITION AND TOTAL YIELD OF HERBAGE

The yield of herbage and of dry matter produced by the annual-crop plots was estimated by weighing and analyzing the herbage harvested from a small representative area in each plot. The areas were protected from the cattle during the grazing period by portable cages, each covering an area of one one-thousandth of an acre. Immediately before the initial grazing period began on each plot, a cage was placed on an area selected at random, where it remained until the cattle were transferred to another plot. Then the protected area was harvested, by cutting or plucking the herbage, and the cage was moved to another location in the same plot before the next grazing period started.

The herbage was weighed soon after it was harvested, and representative 500-gram samples were retained for determining the chemical composition and dry-matter content. This procedure in harvesting and sampling the herbage in each plot was repeated with each rotation of the grazing cattle.

ESTIMATING THE QUANTITY OF NUTRIENTS OBTAINED BY GRAZING

The quantities of total digestible nutrients obtained from the annual-crop plots by the grazing animals were determined by first calculating the nutrients they required for their maintenance, for their change in weight, and for their production of milk and butterfat, and then deducting from this amount the quantity of nutrients they received in supplementary feeds. This difference was considered the amount of nutrients they obtained from pasture.

The amount of nutrients the cows required for milk production was calculated on the basis of the revised Morrison [3] standard.

The maintenance requirements of each animal were based on the average live weight for the trial. The gain or loss for the entire period was computed as the difference between the initial and the final weights. The initial live weight is the mean of three weights taken on consecutive days during the second week of grazing, and the final weight is the mean of three weights taken on consecutive days at the conclusion of the grazing period. The average live weight

[3] MORRISON, F. B. FEEDS AND FEEDING, A HANDBOOK FOR THE STUDENT AND STOCKMAN. Ed. 20, unabridged, 1050 pp., illus. Ithaca, N. Y. 1936.

for the entire period is the mean of weights taken each week during the trial.

As suggested by Knott and associates,[4] the pasture was credited with 3.5 pounds of digestible nutrients for each pound of gain in weight of cattle and debited 2.7 pounds for each pound lost in weight. Where the yields are presented by weekly periods, the amounts of nutrients required for maintenance, and the amounts involved in changes in live weight, were determined for the entire grazing season and then divided equally among the weekly periods.

The milk production of individual cows was summarized by weekly periods, and butterfat tests were made on samples composited from milk taken one day during the week. The milk and butterfat yields were converted to a 4-percent fat-corrected milk according to the Gaines formula.[5]

ESTIMATING THE COST AND VALUE OF THE NUTRIENTS

The cost of producing 100 pounds of total digestible nutrients in each of the annual crops was calculated on the basis of the total expense required per acre to produce the crop and the quantity of nutrients the cattle obtained by grazing it. The costs of the limestone and basic slag, which were applied at the beginning of the trials, were prorated over the 5-year period. Since a double-cropping system was used, the crop-acre was doubled for each year. In calculating the crop-production costs, the following basic figures were used: Limestone, $6.25 per ton; basic slag, $11.25 per ton; manure, $1.50 per ton; seeds and commercial fertilizers, market price at time of purchase; man-hour, $0.10; mule-hour, $0.15; and tractor-hour, $1.25. Of these items, the rate per hour for man labor is lower than would be paid in many regions. On account of the small units of land used in these experiments, however, the labor, mule, and tractor costs are probably higher than they would be where larger units of land are cropped.

To indicate the value of the system of growing annual crops for grazing, calculations were made to determine how much would have to be paid for a ton of alfalfa hay if the nutrients in the hay were charged at the same rate as the cost of producing their equivalent in the various annual crops. Morrison's data [6] show that an average ton of alfalfa hay contains 1,006 pounds of total digestible nutrients. If the cost of producing 100 pounds of nutrients in one of the annual crops was $3.28, for example, the equivalent feeding value in alfalfa hay would make the hay worth $33 a ton ($10.06 \times \$3.28$).

[4] KNOTT, J. C., HODGSON, R. E., and ELLINGTON, E. V. METHODS OF MEASURING PASTURE YIELDS WITH DAIRY CATTLE. Wash. Agr. Expt. Sta. Bul. 295. 20 pp. 1934.

[5] GAINES, W. L. THE ENERGY BASIS OF MEASURING MILK YIELD IN DAIRY COWS. Ill. Agr. Expt. Sta. Bul. 308, pp. 403–438, illus. 1928.

[6] See footnote 3, p. 11.

EXPERIMENTAL RESULTS WITH ANNUAL CROPS

Observations on the Growth of the Crops and How They Were Grazed

The rotational system was used in grazing the annual crops because it was felt that larger yields of pasturage would be obtained, the grazing season would be extended, and a more uniform supply of grazing would be available. In order to obtain optimum returns from an annual crop it must be grazed at the proper time and rate. Both the growth response of the plants and the grazing characteristics of the cattle are important factors in determining the extent to which the crop can be utilized.

THE WINTER-GRAZING CROPS

Uniform grazing of the combination of oats, barley, rye, and vetch was the most difficult to accomplish. This was due primarily to the rapid growth of the rye in late winter and early spring. When the rapidly growing rye was not grazed to capacity, it headed and subsequently was not consumed by the cattle. This condition was most pronounced when winter was prolonged, followed by a rather sudden change to spring conditons, as was the case in 1934, 1936, and 1937. Oats and barley of the winter crop were later maturing and slower growing than rye; consequently, the control of grazing became easier as the season advanced.

The vetch, which was included in the winter mixture primarily to improve the soil, was not readily grazed by the cattle; but since they would eat it when it was cut and allowed to wilt, the grazing schedule was continued by cutting the estimated amount they would consume daily. The cattle would not eat the cut material until it was completely wilted, however, which was usually the day after it was cut.

The ears were harvested from the corn interplanted with velvetbeans, and the velvetbeans and the corn stover were grazed by the cattle continuously until the crop was consumed. The green leaves of the velvetbeans were consumed before the pods were eaten. As a rule, the cattle refused the pods until after they had been frosted.

The combined crop of crimson clover and Italian ryegrass was very palatable. Though grazing was started rather late on this crop, all the material was entirely consumed.

THE SUMMER-GRAZING CROPS

Soybeans and pearl millet, two crops that are markedly different in their growth characteristics, were almost ideal for summer grazing when grown as a combined crop. Soybeans supplied the principal grazing in early summer, and pearl millet in midseason and late summer. With each rotation less feed was available from the soybeans and more from the pearl millet. Whenever a fourth grazing was possible, the only available forage was the pearl millet.

It was interesting to note the manner in which the cattle grazed this combined crop. When the cows were first turned on the forage, in the years 1933, 1934, and 1935, they consumed all available millet before they started grazing the soybeans. In 1936 and 1937 the order of grazing was reversed, that is, the soybeans were consumed before the pearl millet. It is difficult to explain this change in manner of grazing.

The stage of plant development when grazing was started was about the same each year. The cattle were turned on the crop when the soybeans were 14 to 16 inches high and the pearl millet was in a very early stage of growth. In 1937 the crop was somewhat farther advanced than in previous years, and the rate of growth was retarded by drought.

Yields of Herbage and Dry Matter as Estimated From Harvested Areas

The material harvested from protected areas in each of the annual-crop plots was used to estimate the yields of green forage per acre and of dry matter in the forage, and to furnish samples for chemical analyses. The results of this phase of the study are presented in table 4.

The general change in the composition of all the crops indicates that the plants were more nutritious in the early periods of seasonal growth, as shown by the higher contents of protein, ash, and ether extract, and lower content of crude fiber than in later stages of growth. The crude fiber tended to increase, and the protein, ash, and ether extract to decrease with each successive grazing period for all the crops.

The oats, barley, rye, and vetch combination changed less in composition than any other crop, from grazing period to grazing period, and the dry-matter yield increased progressively with each successive period. The other crops tended to reach their peak in yields at the second grazing period.

Based on the average of all clippings, the pearl millet had the lowest protein, lowest ether extract, and the highest crude-fiber content of all the crops, but also the highest total yields of green matter or dry matter per acre, and the most uniform distribution of the yields throughout the grazing season. When soybeans were planted with the pearl millet, the total yields were lowered considerably and the distribution of the yields was less favorable, but the composition was improved, as indicated by the increased percentage of protein and ether extract and the lower percentage of crude fiber.

The corn stover and velvetbeans showed next to the lowest yield when compared with the other crops. It is pointed out, however, that a considerable amount of ear corn was harvested each year from the corn plants and this is not included in the above yields. The Italian ryegrass and crimson clover combination was low in yield and inferior in composition, as compared with most of the other crops grown at the same time.

TABLE 4.—*The green-matter and dry-matter yields per acre, and the composition of the dry matter, of the annual crops used for grazing dairy cattle, as estimated from clippings or pluckings obtained from caged areas, during the period 1933–37* [1]

SUMMER-GRAZING CROPS

Crop and period of analysis	Acres in crop	Estimated yearly yield per acre		Clipping analyses	Dry matter	Average composition of the dry matter				
		Green matter	Dry matter			Ash	Ether extract	Crude protein	Crude fiber	Nitrogen-free extract
	Number	*Pounds*	*Pounds*	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Soybeans and pearl millet:										
First clipping	......	5,531.2	1,183.7	15	23.31	8.55	3.97	18.15	24.32	45.01
Second clipping	......	5,518.7	1,426.1	14	26.11	7.17	3.81	16.83	27.46	44.73
Third clipping	......	225.0	54.3	3	23.43	8.00	2.71	11.20	29.26	48.73
Total or average	32	11,274.9	2,664.1	32	24.54	7.89	3.78	16.93	26.16	45.23
Pearl millet:										
First clipping	......	5,522.2	1,014.2	8	19.83	9.84	3.33	12.53	29.78	44.52
Second clipping	......	7,700.0	1,523.3	7	20.81	8.78	2.95	8.86	32.05	47.36
Third clipping	......	3,611.1	744.1	5	20.47	8.34	2.48	8.59	32.60	47.98
Fourth clipping	......	444.4	113.3	1	25.49	6.72	2.66	7.09	30.45	52.47
Total or average	18	17,277.7	3,394.9	21	20.58	8.98	2.97	10.14	31.24	46.67

WINTER-GRAZING CROPS

Crop and period of analysis	Acres in crop	Green matter	Dry matter	Clipping analyses	Dry matter	Ash	Ether extract	Crude protein	Crude fiber	Nitrogen-free extract
Corn stover and velvetbeans:										
First clipping	......	6,767.0	1,686.0	3	25.46	5.47	3.01	16.58	23.99	50.95
Total or average	6	6,767.0	1,686.0	3	25.46	5.47	3.01	16.58	23.99	50.95
Oats, barley, rye, and vetch:										
First clipping	......	2,553.6	477.1	13	19.69	9.13	5.26	18.51	22.55	44.56
Second clipping	......	4,055.7	836.6	14	20.42	7.68	4.03	16.12	26.61	45.59
Third clipping	......	4,242.8	946.4	12	22.39	7.26	3.67	17.07	29.97	44.05
Fourth clipping	......	792.9	328.3	3	41.41	5.16	3.21	15.29	26.42	40.94
Total or average	28	11,645.0	2,588.4	42	22.25	7.83	4.25	17.07	25.73	45.14
Italian ryegrass and crimson clover:										
First clipping	......	1,564.0	486.0	5	34.92	8.67	4.74	11.60	23.79	51.22
Second clipping	......	1,260.0	410.8	3	34.50	7.59	4.04	11.35	25.60	51.42
Third clipping	......	118.0	48.2	1	40.93	8.40	4.41	13.98	33.25	39.98
Total or average	10	2,942.0	945.0	9	35.45	8.28	4.47	11.78	25.44	50.04

[1] For number of years each crop was included in the experiment, see table 5.

YIELDS OF NUTRIENTS AS ESTIMATED BY GRAZING

Results from the grazing of annual crops with dairy cattle in this experiment are presented in tables 5 and 6. Table 5 is a general summary of the yearly results from various crops. The data include period of grazing, supplementary feeds, milk and butterfat production, changes in live weight, nutrients required, percentage of nutrients supplied by supplementary feeding, and nutrients credited to each crop. Table 6 shows the distribution of the yields of nutrients by crops, by years, and by months.

TABLE 5.—*Yearly data showing period of grazing, supplementary feed, milk and butterfat production, nutrients required by cows, and nutrients credited to each crop*

SUMMER CROPS

Crop and year	Period of grazing			Cow-days per acre	Heifer-days per acre	Supplementary feed per acre			Production per acre		Gain (+) or loss (−) in live weight per acre		Digestible nutrients required per acre				Proportion of total nutrient requirements supplied in supplementary feeds per acre		Digestible nutrients credited to crop per acre
	Date begun	Date ended	Days			Concentrates eaten by cows	Concentrates eaten by heifers	Hay eaten by cows	4 percent fat-corrected milk	Butterfat	Cows	Heifers	For maintenance	For milk production	For change in live weight	Total			
			No.			*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*
Soybeans and pearl millet:																			
1933	June 14	Oct. 31	140	67	0	429	0	0	1,918	88.6	+30	0	525	621	108	1,254	328	26.2	926
1934	June 20	Oct. 17	[1] 106	90	0	565	0	0	2,412	101.8	+47	0	689	781	163	1,633	441	27.0	1,192
1935	June 12	Oct. 9	119	109	0	828	0	0	3,093	110.7	+34	0	842	1,002	125	1,969	608	30.9	1,361
1936	July 1	Oct. 6	98	95	0	734	0	0	2,918	125.4	+48	0	720	946	202	1,868	535	28.6	1,333
1937	June 23	Oct. 5	105	101	0	754	0	[2] 39	2,940	126.8	+16	0	815	953	63	1,831	568	31.0	1,263
Average	June 20	Oct. 13	114	92		662			2,656	112.5	+35		718	861	132	1,711	496	28.7	1,215
Pearl millet:																			
1934	June 6	Sept. 29	116	[3] 99	32	213	0	0	905	38.5	+34	+15	1,087	293	171	1,551	163	10.5	1,388
1935	June 12	Oct. 14	[1] 116	0	160	0	320	0	0	0	0	+169	1,052	0	590	1,642	226	13.8	1,416
1936	June 25	Sept. 18	86	[4] 43	67	86	133	0	0	0	+23	+34	868	0	259	1,127	168	14.9	959
1937	June 9	Oct. 2	116	171	28	0	0	0	0	0	+138	0	1,419	0	496	1,915	0	0	1,915
Average	June 13	Oct. 1	109	78	72	75	113		226	9.6	+49	+55	1,107	73	379	1,559	130	9.8	1,420

FALL-WINTER-SPRING CROPS

Oats, barley, rye, and vetch:																			
1933	Jan. 18	May 31	[1] 128	45	0	280	0	16	1,394	60.7	+20	0	357	452	69	878	222	25.3	356
1934	Jan. 11	May 9	[1] 71	57	0	315	0	24	1,325	58.0	−10	0	430	430	[5] 24	836	253	30.3	583
1935	Jan. 9	May 7 [6]	[1] 140	69	0	451	0	[7] 139	1,884	81.4	+21	0	490	610	79	1,179	378	32.1	801
1936	Mar. 1	May 11	[1] 64	54	0	306	0	0	1,197	52.0	+7	0	447	388	19	854	230	26.9	624
1937	Jan. 14	May 27	[1] 86	52	0	291	0	0	1,158	52.4	+25	0	408	375	100	883	221	25.0	662
Average	Jan. 22	May 17	99	55		329			1,392	60.9	+13	...	426	451	49	926	261	27.9	665
Italian ryegrass and crimson clover:																			
1935	Apr. 3	May 28	[1] 35	21	20	119	41	0	538	22.4	0	0	275	174	0	449	122	27.2	327
1936	Apr. 29	May 11	12	18	0	114	0	0	498	21.5	−31	0	144	161	[5] 86	219	83	37.9	136
Average	Apr. 16	May 20	24	20		117			518	22.0	−15		210	168	[5] 43	334	103	32.6	231
Corn stover and velvetbeans:																			
1935	Oct. 9	Nov. 12	35	18	0	172	0	0	607	26.4	−10	0	154	197	[5] 26	325	125	38.5	200
1936	Oct. 28	Dec. 25	[1] 55	41	0	344	0	[8] 374	1,187	54.1	+37	0	297	384	129	810	329	40.6	481
1937	Nov. 3	Mar. 2 [9]	119	74	0	466	0	0	1,456	67.5	+75	0	559	472	262	1,293	334	25.8	959
Average	Oct. 23	Dec. 30	70	44		327	...	...	1,083	49.3	+34	...	337	351	122	809	263	35.0	546

[1] Grazing was not continuous.
[2] Beet pulp.
[3] Milking cows advanced in lactation and dry cows.
[4] Dry cows.
[5] Deduction.
[6] 1935 spring grazing concluded May 7 and autumn grazing of new crop Dec. 17.
[7] 105 pounds of silage and 34 pounds of hay.
[8] Corn and soybean silage.
[9] 1938.

TABLE 6.—*The distribution of yields of digestible nutrients obtained per acre from rotational grazing of annual crops, by months, 1933–37*

ORIGINAL CROPS

Crop and month	1933		1934		1935		1936		1937		Yearly average	
	Period of grazing	Total digestible nutrients per acre	Period of grazing	Total digestible nutrients per acre	Period of grazing	Total digestible nutrients per acre	Period of grazing	Total digestible nutrients per acre	Period of grazing	Total digestible nutrients per acre	Period of grazing	Total digestible nutrients per acre
Winter and spring—oats, barley, rye, and vetch:	*Days*	*Lb.*	*Days*	*Lb.*	*Days*	*Lb.*	*Days*	*Lb.*	*Days*	*Lb.*	*Days*	*Lb.*
January	13	92.0	14	84.0	23	122.3			14	74.3	13	74.7
February	25	118.6	7	31.5	14	63.9					9	42.8
March	31	159.1	11	84.8	31	223.0	31	304.6	15	96.9	24	173.8
April	30	136.6	30	298.6	30	200.5	28	275.4	30	250.4	30	250.3
May	31	148.7	9	82.5	7	40.3	5	41.1	27	233.0	16	109.1
November [1]					18	33.5					4	6.7
December [1]					17	26.9					3	5.4
Summer and fall—soybeans and pearl millet:												
June	17	108.4	11	94.3	19	148.7			8	64.4	11	83.2
July	31	233.7	17	125.2	31	294.6	31	323.2	31	499.7	28	295.3
August	31	222.1	31	424.2	31	411.0	31	401.1	31	354.8	31	380.6
September	30	210.6	30	356.2	30	417.7	30	448.5	30	291.2	30	344.9
October	31	152.1	16	186.6	8	91.4	6	73.7	5	50.9	13	111.3

TRIAL CROPS

Crop and month	1933		1934		1935		1936		1937		Yearly average	
Winter and spring—Italian ryegrass and crimson clover:												
April					14	97.9	2	36.6			8	67.3
May					21	232.0	10	90.2			16	165.6
Summer and fall—pearl millet:												
June			25	207.9	19	222.5	6	54.7	22	327.7	18	218.2
July			31	277.2	22	306.4	31	287.5	31	612.3	29	370.0
August			31	339.3	31	394.0	31	396.5	31	618.2	31	437.0
September			29	496.9	30	333.3	18	220.6	30	334.3	27	346.3
October					14	157.6			2	22.3	4	45.0
Fall and winter—corn stover [2] and velvetbeans:												
October					23	132.1	4	41.2			9	57.8
November					12	66.8	30	278.1	27	186.5	23	177.1
December							21	164.4	31	220.2	17	128.2
January [3]									31	282.1	10	91.0
February [3]									28	258.6	9	86.2
March [3]									2	11.7	1	3.9

[1] Same calendar year but different crop year.
[2] Ears husked from stalks in the field.
[3] Year 1938.

It is obvious that the seasonal yields of nutrients by the summer-grazing crops were considerably greater than those by the winter-grazing crops. Both the relative length of season and rate of growth contributed to these differences. With the time factor as a unit for all crops, the yields of total digestible nutrients per acre per day were as follows: Soybeans and pearl millet, 10.66 pounds; pearl millet alone, 13.03; oats, barley, rye, and vetch, 6.72; Italian ryegrass and crimson clover, 9.62; and corn stover and velvetbeans, 7.80. The two summer-grazing crops (soybeans and pearl millet), which provided grazing at the same time, were slightly different in yield. Pearl millet alone produced somewhat greater yields than when it was combined with soybeans (table 6).

With the exception of the crops of crimson clover and Italian ryegrass, the annual grazing in nearly all cases produced slight increases in live weight of the cattle (table 5).

The average daily yield of 4-percent fat-corrected milk per cow was 28.9 pounds for soybeans and pearl millet, 25.3 for oats, barley, rye, and vetch, 25.9 for Italian ryegrass and clover, and 24.6 for corn stover and velvetbeans. However, this variation in milk yields cannot be attributed entirely to the grazing crops, since there were differences in seasons, length of grazing periods, and some difference in stage of lactation of the cows when grazing the several crops.

The yields of total digestible nutrients that were credited to the various crops by the grazing results (table 5) are not entirely consistent with the yields indicated by the dry-matter content of the herbage that was clipped from the protected sample areas in each crop (table 4). In all cases, the yields of nutrients indicated by the clipped material are higher than the yields indicated by the grazing results. This is logical, but the differences in the yields indicated by the two methods are considered too wide for the oats, barley, rye, and vetch combination, and also for the Italian ryegrass and crimson clover combination. There are probably two reasons why the yields indicated by the grazing results are so much lower. In the case of the oats, barley, rye, and vetch, the herbage grew so rapidly near the end of the season that the cows were unable to graze all of it before it became too mature and unpalatable. Also, there was probably some loss of nutrients caused by the practice of mowing the vetch and wilting it so the cows would eat it more rapidly. The growth of Italian ryegrass and crimson clover came on very rapidly also, and a considerable portion of the ryegrass became too mature and unpalatable before the end of the grazing period.

Variations in Yields of Nutrients by Years and Months

The yearly variations in yields of nutrients from grazing the various crops are shown in table 5, and the monthly variations by years are presented in table 6.

Two of the most important causes of variations in crop yields are temperature and moisture conditions. In this experiment, the importance of the amount and distribution of rainfall (table 2) is evident, especially when the nature of the soil is considered. The open, porous soil does not retain moisture well and permits excessive leaching by rains. Also when a crop is growing rapidly, an interval of several days without rain may seriously retard the rate of growth. Seasonal and monthly variations of temperatures affect not only the length of the growing period of each crop (table 5) but also the rate of growth (table 8). With winter crops, periods of warm weather during December, January, and February stimulated growth sufficiently to provide some grazing, but maximum monthly growth of these crops was not attained until after the last killing frost in the spring (table 1).

THE WINTER-GRAZING CROPS

In 1933, the yield of nutrients by the winter-grazing crop (oats, barley, rye, and vetch) varied relatively little from month to month (table 6), and the yield for the year was about average (table 5). However, as a result of the low rainfall in April, the yield that month was low in comparison with the yields for the same month of other years.

In 1934 the extremely low temperatures during the winter months severely damaged the grazing crop. As previously stated, barley had been replaced in the seed mixture by an increased amount of oats for this year. Approximately 75 percent of the resulting oat plants were killed by the low temperatures, and grazing was then limited largely to rye. With the change to favorable weather conditions, the growth of the rye was so rapid that it was impossible to graze this one available material adequately. The ultimate result was a short grazing season, inferior grazing, and a consequent low yield.

In sharp contrast to 1934 unusually favorable climatic conditions in 1935 resulted in a high yield from the winter and spring grazing.

In 1936 unfavorable temperatures in the early part of the year and a shortage of moisture in the spring, resulted in an abbreviated grazing period. Only during 2 months was there an abundance of grazing available from the oats, barley, vetch, and rye. The effect of deficiency of moisture was also shown in the low yields of the crimson clover and Italian ryegrass crop.

Moisture conditions in 1937 were suitable for the development of the winter-grazing crops, but the grazing season was relatively short. As a result the seasonal yield was somewhat below average, except for the corn and velvetbeans, which crop obviously had been grown during the summer.

THE SUMMER-GRAZING CROPS

In the early summer of 1933, low rainfall uniformly distributed was favorable to the development of the summer-grazing crops; but during the latter part of the season, a deficiency of moisture greatly retarded growth. Thus the yield of soybeans and pearl millet was decidedly low for the season.

The early growth of the summer-grazing crops of 1934 was retarded by insufficient moisture, but later in the season the growth was greatly accelerated by more favorable conditions and the yields for the year were only slightly below the average for all years.

Favorable climatic conditions prevailed throughout 1935. Therefore an abundance of good-quality grazing material in summer and fall was available from pearl millet and pearl millet combined with soybeans. Though the combination of corn and velvetbeans is considered a fall-grazing crop, the growth and consequent yield are largely determined by summer conditions. The yields of both harvested corn and remaining grazing material were extremely low in 1935 as a result of destruction by army worms. The yield of harvested corn was only 7 bushels per acre in comparison with a 3-year average of 15 bushels.

Periods of drought during the growing season of 1936 greatly reduced the yields of pearl millet, which crop seems to be very susceptible to changes in moisture conditions.

During the summer months of 1937, moisture conditions were suitable for optimum growth of crops. However, conditions were unique in that yields of the summer crops reached their peak early in the grazing season. The high yield of harvested corn (22.4 bushels per acre) and the large returns from grazing the corn fodder and velvetbeans, are further indications of the effects of the favorable seasonal conditions of 1937.

Distribution of Grazing From the Annual Crops

One of the principal objects of this investigation in grazing annual crops was to develop a system that would supply continuous grazing throughout the year. The extent to which continuous grazing was attained is indicated in table 5. The nearest approach during the 5 years of investigation was in 1935, when continuous grazing was available for a total of 315 calendar days, as shown graphically in figure 4.

For the entire 5-year period, the number of calendar days of available grazing obtained with all crops averaged between 250 and 260 per year. Considering the crops independently, the number of days grazed annually were as follows: Oats, rye, barley, and vetch, range 64 to 140, average 99; Italian ryegrass and crimson clover, range 12 to 35, average 24; soybeans and pearl millet, range 98 to 140, average 114; pearl millet alone, range 86 to 116, average 109; and corn stover and velvetbeans, range 35 to 119, average 70. Since several of these crops were grazed simultaneously, grazing was not available throughout the year.

As a rule the grazing of the primary winter-grazing crop (oats, barley, rye, and vetch) was started about the middle of January and continued to the middle of May. The maximum growth was usually early in April. Obviously, the amount of early grazing from this crop was determined by climatic conditions. The temperatures during the early development of the crop usually were sufficiently high to afford limited grazing in January and February. Grazing was interrupted occasionally by unfavorable growth conditions.

Italian ryegrass and crimson clover was a trial crop designed to span the interval between the primary winter-grazing crop and the principal summer-grazing crop, soybeans and pearl millet. This trial crop supplied some grazing in April and May. Since both Italian ryegrass and crimson clover are seriously affected by high temperatures, the period of growth for this crop was very limited.

The summer-grazing crops, a combination of soybeans and pearl millet or pearl millet alone, supplied grazing from the middle of June to the first part of October. The stage of maximum production was usually during the latter part of August.

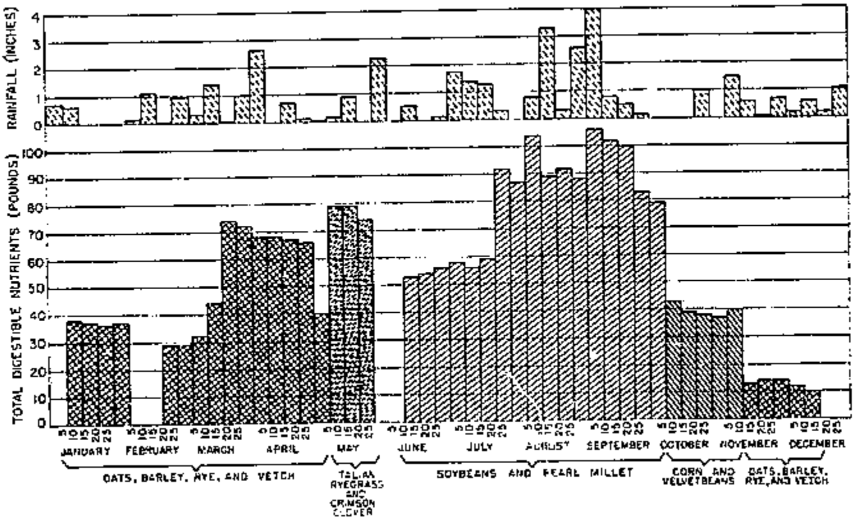

FIGURE 4.—Weekly distribution of rainfall and of calculated yields of digestible nutrients obtained per acre by grazing annual crops during 1935.

Corn stover and velvetbeans, another trial-crop combination, was utilized during the interval between summer- and winter-grazing crops. The crop was mature before grazing was started; therefore, the period of grazing was determined by the total amount available and the rate of stocking. After the corn was husked, usually by the last of October, either grazing was started immediately or the crop was reserved until needed.

Cost of Producing the Nutrients Obtained by Grazing

The itemized amounts of labor and power, seeds, and fertilizer, and the calculated costs of the annual crops used in this grazing experiment, are given in table 7. No credit was given for crop residues plowed under. An average of 15 bushels of ear corn was harvested

TABLE 7.—*Average yearly amounts per acre and costs per acre of the labor, seeds, and fertilizer used for the annual crops in grazing experiment at the Sandhill dairy farm*

Crop	Labor and power per acre: Man labor, Amount	Man labor, Cost	Mule labor, Amount	Mule labor, Cost	Tractor operation, Amount	Tractor operation, Cost	Total cost	Seeds per acre: Kind	Amount, By measure	Amount, By weight	Cost	Total cost
	Man-hours	*Dollars*	*Mule-hours*	*Dollars*	*Tractor-hours*	*Dollars*	*Dollars*		*Bushels*	*Pounds*	*Dollars*	*Dollars*
Oats, barley, rye, and vetch	13.0	1.30	9	1.35	2.5	3.13	5.78	Oats	1.3		1.77	6.94
								Barley	.8		1.17	
								Rye	1.0		1.59	
								Vetch		22.0	2.41	
Italian ryegrass and crimson clover	12.0	1.20	8	1.20	1.0	1.25	3.05	Ryegrass		40.0	2.00	2.90
								Clover		6.0	.90	
Soybeans and pearl millet	35.0	3.50	32	4.80	1.4	1.75	10.05	Soybeans	1.0		2.17	4.33
								Millet		30.0	2.16	
Corn interplanted with velvetbeans	40.0	4.00	25	3.75	1.0	1.25	9.00	Corn		10.0	.18	.87
								Velvetbeans		30.0	.69	
Pearl millet	17.0	1.70	12	1.80	1.5	1.88	5.38	Millet		30.0	2.16	2.16

Crop	Fertilizer and manurial treatment per acre: Limestone, Amount	Limestone, Cost	Basic slag, Amount	Basic slag, Cost	Manure, Amount	Manure, Cost	Complete commercial fertilizer, Amount	Complete commercial fertilizer, Cost	Nitrogen fertilizer, Amount	Nitrogen fertilizer, Cost	Total cost	Total cost per acre
	Pounds	*Dollars*	*Pounds*	*Dollars*	*Tons*	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*	*Dollars*	*Dollars*
Oats, barley, rye, and vetch	200	.63	50	.28	3	4.50	267	2.10	100	1.58	9.09	21.81
Italian ryegrass and crimson clover	200	.63	50	.28	3	4.50	200	1.58	100	1.58	8.57	15.12
Soybeans and pearl millet	200	.63	50	.28	3	4.50	288	2.27	89	1.41	9.09	23.47
Corn interplanted with velvetbeans	200	.63	50	.28	3	4.50	200	1.58	114	1.81	8.80	18.67
Pearl millet	200	.63	50	.28	3	4.50	255	2.01	114	1.81	9.23	16.77

before the corn and velvetbean crop was grazed. In determining the cost of this crop for grazing, the harvested corn was credited with a net value of 60 cents per bushel.

The labor and power costs were considerably higher for the combination of soybeans and pearl millet and the combination of corn stover and velvetbeans, chiefly because of the greater amount of man and mule labor used, than for the other crops. On the other hand, the seed costs were much higher for the mixture of oats, barley, rye, and vetch, because of the high rate of seeding employed (table 3) and because of the comparatively high prices paid to get choice seed. As a matter of fact, the cost of seeds amounted to over 30 percent of the total cost of growing this crop. The seed cost for the corn stover and velvetbeans was remarkably low. The labor, power, and seed costs for soybeans and pearl millet were approximately double what they were for the pearl millet alone. This is reflected in the relative low costs per 100 pounds of total digestible nutrients in the pearl millet.

Table 8 shows the cost of producing 100 pounds of total digestible nutrients in each of the annual crops. These calculations were based on the total production costs per acre (table 7) and the quantities of nutrients obtained per acre by the grazing cattle (table 5).

TABLE 8.—*Cost of producing 100 pounds of total digestible nutrients in each of the annual crops, and the comparative value of a ton of alfalfa hay*

Crop	Cost per acre	Cost per 100 pounds of total digestible nutrients [1]	Comparative value of a ton of alfalfa hay [2]
	Dollars	*Dollars*	*Dollars*
Primary:			
Oats, barley, rye, and vetch	21.81	3.28	33.00
Soybeans and pearl millet	23.47	1.93	19.42
Trial:			
Italian ryegrass and crimson clover	15.12	6.55	65.89
Pearl millet	16.77	1.18	11.87
Corn stover and velvetbeans	[3] 9.67	1.77	17.81

[1] As from grazing—see table 5.
[2] The 1,006 pounds of total digestible nutrients in a ton of alfalfa hay were valued at the same rate as in the annual crops.
[3] This crop was given a yearly credit of $9 per acre for an average of 15 bushels of corn harvested by hand before grazing started.

Figures are also included in table 8 to show what a ton of alfalfa hay would be worth if the nutrients in the hay were figured at the same price per 100 pounds as the cost of producing the nutrients in the various annual crops. For example, alfalfa hay contains 1,006 pounds of total digestible nutrients and if the nutrients are valued at the same price as the cost of producing 100 pounds in the oats, barley, rye, and vetch combination, the value of a ton of alfalfa hay ($10.06 \times \$3.28$) would be $33. If the hay could be obtained for less than $33 a ton, it would appear to be more economical to buy alfalfa hay than to grow this particular annual crop; and if the hay cost more than $33, it would appear to be more economical to grow the annual crop.

Of course, other factors may need to be considered in deciding whether to grow any of these annual crops or to buy alfalfa hay or other feed instead, but these calculations based on average costs and yields of the annual crops at the Sandhill station over a period of years can be used as a guide for those located on similar soils in this region.

Discussion of Results With Annual Crops

One of the main objects of the pasture program at the Sandhill station is to determine whether a system of crops can be devised that will supply adequate grazing for dairy cattle throughout the year, under conditions similar to those at this station. The results of this experiment indicate that the extent to which this may be accomplished by growing a succession of annual crops on heavily fertilized plots, depends on the crops selected, their total and seasonal yields, the degree to which they are utilized by the animals, and the weather conditions.

In this investigation, the most favorable series of crops for this purpose proved to be the combination of oats, barley, rye, and vetch for winter and early-spring grazing, either a combination of soybeans and pearl millet or pearl millet alone for summer and early-fall grazing, and corn interplanted with velvet beans for fall grazing.

The choice between using pearl millet alone or in combination with soybeans for summer and fall grazing seems to be in favor of the former when results are measured in terms of yields and cost of production. Measured on the basis of chemical composition, however, the combined crop is preferable.

The combination of crimson clover and Italian ryegrass is not to be recommended, primarily because its susceptibility to hot weather causes it to mature so early or so rapidly in the spring that grazing is available for only a relatively short time, and also because of the high cost of producing nutrients with this crop under the conditions prevailing in the Sandhill region.

The crop of corn and velvetbeans produced considerable corn which was harvested and utilized independently of the grazing. This introduces the possibility of selecting crops that not only supply grazing but also yield considerable seed, which may be utilized either for reseeding or as a source of cash income.

The yields of nutrients obtained by grazing the annual crops in this investigation, varied considerably from year to year. Paramount among the factors affecting yields are the climatic conditions, temperature, and rainfall. Other factors that affect yield, and which may be controlled to a certain extent, include the use of commercial fertilizers or barn manure or both, the control of insects, time and method of seeding, cultivation methods, and the system and rate of grazing.

Closely related to the total yield of nutrients is the distribution throughout the year. The best distribution of yields was obtained in 1935. (See fig. 4.) Throughout this investigation, the average daily yield of total digestible nutrients per acre was 6.72 pounds over a period of 99 days for oats, barley, rye, and vetch; 9.62 pounds over a period of 24 days for crimson clover and Italian ryegrass; 10.66 pounds over a period of 114 days for soybeans and pearl millet; 13.03 pounds over a period of 109 days for pearl millet; and 7.80 pounds over a period of 70 days for corn stover and velvetbeans. Since the latter crop was mature before grazing started, the distribution was determined largely by the rate of grazing. In this system of annual crops the days of available grazing ranged from about 195 in 1934 to 315 in 1935, a difference of 120 days due primarily to weather conditions.

With such a system of annual crops, the distribution of the grazing also may be regulated partly by the dates of seeding the crops. Hot, dry weather in September would be hazardous to early seeding of winter-grazing crops, which grow very little before cool weather of November. Thus it is probable that late seeding, in January or early February, of part of the winter-grazing crop would extend the spring grazing. Pearl millet, a hot-weather plant that generally is ready for grazing about 30 days after seeding, is usually sown between early April and late May. A second seeding of pearl millet in July or early August would extend the summer grazing. The same procedure may be followed with soybeans also. As a precautionary measure against loss of grazing from destruction of the forage by army worms, it is advisable to plant the combined crop of corn and velvetbeans not later than the middle of May.

Another important phase of grazing annual crops efficiently is the problem of complete utilization, especially when growth is greatly accelerated. The growth of rye, as noted in the experimental results, was so rapid during early spring that the cattle could not graze it completely at the proper time and much of it became unpalatable and remained unutilized. In order to reduce this loss more intense grazing at certain seasons would be desirable.

Observations indicate that when milking cows only are used in grazing these annual crops, the milk production decreases rather rapidly before the crop has been utilized completely. If the milking cows, after grazing the more palatable and succulent parts of the plants, were followed with heifers and dry cows in the rotation to consume the less nutritious parts of the plants, as in the Hohenheim system, it is possible that more available grazing would be obtained and milk production would be maintained at a higher level.

More intense grazing with more frequent rotation of the cattle might also result in better utilization of the crops. The need for rapid grazing is more acute during spring or summer when growth of the plants is most vigorous. With the use of the electric fence for temporary fencing, the adjustment of the rotation area to the number of grazing animals is greatly facilitated.

In the final analysis, the primary factor that will determine whether or not annual crops are to be grown for grazing in the Sandhill region is the cost of producing the nutrients. The various items involved in the cost of producing these annual crops were high, particularly the cost of the labor items though labor was cheap. This was because frequent plowing and planting was necessary. Operating on a larger scale would probably reduce these costs somewhat.

When the nutrients obtained by grazing the annual crops were converted to their equivalent feeding value in alfalfa hay, a standard roughage of known market value, the costs of production for several of the crops (table 8) were very high. This is especially true of the primary winter-grazing crop (oats, barley, rye, and vetch), for which the cost of production was the same as paying $33 for a ton of alfalfa hay. In contrast, one of the summer trial crops, pearl millet, had an average cost that was equivalent to paying $11.87 for a ton of alfalfa hay. Next in order was the cost of the grazing obtained from the corn and velvetbean crop, which yielded considerable harvested corn with a net value that was deducted from the total cost of production. It would seem that the costs of most of these annual crops are too high to make grazing feasible, especially when an effort is made to grow a succession of crops on the same land.

In order to obtain more economical returns from annual crops, it would seem necessary to use crops that can be grazed in the early stages and then be allowed to produce seed crops. The use of crops that will reseed themselves, such as the bur-clovers and certain vetches, is being tried. This would mean that more acreage would have to be used, but it would eliminate seed costs and much cultivation. At current values for land in the Sandhill region it appears to be more economical to use a greater acreage, with perhaps only one crop per year, than to attempt to obtain a succession of crops on the same acreage. Elimination of grazing crops that require row planting and subsequent cultivation may also reduce the labor costs. This is one item that increased the cost of the nutrients from the crop of soybeans and pearl millet in this experiment.

There are indications that some crops that are grazed more or less continuously, when used for temporary pasture, do not produce as great a total yield of nutrients as they will if permitted to reach a stage of growth approaching maturity before they are harvested. If this should prove to be the case at the Sandhill station, it would seem desirable in raising feed for the herd at this station, on typical Sandhill soil, to ensile those annual crops that can be produced at the least cost and that produce the most desirable nutrients for milk production.

There is evidence that a grazing system which affords green feed throughout much of the year will result in better health in the animals as well as enabling them to produce milk of higher nutritive value, particularly during the winter season when cows would usually be on dry feeds that are likely to be deficient in carotene. Also the frequent plowing and cultivation of land planted to a succession of annual crops for grazing, should be an effective means of controlling weeds, especially wild onions and bitter weeds, the flavors of which are transmitted to the milk. However, should it prove that annual crops will yield enough more when permitted to mature before harvesting to make it more feasible to ensile than to graze such crops, there is no known reason why cows will not retain their health on rations containing large proportions of silage. Certainly legumes that are properly ensiled will contain sufficient carotene to enable the cows consuming it to produce milk of good color. Recent experiments also indicate that weed seeds are killed for the most part by the ensiling process.

GRAZING EXPERIMENT WITH PERMANENT PASTURE

The general plan of the permanent-pasture grazing experiment was the same as for the experiment with the annual grazing crops, except that the grazing trials, which covered the 5-year period 1933–37, were confined to a 6-acre area within the general 60-acre permanent pasture that had already been established at the Sandhill station.

The development of the permanent pasture, and the cost, will be presented; also the procedure used in estimating the returns from the 6-acre experimental grazing area. Additional data on the development and cost of the permanent pasture will be given in connection with the experimental results, in pages 35 to 37.

Development of the 60-Acre Permanent Pasture

TOPOGRAPHY AND SOIL TYPE

In topography the land on which the 60-acre permanent pasture was developed is a combination of low hills and bottom land. Approximately one-third of the pasture consists of lowlands and the remainder of hillsides. In the lower places along the hillsides and in the bottoms there are many fresh-water springs with outlets near the surface. The continuous seepage provides an abundance of moisture in the immediate area. The two extremes of topography and moisture conditions are typical of much of the area that is best adapted for pasture development in the Sandhill region. The soil types are coarse Norfolk sand on the hillsides and some Hoffman sandy loam in the lowlands.

CLEARING, SEEDING, AND FERTILIZING THE LAND

Previous to the conversion of the 60-acre area into permanent pasture, virgin forests were growing on the soil. In the winter of 1927–28 all woodland growth was cleared off and in the early spring of 1928 the soil was prepared for seeding and fertilizing. Commercial fertilizer (4–8–4) was applied at the rate of 450 pounds per acre, and the following seed mixtures were sown at the rate of one unit mixture per acre:

	Pounds
Lowland pasture, unit mixture:	
Common lespedeza (*Lespedeza striata*) (Thunb.) H. and A.	23
Carpet grass (*Axonopus compressus* (Swartz) Beauv.)	8
White Dutch clover (*Trifolium repens* L.)	3
Total	34

	Pounds
Upland pasture, unit mixture:	
Common lespedeza	20
Bermuda grass (*Cynodon dactylon* (L.) Pers.)	8
Total	28

After the general seeding, 12 pounds of Dallis grass (*Paspalum dilatatum* Poir.) was sown at random over the lowland area.

Since germination and growth were not satisfactory for the 1928 season, the 60-acre area was refertilized and reseeded in the spring of 1929. The rate of application of fertilizer was increased to 500, that of the seed mixture used on lowland areas to 40, and that of the mixture used on the upland areas to 30 pounds per acre.

The sod developed considerably in 1929, but improved very little during the following 2 years. In 1931 and each year thereafter 300 pounds of 4–8–4 fertilizer was applied per acre and, in 1932, 1,500 pounds of dolometic limestone was applied per acre.

In the spring of that year, additional efforts were made to improve the sod on upland pasture by seeding methods. Bermuda grass roots from native stock were distributed at about 3-foot intervals in rows 3 feet apart. The area was also reseeded with 20 pounds of common lespedeza and 5 pounds of Dallis grass per acre. Hop clover (*Trifolium procumbens* L.) was sown at the rate of 4 pounds per acre on 6 acres of the lowland in an effort to obtain early grazing.

GROWTH OF THE PASTURE PLANTS

Seasonal conditions in 1929 were almost ideal for the growth of pasture plants; consequently, a good sod developed. The sod improved only slightly in 1930 and 1931, because of the low rainfall which was poorly distributed. The retarded growth was especially noticeable on the upland areas. In the lowlands, where water seepage areas were abundant, pasture plants were not markedly arrested in growth.

The lespedeza failed to thrive on the ridges and hillsides. Apparently this failure was due to the shallow root system of the plants, which lowered their resistance to drought, especially in the early stages of growth. During periods of extended drought, nearly all the lespedeza plants on the elevated areas died. The Bermuda grass survived, although it made only slight growth under adverse climatic conditions, particularly during droughts. The Bermuda grass sod developed from native roots was superior to that developed from domestic seed.

In the lowlands the growth of white Dutch clover was rather sparse. The grazing was primarily from lespedeza and grasses, which were rather late, and grazing was not available until late spring or early summer. As stated previously, hop clover was introduced to provide early grazing.

The cost of developing the permanent pasture, including all labor and materials for clearing the land, draining, preparing the seedbed, seeding and fertilizing in 1928, reseeding and fertilizing in 1929, and fencing, was $41.28 per acre.

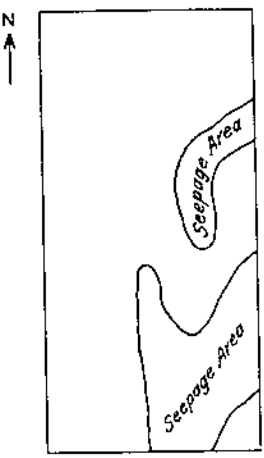

FIGURE 5.—Lay-out of the 6-acre experimental grazing area within the permanent pasture, showing the swampy portions.

EXPERIMENTAL GRAZING AREA WITHIN THE PERMANENT PASTURE

The lay-out of the 6-acre area selected for the grazing experiment is shown in figure 5, and the topography of the general pasture is shown in figure 6.

Of the 6 acres, 4.33 were pasture sward that afforded grazing, and 1.67 was exceedingly swampy ground on which unpalatable weeds, grasses, and small bushes were growing. Approximately one-third of the 4.33 acres was lowland and the remainder was hillside.

In addition to the seedings described previously, two prospective grasses, Japanese lawngrass (*Zoysia japonica* Steud.) and centipede grass (*Eremochloa ophiuroides* (Munro) Hack.), that had been grown previously in trial gardens [7] were planted on a small area of the 6-acre experimental grazing section in 1932. Both grasses grew slowly but they gradually developed dense sods and suppressed the development of other grasses. Since the cattle grazed the Japanese lawngrass only sparingly, this little area was excluded from the experimental grazing in 1937.

Thus the pasture plants on the experimental area consisted of Bermuda grass, carpet grass, Dallis grass, centipede grass, Japanese

[7] The trial gardens were conducted by the Bureau of Plant Industry, Division of Forage Crops and Diseases, in an effort to discover pasture grasses suitable for pastures in the Sandhill region.

lawngrass, lespedeza, and white Dutch and hop clovers. The last two were rather sparse but gradually increased from year to year.

Other plants included noxious weeds, which were controlled by mowing annually. Further details as to the nature of the pasture flora are given on pages 35 and 37.

Along with the general pasture, the experimental area received the annual applications of 300 pounds of 4-8-4 fertilizer per acre. In addition, during the winters of 1934 and 1936, this area also received barn manure at the rate of 2½ tons per acre.

Estimating the Yields of Herbage and Nutrients

To determine the yields of pasture herbage, on the 6-acre grazing area, the herbage was clipped with a lawn mower from three different caged areas, each covering one five-hundredths acre. The yields

Figure 6.—View of part of the permanent-pasture area, showing growth in background similar to that on the pasture area before it was cleared.

were based on the average weight of the herbage clipped from the three areas; the clippings were thoroughly mixed and sampled, and aliquot samples from the respective areas were retained for chemical analysis. Originally it was planned to clip the areas at 2-week intervals, but subsequent observations indicated that the stage of growth would be the preferable basis for determining the time of clipping. Therefore, the rate of growth was the major factor determining the frequency of clipping. The cages remained on the same areas throughout the year, but they were moved at random to different areas at the beginning of each grazing season.

To determine the yields of nutrients, the quantities obtained by the grazing animals were calculated by the same general methods as were used in estimating the yields of the annual crops. The 6-acre pasture was grazed with either milking cows alone or a combination of milking and dry cows. Dry cows remained on the pasture continuously; whereas, the milking cows were on the pasture only during the day between milking hours, being held in a dry lot at night. Supplementary feed (the grain mixture described previously) was given to the milking cows only. It was fed three times daily at the rate of approximately 1 pound of concentrate for each 3 pounds of milk produced.

EXPERIMENTAL RESULTS WITH PERMANENT PASTURE

Yields of Herbage and Dry Matter as Estimated From Clipped Areas

The yields of herbage and dry matter per acre, as estimated from the weights of the herbage clipped from the caged areas in the permanent pasture, are shown in table 9.

Table 9.—*The green-matter and dry-matter yields per acre obtained from the permanent pasture, and the composition of the dry matter, as estimated with clippings from caged areas, 1933–37*

Year and clipping	Date cut	Green matter per acre	Dry matter per acre	Dry-matter content of pasture	Composition of dry matter: Ash	Ether extract	Crude protein	Crude fiber	Nitrogen-free extract
		Pounds	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1933									
First	June 2	1,050	326	31.00	6.70	2.93	9.29	25.77	55.30
Second	June 16	430	134	31.26	7.32	2.82	11.30	25.70	52.80
Third	July 26	1,585	399	25.15	9.35	3.10	12.19	25.98	49.38
Fourth	Aug. 25	2,615	660	25.24	7.16	3.07	12.55	29.66	47.60
Fifth	Sept. 20	2,065	573	27.77	6.82	2.50	9.58	29.58	51.51
Sixth	Oct. 26	650	224	34.52	7.20	1.96	10.02	28.05	52.77
Total or average		8,395	2,316	29.16	7.43	2.73	10.83	27.44	51.57
1934									
First	June 14	4,300	1,146	26.66	7.55	3.56	13.17	29.98	45.74
Second	July 12	1,315	327	24.90	8.00	2.98	13.01	25.65	50.35
Third	July 31	1,100	319	28.97	7.80	2.69	12.82	28.58	48.11
Fourth	Aug. 23	1,680	466	27.73	7.10	2.63	9.13	29.84	51.30
Fifth	Oct. 16	2,735	746	27.29	6.37	2.75	11.18	32.55	47.15
Total or average		11,130	3,004	27.11	7.36	2.92	11.86	29.32	48.53
1935									
First	May 22	915	297	32.41	6.40	3.35	12.08	31.99	46.17
Second	July 1	330	161	48.65	5.95	3.39	10.76	24.39	55.51
Third	July 29	5,600	1,605	28.66	6.58	2.78	10.42	28.53	51.70
Fourth	Aug. 27	1,550	473	30.49	6.04	3.02	9.40	30.17	51.31
Fifth	Sept. 30	1,465	438	29.87	6.16	2.44	9.43	29.40	52.57
Total or average		9,860	2,971	34.02	6.23	3.00	10.43	28.90	51.45
1936									
First	July 15	2,100	710	33.81	5.67	3.28	9.14	29.80	52.09
Second	Aug. 18	2,950	847	28.71	6.60	2.61	8.51	28.39	53.89
Third	Sept. 2	760	201	26.86	6.87	2.66	11.21	29.77	49.50
Fourth	Oct. 13	1,150	361	31.43	7.25	2.37	8.59	30.55	51.24
Total or average		6,950	2,119	30.20	6.60	2.73	9.36	29.63	51.68
1937									
First	May 26	5,050	1,788	35.41	5.87	1.98	14.11	33.14	44.90
Second	June 24	900	284	31.59	6.54	2.09	15.30	29.75	45.33
Third	July 22	2,550	699	27.42	6.48	1.99	10.73	31.54	49.26
Fourth	Aug. 13	3,500	826	23.60	6.15	2.17	9.00	32.32	50.27
Fifth	Sept. 21	4,200	1,028	21.48	6.39	2.35	10.09	27.31	53.86
Total or average		16,200	4,625	28.50	6.29	2.30	11.88	30.81	48.72

The chemical analyses of the pasture plants show there was a tendency toward a higher percentage of protein and ether extract early in the growing season and a higher percentage of crude fiber in the latter part of each season. There was no apparent significant difference in the composition of the pasture plants from season to season, with the possible exception of 1937. In 1937 an increase in clovers early in the season was observed, which might have been responsible for the higher content of protein in the first and second clippings. The ether extract and the ash contents, however, did not show the same increase as protein. The relative higher yield of dry matter from the first clipping may also be due to more clover in the plant mixture that spring than in previous seasons.

Yields of Nutrients as Estimated by Grazing

The results obtained from grazing the experimental section of the permanent pasture with dairy cattle are summarized by years in table 10.

The supplementary concentrates were fed to milking cows only. The ratio of grain fed to milk produced by the cows for 5 years was 1 pound of grain for each 3.4 pounds of milk. The supplementary feed supplied an average of 24 percent of the total amount of nutrients needed by all cows, dry and milking. The relatively large proportion of dry cows was probably the principal factor contributing to the low percentage of supplementary feed.

As evidence of the adequacy of the pasture for the dry cows, the body weights were either maintained or increased slightly. The weights of all cows were relatively uniform from week to week.

A more significant estimate of the value of the grazing is the average quantity of total digestible nutrients credited to the pasture. This average per season for 5 years was 1,253 pounds per acre. In terms of alfalfa hay, the yield was 1.25 tons per acre.

The variation in the yearly yields of digestible nutrients over the 5-year period was from 967 pounds per acre in 1936 to 1,578 pounds in 1937. However, if the yields are converted to a daily basis for the grazing season, the lowest yield was in 1933, which averaged 6.6 pounds of digestible nutrients per acre per day and the highest in 1937, which was 9.9 pounds. On the same basis the average daily yield for the grazing season of 1936 was relatively high, being 8.6 pounds, or the same as for 1934. That for 1935 was 7.7.

TABLE 10.—*Summary of the grazing returns obtained from a representative section of the permanent pasture*

Year	Grazing				Supplementary feed (concentrates eaten per acre)	Production per acre		Gain (+) or loss (−) in live weight per acre	Digestible nutrients required				Proportion of total nutrient requirements supplied in supplementary feeds per acre		Digestible nutrients credited to pasture per acre
	Date begun	Date ended	Calendar days	Cow-days per acre		4-percent fat-corrected milk	Butterfat		For maintenance	For milk production	For gain in weight	Total			
			Number	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Pounds*
1933	June 3	Nov. 10	161	101	574	1,986	84.9	−7	836	643	−15	1,464	409	27.9	1,055
1934	June 8	Nov. 6	152	[1] 127	296	1,194	53.0	+15	1,072	387	66	1,525	211	13.8	1,314
1935	May 1	Oct. 22	175	[1] 136	665	2,379	104.0	+2	1,012	771	54	1,837	484	26.3	1,353
1936	June 17	Oct. 6	112	78	302	1,429	63.7	+37	691	463	129	1,253	286	22.8	967
1937	Apr. 28	Oct. 5	[2] 159	[1] 155	813	2,983	129.0	+28	1,105	952	104	2,161	583	27.0	1,578
Average			152	119	548	1,994	86.9	+15	937	643	68	1,648	395	24.0	1,253

[1] Milking cows and dry cows.
[2] Grazing was not continuous.

DISTRIBUTION OF PASTURE PLANTS

The plant population of the pasture was mentioned in discussing the development of the permanent pasture and in the description of the experimental grazing area (pp. 29–31).

No attempt was made to obtain definite information on the botanical composition or changes in the distribution of the plants during the experiments. In general, the plant population remained essentially the same, that is, all species seeded or planted were present. The sward was almost complete on the lowlands, particularly in the vicinity of seepage areas. On the uplands where the moisture conditions were frequently unfavorable and the soil was relatively deficient in plant nutrients, there was a high percentage of bare ground.

The most pronounced change in the pasture sod was the increase of hop clover and white Dutch clover on both lowland and upland areas. A gradual increase of Bermuda grass, Dallis grass, centipede grass, and Japanese lawngrass, and a decrease of carpet grass were also noted. Lespedeza diminished each year on the upland but remained about the same on the lowland.

The most common obnoxious weeds were purplish cudweed (*Gnaphalium purpureum* L.) and common sorrel. In general, weeds were controlled by mowing.

It is interesting that the two highest seasonal yields (table 10) followed the two winters (1934 and 1936) in which barn manure was applied to the pasture. However, the favorable climatic conditions during 1935 and 1937 undoubtedly contributed to the large seasonal yields, and must be considered in conjunction with the manurial treatments.

Distribution of Nutrients Throughout the Grazing Season

The date when grazing was started each season (table 10) for the 5-year period ranged from April 28 to June 17, and an average date would be May 24. Though climatic conditions, particularly the last killing frost, are factors that generally determine when grazing may be commenced, a more important factor in this case was the character of the pasture sod. As previously stated, there was a paucity of clovers, which are needed to supply early grazing. The increase of these plants resulted in the relatively early grazing date of 1937. The date grazing was discontinued in the fall ranged from October 5 to November 10, and would average October 22. It was determined primarily by the amount of available moisture rather than the time of the first killing frost.

The average number of grazing days for the season ranged from 112 in 1936 to 175 in 1935, and averaged 152 (table 10). The abnormally long period between frosts, 268 days, and the favorable moisture conditions accounted for the long grazing season in 1935. In 1936 the droughts at the beginning and the end of the growing season resulted in a short grazing period.

The percentage of the total pasture yields by successive 4-week periods, by years, is given in table 11. In 1933 there was little difference between the average yield for the first, second, and third monthly periods and an average for the fourth, fifth, and sixth periods. In 1934 the average was much higher for the first three monthly periods than that for the last three periods. In 1935 the yields were somewhat greater for the last three monthly periods than for the first three periods; and in 1937 the last three full monthly periods (the third, fourth, and fifth) averaged more than the first and second. In 1936 the yield was quite uniform for the four monthly periods shown. Thus there was considerable variation in the months that supplied the best grazing.

TABLE 11.—*Percentage distribution of the annual pasture yields obtained during successive 4-week periods of the grazing season, 1933–37*

4-week average	1933	1934	1935	1936	1937	5-year average
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
First	19.3	21.2	19.1	24.2	15.4	19.7
Second	17.6	21.9	14.7	20.8	11.9	18.2
Third	20.9	24.6	10.2	26.0	22.6	20.5
Fourth	14.5	17.5	9.1	23.0	21.7	16.8
Fifth	21.8	10.5	18.3	----	19.7	14.5
Sixth	[1] 5.9	[1] 4.3	24.5		[1] 8.7	[1] 9.4
Seventh	----	----	[1] 4.1		----	[1] .9
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1] Represents a period of less than 28 days.

Even though the clovers increased from year to year, the quantity present was not adequate to provide early grazing. Consequently, when the grasses were developed sufficiently to supply enough material to initiate grazing, the clovers had matured and had started to deteriorate. White Dutch clover supplied a small part of the grazing early and late in the season; whereas, hop clover provided only a small amount, early in the season.

In general, grasses did not supply grazing before late spring or early summer. Bermuda grass, though relatively sparse, provided considerable herbage in late May and in June, very little in July and August when drought and high temperatures retarded growth, but resumed growth in September and supplied late grazing. This grass was generally palatable as evidenced by thoroughness of grazing.

The early growth of carpet grass was always slow. It furnished grazing during June, July, and August, after which the cattle refused it. Therefore, the grass matured and was not utilized further.

Dallis grass was perhaps the most desirable of the grasses. It provided grazing throughout the season, even during periods of drought. Apparently the palatability was about the same as for Bermuda grass.

Several characteristics of the centipede grass were observed to be similar to those of Dallis grass—as it was relatively drought-resistant, and had a long period of growth. It formed a very good sod and was palatable.

Japanese lawngrass, which is somewhat similar to centipede grass in nature of growth, was eaten sparingly by the cattle. Growth was adequate by early May for grazing, but it was too unpalatable to be utilized.

Cost of Nutrients Obtained From Permanent Pasture

Although the cost of developing the 60-acre permanent pasture was $41.28 per acre (see p. 30), the cost of producing the nutrients obtained in this experiment was principally the cost of maintaining and improving the 6-acre experimental grazing area. The itemized expenditures by years for the 5-year period 1933–37 are shown in table 12. The total costs for limestone and manure were prorated over the 5-year period. As a basis for expressing the cost of the nutrients in monetary terms, the following estimations were used in preparing this table: Man-hour, $0.10; mule-hour, $0.15; fertilizer, $14.80 per ton; limestone, $6.25 per ton; and barn manure, $1.50 per ton.

Table 12.—*Average yearly amount and cost of labor, power, and fertilizer per acre for maintenance of permanent pasture*

Year	Man labor		Mule labor		Commercial fertilizer		Limestone		Manure		Total cost per acre
	Amount per acre	Cost	Amount per acre	Cost	Amount per acre	Cost	Amount per acre	Cost	Amount per acre	Cost	
	Man-hours	*Dollars*	*Mule-hours*	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*	*Dollars*
1933	3.9	0.39	2.8	0.42	300	2.22	1,500	4.69			7.72
1934	13.9	1.39	2.8	.42	300	2.22			5,000	3.75	7.78
1935	13.9	1.39	2.8	.42	300	2.22					4.03
1936	13.9	1.39	2.8	.42	300	2.22			5,000	3.75	7.78
1937	13.2	1.32	3.0	.45	300	2.22					3.99
Average (5-year period)	11.8	1.18	2.8	.43	300	2.22	300	.94	2,000	1.50	6.26

On the basis of these cost figures, and the yields shown in table 10, the average cost per 100 pounds of digestible nutrients for maintenance alone was $0.50, which in terms of alfalfa hay equivalent is about $5 per ton. When the cost of development is included and this is spread over the 8-year period (1930–37) that the pasture was in production, the total estimated cost becomes $0.82 per 100 pounds of nutrients, or expressed in alfalfa hay equivalent, $8.20 per ton.

Discussion of Practical Results of Permanent-Pasture Experiment

In developing a permanent pasture at the Sandhill station, on the type of soil typical of most of the Sandhill region, the cost per acre for establishing the pasture was high in comparison to the relative value of such land. The annual returns in amount of dry matter and in yield of digestible nutrients per acre were low.

The yields during the last 5-year period of the investigation, as estimated from grazing the small experimental pasture, averaged 1,253 pounds of digestible nutrients per acre per season of 152 days. The average daily yield when grazing was available during the season was therefore 8.24 pounds of nutrients per acre, which shows that the carrying capacity of the pasture was relatively low, as compared to a succession of annual crops. With continued improvement of the permanent pasture, it is probable that the yields would increase.

As an example of the yields of nutrients that can be expected from permanent pastures, on a type of soil differing from that at the Sandhill station, the results of a series of grazing experiments reported [8] by the South Carolina Agricultural Experiment Station are of interest. The grazing tests were conducted at Clemson College, on established Bermuda grass sod on land that was classed as Cecil sandy clay loam, and the various plots received different fertilizer treatments. Some of the plots also contained a considerable amount of volunteer hop clover and white clover. The plots that received lime and fertilizer averaged 4,017 pounds of total digestible nutrients per acre, and the plot that received no lime or fertilizer averaged 2,682 pounds. These yields were 3.2 and 2.1 times as much, respectively, as the average annual yields by the permanent pasture at the Sandhill station. A carpet grass plot at Clemson College, on land classed as Wehadkee sandy loam, that received an application of superphosphate the first year averaged 2,154 pounds of total digestible nutrients per acre, or 1.7 times as much as the permanent pasture at the Sandhill station.

To improve the permanent pasture at the Sandhill station, one of the principal needs is to introduce pasture plants that are adaptable to the soil and climatic conditions of the region. Dallis grass seems to be one of the few plants that will survive the adverse climatic conditions of this region and provide some grazing throughout the pasture season. Bermuda grass, though persistent, goes into a dormant state during extreme droughts. There is a pronounced need for plants that will provide early grazing. Clovers, hop and white Dutch, are gradually becoming established, and probably will eventually provide grazing early in the season. The seeding of crimson

[8] Elting, E. C., Lamaster, J. P., and Mitchell, J. H. permanent pasture studies. S. C. Agr. Expt. Sta. Bul. 308, 54 pp., illus. 1937.

clover or vetch on the pasture sod in the fall, also appears to offer a means of improving the yields in the early spring months. In addition to offering good grazing during the spring months these legume crops provide nitrogen that stimulates the growth of grass after their grazing is completed.

The cost of nutrients from the permanent pasture, approximately $8.20 per ton of alfalfa hay equivalent, is considerably less than the cost of nutrients obtained from the crops used in the grazing experiment with annual crops. Developed permanent pastures are probably the cheapest source of nutrients for dairy cattle in the Sandhill region.

SUMMARY AND DISCUSSION

Summary of the Grazing Experiment With Annual Crops

The climatic conditions in the Sandhill region and the physical nature of the soil make the region well adapted to all-year grazing.

Eight lots of 2 acres each, located on typical Sandhill land, were each seeded to various annual crops in succession and grazed with dairy cattle to determine the possibility of providing year-round pasturage, as well as the cost of producing feed for milk production in this way. The experiment extended over a period of 5 years.

Plant nutrients were supplied in the form of barn manure, basic slag, and commercially mixed fertilizer.

The two major crops selected were (1) a combination of oats, barley, rye, and vetch used for winter and early-spring grazing, (2) a combination of soybeans and pearl millet used for summer and early-fall grazing. Three other crops included in the experiment, as trial crops, were (1) corn interplanted with velvetbeans for fall, (2) crimson clover and Italian ryegrass for spring, and (3) pearl millet for summer.

All crops were sown broadcast except the corn and velvetbeans, and the soybeans. These two crops were planted in rows and cultivated.

Yields of crops were estimated by harvesting representative caged areas and by grazing with dairy cattle.

The yields, and the distribution of the yields, varied from season to season and from year to year. Apparently rainfall and temperature variations were the two principal factors causing variations in yields of the same crop. The lowest yields were obtained from winter-grazing crops and the highest from summer-grazing crops. The total number of calendar days during the year when grazing material was available ranged from about 195 to 315, with an average of approximately 255. There were usually intervals during the early winter and late spring when grazing was not available.

Of the crops investigated, the combination of oats, barley, rye, and vetch, the pearl millet, and the corn and velvetbeans produced the best results in terms of total yield and its distribution throughout the year.

The costs of the annual crops were high. This high cost was due to the necessity of plowing, fertilizing, and seeding for each crop produced; to the rather small yields obtained; and to some extent to the smallness of the plots used in the experiments.

Changes in methods and management are suggested for reducing costs, such as the use of crops that will reseed themselves; the use of seeds that will produce some grazing and also a seed or grain crop; and harvesting some of the crops, when they reach maximum growth, and making them into hay or silage.

Summary of the Permanent-Pasture Experiment

A permanent pasture was established on a typical Sandhill area including upland, bottom land, and seepage areas.

The rate of pasture development was rather slow, primarily because of the difficulty in establishing a satisfactory sod.

Annual applications of plant nutrients were made in the form of commercial fertilizers. Also, two applications of barn manure were made during the 5-year experimental grazing period.

The date when the first grazing was available in the spring was relatively late. This condition is gradually being remedied by the introduction of clovers.

The average yield of nutrients from grazing per season of 152 days was 1,253 pounds of digestible nutrients per acre, or the equivalent of 1.25 tons of alfalfa hay.

The cost of establishing and maintaining the permanent pasture was relatively high, and the carrying capacity was low.

The estimated cost of producing the nutrients, that were obtained by grazing the permanent pasture, was $0.82 per 100 pounds of digestible nutrients, which is relatively low in comparison with the costs of the nutrients in the grazing experiment with annual crops.

Discussion of the Two Systems of Providing Pasturage

The two systems of providing grazing (with permanent pastures and with annual crops) at the Sandhill station were supplementary only to a limited extent. There were two periods when it was difficult to provide grazing with the permanent pasture. These periods came during the early spring and the early fall, when there was also a dearth of grazing material from the annual crops.

The establishment of clovers in the permanent pasture is helping to reduce the period of spring shortage. The seeding of crimson clover, vetch, and hop clover on permanent pasture sod in the fall is proving to be promising for furnishing early-spring grazing. Some of the annual crops that are now being studied may prove to be effective in supplementing the permanent pasture, during periods when the permanent pasture is least productive.

Considering the relative costs of the two systems, it is evident that the permanent pasture furnished nutrients at a much cheaper rate than any of the annual grazing crops, singly or in combination. This is clearly indicated in table 13, which summarizes the total digestible nutrients produced per acre, the cost per 100 pounds of nutrients produced, and the cost per ton of alfalfa hay equivalent for the several annual grazing crops and the permanent pasture.

TABLE 13.—*Summary of yields and costs of total digestible nutrients obtained from the permanent pasture and the annual crops used in the grazing experiments*

Crop	Grazing period	Total digestible nutrients			Cost per ton of alfalfa hay equivalent
		Yield per acre per day	Yield per acre	Cost per 100 pounds	
	Days	*Pounds*	*Pounds*	*Dollars*	*Dollars*
Permanent pasture	152	8.24	1,253	0.82	8.20
Pearl millet	109	13.03	1,420	1.18	11.87
Soybeans and pearl millet	114	10.66	1,215	1.93	19.42
Oats, barley, rye, and vetch	99	6.72	665	3.28	33.00
Italian ryegrass and crimson clover	24	9.62	231	6.55	65.89
Corn stover and velvetbeans	70	7.80	546	1.77	17.81

The costs of nutrients furnished by the combination of oats, barley, rye, and vetch at $3.28 per 100 pounds, and by Italian ryegrass and crimson clover at $6.55 per 100 pounds, are prohibitive.

It is possible that the returns from the annual crops would be greater if they were not grazed but were made into silage. While this would involve additional harvesting and handling costs, it would make possible the harvesting of the crops at a stage of maturity that would insure a maximum yield and feeding value. Such a plan would provide a more uniform ration for the cattle than was obtained by grazing the crops. The chemical composition probably would be more uniform, and the silage could be fed in amounts required. Under this plan, the silage would be available when needed to supplement the poor grazing periods on the permanent pasture. The annual crops that give the most economical yields could be utilized. Making good silage from these crops is not difficult, as modern methods insure the making of good-quality silage from legumes and grasses when cut and stored in the proper manner.

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