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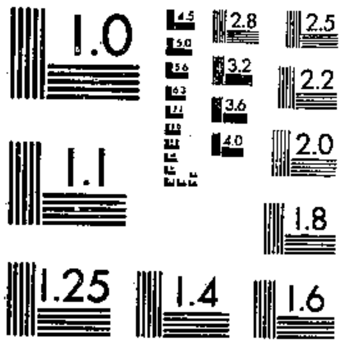

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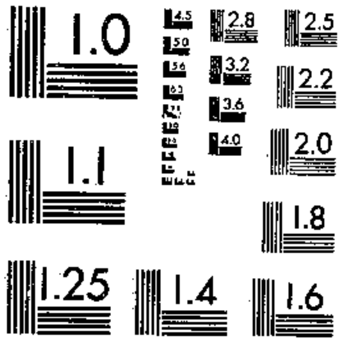

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THE HOHENHEIM SYSTEM IN THE MANAGEMENT OF PERMANENT PASTURES FOR DAIRY CATTLE [1,2]

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INTRODUCTION

The Hohenheim system of pasture management is so called because it was first introduced at Hohenheim, Germany. A description of this system is contained in a review of the original experiment, which appears to have been written by a representative of the Journal of the Ministry of Agriculture for Great Britain (*6*).[3] The following comments were taken from that review:

The original Hohenheim experiment established by Dr. Warmbold included 60 acres of pasture divided into 10 enclosures from 4 to 10 acres each. The experiment started in 1916 when the pasture required 1.4 acres to maintain a 1,000-pound cow from the end of April to the beginning of October.

The fertilizer applied annually under the Hohenheim system was 107 pounds per acre of pure nitrogen (500 pounds sulphate of ammonia equivalent) besides

[1] Submitted for publication May 26, 1938.

[2] This is a cooperative investigation between the Division of Dairy Cattle Breeding, Feeding, and Management, Bureau of Dairy Industry, and the Division of Forage Crops and Diseases, Bureau of Plant Industry. The Bureau of Dairy Industry was responsible for the management of the pastures and measuring the yields with dairy cattle. The Bureau of Plant Industry was responsible for all the agronomic phases of the work; H. N. Vinall, senior agronomist, deceased, had an active part in the initiation and planning of the investigation.

[3] Italic numbers in parentheses refer to Literature Cited, p. 32.

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phosphate and potash. At the beginning of the treatments, 36 pounds of phosphoric acid (260 pounds of superphosphate equivalent) and 80 pounds of potash (200 pounds 40 percent potash salts equivalent) per acre were applied to the pasture. Later, the phosphates and potash were reduced but the amount of nitrogen continued the same.

Phosphates and potash were applied in autumn. Half of the nitrogen in the form of sulphate of ammonia was applied about February 1, and the other half in three separate applications, usually as urea, in May, June, and July. The urea seemed to have some special advantage for summer application. Lime was applied at intervals of 6 years, at the rate of about 900 pounds per acre.

A requirement of the system is that the grass must be grazed in a young, leafy stage. If the herd was insufficient to keep down the vigorous growth at a certain time of the year, part of the pasture was cut for hay. The first "bite" of each enclosure was obtained by the best milk cows; after 2 or 3 days on a plot these cows were followed by lower-yielding cows or by dry cows and stock cattle.

Also, it appears that, from 1918 onwards the heavy application of fertilizers resulted in a carrying capacity of 0.5 acre per cow for the grazing season as against 1.4 acres required at the beginning of the experiment.

American investigators are not in agreement as to what practices constitute all the essential phases of the Hohenheim system. They do, however, agree that two of the main practices involved are (1) rotating the cattle over separate parts of the same pasture, and (2) liberal application of fertilizers, particularly those carrying nitrogen. Some maintain that dividing the herd according to the quantity of milk produced, and then giving the highest-producing cows the first chance at the fresh pasturage, is an additional essential part of the system. Others assert that harvesting hay from some of the pasture fields early in the season is also an integral part of the system. It appears certain that all of these variations were actually practiced by Dr. Warmbold at Hohenheim.

The Hohenheim system of pasture management is primarily intended for dairy cattle, although other livestock may be benefited also. Its principal purpose is to increase the yield of nutrients for milk and butterfat production from the pasture, by maintaining the herbage in an immature, rapidly growing stage throughout the growing season, as well as to increase the total yield of nutrients obtained by the cattle and other livestock.

In view of the apparent success of the Hohenheim system in Germany and the favor with which it or similar systems were regarded in some other countries, notably the Netherlands, England, and New Zealand, it seemed desirable to conduct an investigation to determine whether or not the Hohenheim system is adapted to conditions that prevail in the United States. In the countries mentioned the climate and soil are excellently adapted to the growing of pasture plants. The cool summer weather prevents excessive drying of the soil and lessens the loss of organic matter from the soil. While the total precipitation in those countries may not be any greater than over a great part of the United States, the rains are more frequent as well as less violent. Because of the high content of organic matter in the soil and the gentleness of the rains there is much less surface run-off than in the United States.

Agriculture is less intensively practiced in this country, the land values are lower, and high yields per acre are not so essential to success. The densely populated European countries cannot raise enough food on their land to feed the inhabitants. The United

States, on the other hand, usually produces more than enough food, and the surplus in recent years has not been salable abroad. The tendency in Europe is to produce more abundantly; the tendency in the United States is to produce less abundantly by raising crops that are naturally less productive, but which will at the same time conserve the fertility of the soil and reduce erosion. Because of the differences in the soil, climate, and economic conditions here and abroad, it is readily apparent that pasture practices which meet the needs of other nations will not necessarily prove desirable here. At the time this investigation was started there had been no investigations reported of the Hohenheim system in the United States.

REVIEW OF AMERICAN INVESTIGATIONS

Salter and Yoder (*15*) have reported on 2 years' work (1928–29) with the Hohenheim system in Ohio. Three 6-acre and three 4-acre pastures were used. The fertilizers applied per acre were 500 pounds of superphosphate (20 percent P_2O_5), 120 pounds of muriate of potash, and four applications of sulphate of ammonia (20.5 percent N) totaling 500 pounds. They conclude that it is more profitable to produce both protein and dry matter by the application of fertilizers than it is to buy these materials in feed. The grazing season was said to be lengthened by about 3 weeks and the herbage of the Hohenheim pastures to have a higher content of protein. These pastures were also said to have a denser turf and to yield more heavily. Difficulty was noted in maintaining a stand of white clover in the pasture herbage.

Foley (*5*), in reporting three seasons' work (1928–30) with the Hohenheim system at the Massachusetts Agricultural Experiment Station, states that the return per acre over feed, fertilizer, field, and land costs, was greater on pastures treated with a complete fertilizer than on pastures treated only with the phosphoric acid and potash, and these latter showed a greater return than untreated pastures.

Archibald and Nelson (*1*) at the same station, reported that intensive fertilizing and grazing not only increased the yields of dry matter, but also increased the nutritive value of the dry matter.

There are few published accounts of rotation-grazing experiments in the United States.

Hodgson and associates (*8*) reported the results of three seasons' work (1931–33) in western Washington with dairy cows. They compared the effects of rotating cattle over separate parts of a pasture with the customary practice of grazing an entire pasture continuously. They state that the pasture yields, calculated as total digestible nutrients, averaged 5,986 pounds per acre for the pasture grazed in rotation, and 5,499 pounds for a similar pasture grazed continuously. This was an increase of 8.9 percent in favor of the rotation-grazed pasture. Rotational grazing did not improve the grass from the standpoint of chemical composition. No significant difference was observed in the amount of clumping in the pastures under the two methods of grazing.

Salter, Gerlaugh, and Welton (*14*) conducted a trial of rotational grazing in comparison with continuous grazing for one season near

Dayton, Ohio, using young cattle to measure the yields of the pastures. The pasture yield, expressed in pounds of beef per acre, was 175 for a pasture divided in four parts and grazed in rotation, and 179.5 for a similar pasture grazed continuously.

Comfort and Brown (*3*) conducted an experiment at Grain Valley, Mo., in which they compared rotational with continuous grazing of bluegrass pasture, using young cattle. Three years' results showed that on an average the yield in pounds of beef per acre for the continuously grazed pasture was 112 and that of the rotation-grazed pasture was 97. The yield of grass as determined by monthly clippings of small areas, stated in pounds of air-dry herbage per acre per season, was 1,589 on the continuous pasture and 1,648 on the rotation pasture.

Holdaway and Pratt (*9*) conducted an experiment in Virginia, in which 20 acres of bluegrass pasture was grazed in rotation by dairy cows, and an equal area of similar pasture was grazed continuously. The results for 1 year, measured in terms of total digestible units, showed that the yield for the rotation pasture was 1 percent greater than that for the continuous pasture.

The literature regarding the influence of fertilizers on pastures is too voluminous to review. In general, it can be said that fertilizers increase the yields, thicken the turf, and discourage the growth of weeds. They do not generally improve the uniformity of growth from one part of the pasture season to another. Applications of nitrogen not only increase the nitrogen content of the herbage but also may promote the growth enough so that the pastures will be ready for grazing as much as 3 weeks earlier than those not receiving such applications. In many cases it is reported that applications of nitrogen discourage the growth of legumes.

PLAN OF THE INVESTIGATION

The study of the Hohenheim system described in this bulletin was conducted on the experimental dairy farm at Beltsville, Md. The Bureau of Dairy Industry stocked and managed the pastures during the experiment, and measured the yields of pasture nutrients with dairy cattle. The cattle used in grazing the pastures were from the Bureau's experimental dairy herd at Beltsville. The Bureau of Plant Industry prepared the soil of the fields used, seeded and fertilized the pastures, carried out plant-population studies, and made chemical analyses of the herbage.

PREPARATION OF THE PASTURES

LAY-OUT OF THE PASTURES

The original plan was to establish a 12-acre pasture, then divide it into six equal parts, and manage it as advocated by the sponsors of the Hohenheim system. That is, the six units were to be grazed in rotation and the whole pasture was to be fertilized during the entire period of the experiment. The work had barely started when it was decided that this plan was inadequate for two reasons. One was that no control pasture had been provided. The other was that, if the Hohenheim system proved advantageous, there would be no way of telling whether it was advantageous because of the method of grazing or because of the fertilizer applications. For these reasons, two 4-acre pastures were added to the experiment. Both 4-acre pastures were to be grazed continuously, one was to be fertilized and the other unfertilized, for the duration of the experiment. This will explain why the three experimental pastures are not all the same size, and why the seedings were not all made at the same time. The lay-out of the pastures is shown in figure 1, and the topography in figure 2.

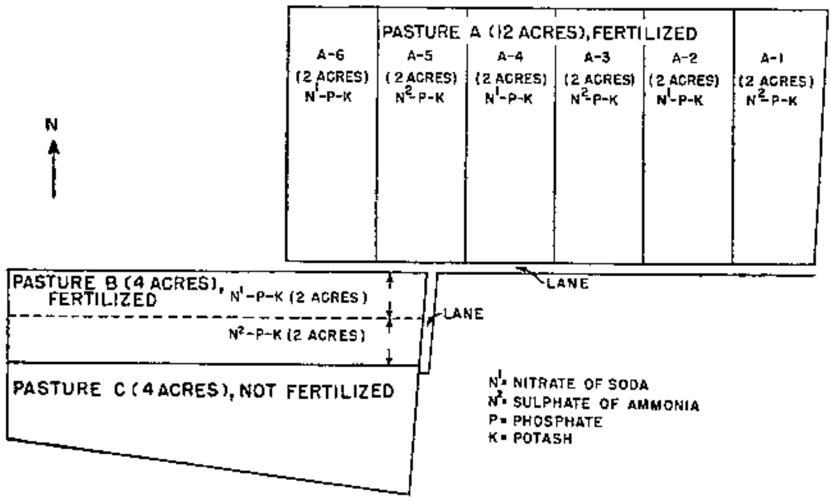

FIGURE 1.—Lay-out of the pastures.

The fields used for the three pastures were selected after due consideration had been given to the productivity of the soil and its previous treatment. The soil in all fields was Sassafras silt loam, all fields had received generous applications of lime and stable manure in previous years, and all had good stands of alfalfa when plowed up for seeding to a pasture mixture. The same pasture mixture was used for all three. It was expected, with pastures so much alike, that they could be compared directly year by year and for the entire period of the experiment. If the plan outlined for managing the pastures could be followed throughout the experiment, then comparison of the fertilized pastures, A and B, one to be grazed in rotation and the other continuously, would show the effect of rotation grazing; a comparison of the fertilized pasture B and the unfertilized pasture C, both to be grazed continuously, would show the effect of fertilizer applications; and a comparison of pasture A (fertilized and grazed in rotation) with pasture C (unfertilized and grazed continuously) would show the combined effect of rotation grazing and fertilization. The comparisons could not be made as simply as this, however, because several adjustments became necessary.

For example, in the management of pastures A and B, it appeared desirable after results for 3 years (1930–33) had been studied, to interchange the methods of grazing them because of the obvious superiority of the turf in pasture A. This superiority was attributed either

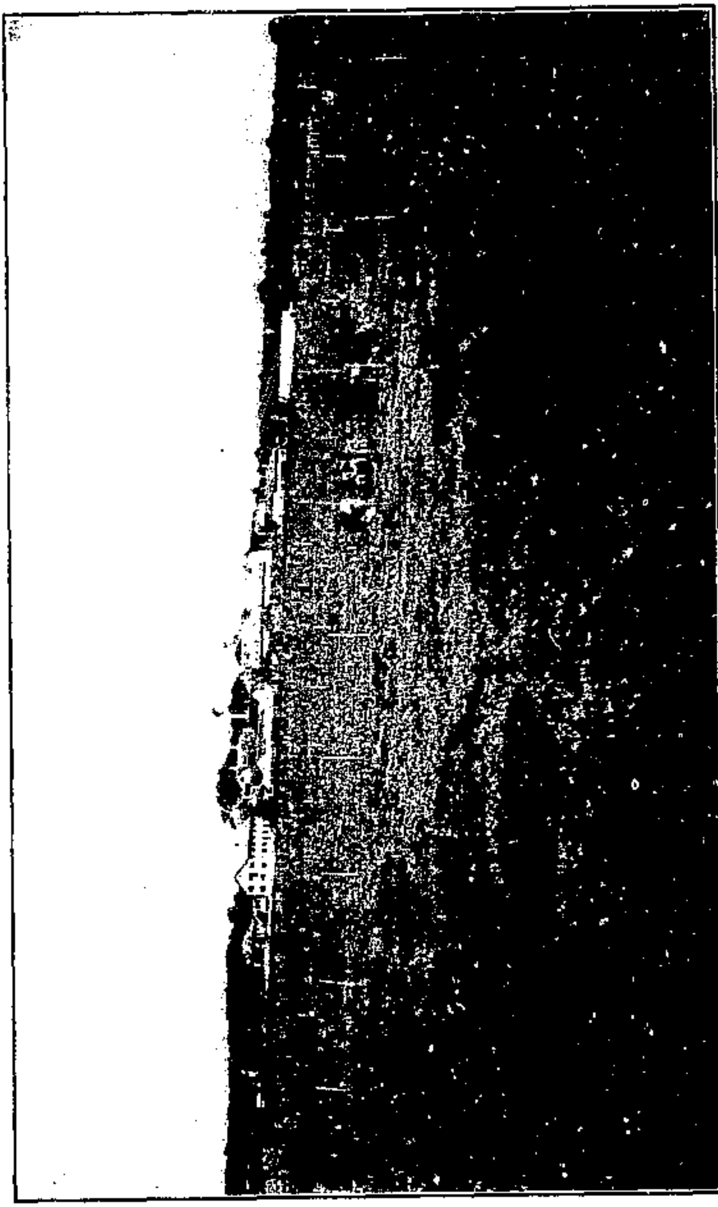

FIGURE 2.—Hohenheim pastures on the Bureau of Dairy Industry experimental farm, Beltsville, Md.

to a more fertile soil or to a more favorable topography. Hence pasture A (12 acres) was rotationally grazed for 3 years, then grazed continuously as a single pasture for 3 years. Pasture B was grazed continuously for 3 years, then divided into six equal (⅔-acre) units and rotation-grazed for 3 years. Although the interchange mentioned does not complicate materially the comparison between A and B to determine the effect of the method of grazing, it does necessitate certain adjustments when other comparisons are made to determine the effect of fertilizer applications when used alone or in combination with rotation grazing.

The effect of using fertilizer in this experiment was to be determined by comparing pasture B, fertilized, and C, unfertilized. These two pastures were both made from a field which had been uniformly treated as regards the crops grown, and the manure, lime, and fertilizer applied for a period of 15 years before this investigation began. Also, the topography of the two pastures is similar. Notwithstanding their great similarity, they cannot be compared directly to determine the effect of fertilizer applications because of the change in method of grazing pasture B. Pasture C was continuously grazed during the 6-year period, but pasture B, during 3 of the 6 years of experimental work, was grazed in rotation. Hence, the yields of pasture B must be adjusted to the basis of continuous grazing before the comparison can be made between B and C for the influence of fertilizer.

Furthermore, in order to arrive at the combined effect of fertilizers and rotation grazing, two courses are open. One way would be to estimate the difference in yields due to the difference in natural productivity between pastures A and C (assuming that B and C were equal in natural productivity), and deduct this difference from the yield of pasture A; then make an additional adjustment for the 3 years' continuous grazing of pasture A. After the results for pasture A have thus been converted into terms of rotation grazing and fertilization for the 6-year period, the comparision can be made between A and C.

The other course is to convert the results for the 3 years of continuous grazing of pasture B into terms of rotation grazing, and consider this as a rotation-grazed pasture for the 6 years. Then the comparison can be made between pasture B, as a rotation-grazed fertilized pasture, and pasture C as a continuously grazed unfertilized pasture. This latter course is preferable because it is simpler, though both should lead to the same ultimate result.

PREVIOUS SOIL TREATMENT

The field selected for pasture A had been in pasture previous to 1924, but during the next 3 years, 1924–26, it was cropped to corn. In the fall of 1926 limestone was applied at the rate of 2 tons per acre. In the spring of 1927 it was seeded to alfalfa, and remained in this crop until the fall of 1928, when the land was prepared for the experimental-pasture seedings. The alfalfa made excellent growth, although, due to heaving, it was subject to winter-killing. During the 5 years just before the pasture was established, the land had received approximately 600 pounds of phosphate per acre.

The field selected for pastures B and C had been cropped in a rotation of 3 years' corn and 3 years' alfalfa for a period of 15 years before this experiment began. The practice was to apply barnyard manure before the second and third crops of corn and before the seeding of the alfalfa. About 300 pounds of superphosphate and muriate of potash and about 2 tons of ground limestone were applied at the time the alfalfa was seeded. In the spring of 1927 alfalfa was seeded and this was plowed under in the winter of 1928–29 preparatory to seeding the pasture mixture early in the spring of 1929.

SEEDING

All seedings were made before the fields were divided into their respective pastures in order that uniform treatment might be given. Pasture A was plowed and a seedbed prepared the last week in September 1928. The grass seedings were made on October 3 and 4. The time between seeding and soil preparation was not sufficient for the natural settling of the soil to produce a compact seedbed. The land was double-disked twice, harrowed, and cultipacked, which, however, did not give a thoroughly compacted subsurface seedbed. The seed was sown broadcast, one-half lengthwise and one-half crosswise of the field to insure uniform distribution, and covered with a cultipacker.

A heavy, complex mixture was used and, although not recommended for ordinary farm practices, for experimental purposes it seemed advisable to include seed of all the pasture plants adapted to this region. The clovers and lespedeza were seeded broadcast on March 13, 1929, without any additional preparation of the seedbed. The following mixture was sown at the rates indicated:

	Pounds per acre
Sown October 1928:	
Kentucky bluegrass (*Poa pratensis* L.)	12
Redtop (*Agrostis alba* L.)	3
Timothy (*Phleum pratense* L.)	4
Orchard grass (*Dactylis glomerata* L.)	4
Italian ryegrass (*Lolium multiflorum* Lam.)	8
Perennial ryegrass (*L. perenne* L.)	4
Meadow fescue (*Festuca elatior* L.)	4
Sown March 1929:	
Red clover (*Trifolium pratense* L.)	3
Alsike clover (*T. hybridum* L.)	2
White Dutch clover (*T. repens* L.)	2
Common lespedeza (*Lespedeza striata* (Thunb.) Hook. and Arn.)	10
Korean lespedeza (*L. stipulacea* Maxim.)	4

Pastures B and C were not seeded until the spring of 1929, as it was not possible to prepare a seedbed in time for a fall planting These areas were plowed early in the winter, and a good seedbed was worked down just prior to planting. The same mixture was used as on pasture A.

ESTIMATING THE PLANT COMPOSITION OF THE GROUND COVER

In order to obtain definite information on the plant composition of the pasture grass and the relative amounts of the different kinds of plants in the ground cover, on the fertilized rotationally grazed pasture, the fertilized continuously grazed pasture, and the unfertilized continuously grazed pasture, studies were made of the plant population on selected areas during each year of the experiment.

A permanently marked quadrat, containing 9 square feet, was located in each of three rotation units (2, 3, and 4) of pasture A and one in each of pastures B and C. These quadrats were located as nearly as possible on representative areas, except the one in unit 4 of pasture A. To study the rapidity of pasture plant establishment under adverse conditions, this quadrat was placed on an area which had suffered severe winter injury in the seeding year. All quadrats were open and subject to the same grazing and tramping effect as the remainder of the pasture.

When readings were taken on the quadrats, to facilitate more accurate and rapid estimates they were divided into square-foot areas, giving a total of nine readings on each quadrat. The estimates of the nine areas were totaled and the average calculated per square foot. In 1929 plant counts were made of the individual species. After that year accurate plant counts could not be obtained without disturbing the turf, and the individual composition was measured by estimating the area covered by each species. Also, the area of bare ground was estimated, The readings were taken in May shortly after grazing was started and in October before it was discontinued. These two readings gave an accurate picture of the changes in the sward, but they did not give an accurate estimate of the contributions of the annual lespedezas, since the readings were taken before lespedeza was established in the spring and after its maturity in the fall. Observations were made at the time lespedeza was making its maximum growth during the season, to determine its contribution to the herbage.

For the purposes of this bulletin the term "weeds" includes all plant material undesirable in permanent sward, although such plants as buckhorn, dandelion, crabgrass, and field paspalum, which were classed as "weeds," might supply some grazing at certain periods.

In addition to the annual population studies on the permanent quadrats, estimates were made on random-selected areas in 1933 and 1935. In selecting these areas at random the procedure was to start at one corner of the pasture and walk toward the opposite corner and at rather definite intervals toss out a 10-inch-square frame onto the pasturage; the plant cover within the area marked by the frame was then estimated. To increase the accuracy and speed of making the estimate of the percentage of cover contributed by the various species, and the percentage of bare ground, the quadrat was divided into 25 equal sized areas; thus each square represented 4 percent of the total area. The interval between each location was so divided that the readings would be representative of the entire pasture.

FERTILIZERS USED

In the initial application in the fall of 1928, phosphate and potash were applied with a drill and worked into the soil just before seeding. Subsequent applications were broadcast either in late fall or early spring, up to and including March 1933, when they were discontinued for the remainder of the experiment. Phosphate was applied at the rate of 400 pounds per acre (64 pounds P_2O_5) and potash at the rate of 100 (50 pounds K_2O), making a total of 2,000 pounds of phosphate and 500 pounds of potash per acre applied during the period 1928 to 1933.

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Nitrogen was applied in the form of nitrate of soda and in the form of sulphate of ammonia, in equivalent amounts of nitrogen. Half of each pasture that received fertilizers (A and B) was treated with nitrate of soda and the other half with sulphate of ammonia. Four applications of nitrogen were made per year in 1929, 1931, and 1932, 100 pounds per acre of nitrate of soda and 75 of sulphate of ammonia being used in each application. Each year, the first application to pasture A (Hohenheim pasture) was made to rotation unit No. 1 at least 1 month before grazing started, and to each succeeding unit at 5-day intervals until all six units had been treated. Pasture B of the continuously grazed series received nitrogen at the same time as unit No. 1 of pasture A. The second nitrogen application to both pasture A and pasture B was made immediately after grazing was started, and the third and fourth applications were made in late June and August, respectively, in the same relative manner as the first application.

Only two nitrogen applications were made in 1930 because the drought retarded growth after June. After 1932 only two applications were made per year, as the results indicated definitely that nitrogen used after June had not been effective in increasing production.

METHODS OF GRAZING AND ANIMALS USED

Pasture A was grazed according to the so-called Hohenheim system or rotation-grazing method, and pastures B and C were each grazed continuously as one unit for the first three seasons, 1930–32. During the next three seasons (1933–35) pasture B was grazed by the rotation method and pastures A and C were each grazed continuously as one unit.

Each of the six units of the rotation-grazed pasture was first grazed by milking cows and then by young stock. Two units were thus being grazed while the other four were recuperating, so that each unit was grazed one-third of the time. By shifting all cattle every 4 days (the young stock being placed on the unit just vacated by the cows) 16 days were allowed for recuperation, which was considered about right in good growing weather. In dry weather the recuperative period could have been much longer and the shifts less frequent without the grass becoming too mature.

Animals were put on or taken off the three different pastures (A, B, and C) in such numbers as would result in the pastures being grazed equally close and also heavily enough so that but little of the grass would grow up and remain uneaten. Clumps of uneaten grass could not be avoided in any of the pastures. Particular attention was directed toward having all three pastures grazed equally close at the end of the season. The cattle were turned on the pastures in the spring when the grass was 3 to 6 inches high. They were taken off usually a week or so after the first killing frost in the fall.

The cattle used were Holstein-Friesians, and Jerseys. About as many heifers as milking cows were used. An effort was made to have the groups of cattle on the three different pastures (A, B, and C) comparable with reference to the breed, age, size, milk production, and stage of lactation. Cows recently fresh and animals nearing parturition were not included. Weights were taken on 3 consecutive days at the beginning and close of the grazing season, also on 3 consecutive days at the first of each month. Any cattle put on or taken off between regular weigh days were weighed on one day only. The cattle were on the pastures 24 hours a day except when taken off to be milked, weighed, or fed.

SUPPLEMENTARY FEEDING

The aim was to give the cattle enough supplementary feed to keep the heifers gaining, to maintain the weights of the cows, and to prevent any undue decline in milk production. At the same time it was desired to have the cattle get as much of their total nutrient requirements as possible from the pasturage. The quantity of supplementary feed given was gaged by the condition of the pastures, the gains being made by the heifers, the gains or losses in weights of the cows, the quantity and fat percentage of the milk, and the decline in daily milk production. Concentrates (18 percent average protein content) were used for the most part as the supplementary feed. The quantity varied from none to as much as or more than would be fed in the stable during the winter. In general, for the first month or so in the spring, cows producing less than 1 pound of butterfat a day received no supplementary feed whatever, and those producing more were fed enough concentrates to provide the nutrients required for all the butterfat produced over and above 1 pound a day. As the pasturage became poorer, the flow of milk that it would sustain became less, and concentrates were provided for all production above 0.75 pound, then 0.5 pound of butterfat a day, and sometimes in the driest part of the summer for all production, the pasturage being expected to provide only the nutrients required for maintenance.

DETERMINATION OF PASTURE YIELDS

ESTIMATION OF NUTRIENTS WITH DAIRY CATTLE

After much study it was decided to measure the yields of pasture grass in terms of digestible nutrients per acre in substantially the same manner as that used for years by Graves and associates (*2*, *13*, *17*) in evaluating pasture yields at the field stations of the Bureau of Dairy Industry. The method comprises several steps as follows: (1) Determine the requirements of the animals for total digestible nutrients; (2) deduct the total digestible nutrients provided in the supplementary feeds; (3) add the digestible nutrients removed from the pasture in the form of hay or otherwise; (4) divide by the number of acres in the pasture.

The calculated requirements of the cattle were based on the Savage (*16*) standard. The Savage and Haecker standards are so nearly in agreement with respect to the total digestible nutrients, that it was immaterial which one was chosen. These standards differ mainly in the protein allowed. Also, the use of any other well-known standard would probably not have materially changed the comparative results obtained for the different pastures. As the protein was always ample in the rations fed in this investigation, even when judged by the most liberal of the standards, the protein requirements may be entirely disregarded.

The allowance of digestible nutrients for maintenance of cows was at the rate of 7.925 pounds a day for 1,000 pounds body weight. The allowance for maintenance of heifers was based on the work of Gullickson and Eckles (*7*). The allowance for gains in weight of heifers was adapted from the data of Eckles and Gullickson (*4*) by applying a straight-line formula (*11*). The allowances for gains and losses in weight of cows were those suggested by Knott, Hodgson, and Ellington (*10*). The supplementary feeds used and the hay removed from the pastures were not analyzed, but the content of total digestible nutrients in each was calculated from tables of Morrison (*12*).

Knott and associates (*10*) suggest a credit to the pastures of 3.53 pounds of digestible nutrients for each 1-pound gain in weight of cows and 2.73 pounds debit for each 1-pound loss in weight. In using these factors the question arose as to how often during the season they were to be applied, also whether they were to be applied to the groups or to the individuals. Obviously, if such factors were applied daily, erratic results would be obtained because of the wide fluctuations in weight due to fill from day to day. On the other hand, if applied only to the gains and losses for the entire season, it would be possible for cows to lose flesh and then regain it before the season closed, thus nullifying the influence of different factors for gain and loss. In this investigation the computations were made monthly, and were based on the gains and losses of individual animals by calendar months. The reason for calculating the gains and losses separately rather than the combined gain or loss of the group is that the figures for gain and loss would cancel out, and the full influence of the different factors for gain or loss would be lost. For example, if there were six cows in a group and two of them showed a combined loss of 30 pounds and four showed a combined gain of 40 pounds, the factors for loss or gain were applied separately to 30 and 40 pounds, making a net credit of 59.3 pounds of nutrients for the pasture, rather than applying the factor for gain to 10 pounds, the difference between 30 and 40, which would make a credit of 35.3 pounds of nutrients for the pasture.

ESTIMATION OF HERBAGE YIELDS FROM HARVESTED QUADRATS

Yields of herbage were also estimated by harvesting at various times during the season small areas representative of the entire pasture. The grass was harvested by hand plucking, with an attempt to obtain herbage similar in quality and quantity to that eaten by the animals. In order to arrive at a standard to govern the harvesting, careful observations were made on the pasture that was being grazed at the time, noting in particular the intensity of the grazing and, if possible, the preference shown by the animals for certain grasses. The practice on the Hohenheim or fertilized rotationally grazed pasture was to harvest four to six areas, each containing 16 square feet, the day before grazing was started. On the continuously grazed pastures 100-square-foot areas were harvested from fenced-off movable quadrats in 1930, 1931, and 1932. Beginning in 1933 wire cages 4 by 4 feet were used (fig. 3). Yields were taken every 15 days during the flush growth in the spring and every 30 days thereafter. After each plucking the cages were moved to a new area that had been previously grazed. Yields were taken in such manner that it was possible to compare the nitrogen carriers, nitrate of soda and sulphate of ammonia. The harvested material was saved for moisture determination and chemical analysis.

ESTIMATION OF RELATIVE ECONOMY OF YIELDS FROM DIFFERENT PASTURE TREATMENTS

A common method of estimating whether certain pasture treatments are profitable is by measuring the difference in terms of milk and then assuming that the value of any additional milk represents

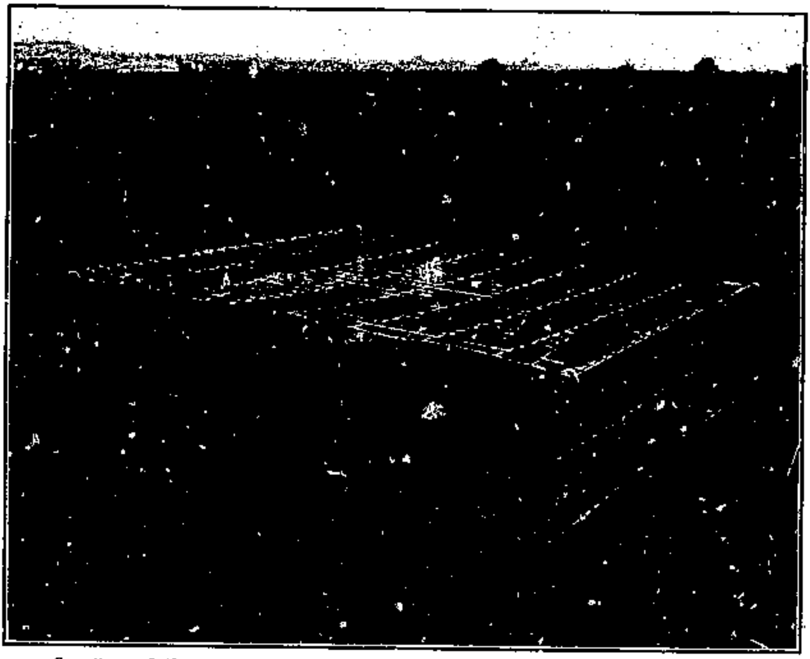

FIGURE 3.—One of the woven-wire cages used in studying the production of the pastures, 1933. Note the ungrazed clumps of grass in the background.

the value of the pasture treatment. The net returns are estimated by deducting the cost of the treatment. The objections to this method are that the net returns of a pasture treatment are influenced by the producing ability of the herd, the efficiency with which the dairy operations are conducted, and the price of the milk. The object in applying improved methods of management or fertilizers to pastures on a dairy farm is to increase the yield of nutrients for milk production which may be obtained from the pastures. The question, however, is not whether the extra nutrients produced in this manner will make a certain amount of milk or other products, but whether they have been produced more cheaply than an equivalent amount could have been produced by other crops or purchased. This is called the feed-replacement method of estimating the economy of pasture yields.

After the effect of a pasture treatment has been measured in terms of total digestible nutrients, the quantity of feed, either commercial or homegrown, that would be required to supply the amount of nutrients provided in the extra pasturage can be readily estimated. The cost of raising or buying this feed can then be compared with the cost of the pasture treatment, in order to find out whether the treatment paid.

CLIMATIC DATA

The total annual rainfall in the vicinity of Beltsville during the period of the experiment is shown in table 1. It did not differ much from the 48-year average except in 1930, when this region experienced the most severe drought in history. During that year the total rainfall of 17.93 inches was 22.42 inches below the 48-year average. The greatest fluctuation was in the total monthly precipitation which ranged from 0.21 inch in October 1930 to 12.41 inches in September 1934. A comparison of the 48-year monthly average precipitation with the 7-year monthly average shows that the greatest deficiency occurred during July. The average precipitation for August and September during this 7-year period was influenced by the heavy rainfall in 1931, 1933, 1934, and 1935, the maximum average monthly precipitation for these months in those years varying from 7.53 inches to 12.41 inches. These large amounts of rain generally occurred with such intensity that much of the moisture was lost in run-off and the physical condition of the soil was affected. In general, temperature conditions were normal except in 1930, when temperatures were above the average during the summer months.

TABLE 1.—*Actual monthly precipitation, 1929–35, compared with 48-year average monthly precipitation*

Month	1929	1930	1931	1932	1933	1934	1935	7-year average (1929–35)[1]	48-year average[1]
	Inches	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
January	2.84	2.42	1.58	4.98	3.19	2.72	2.52	2.88	3.20
February	3.25	1.98	1.35	2.24	2.27	1.57	2.38	2.15	2.81
March	2.64	2.13	3.84	5.59	3.22	5.49	3.29	3.74	3.50
April	6.48	3.80	2.20	2.45	5.43	2.01	5.19	3.94	3.42
May	2.92	1.05	3.87	4.94	4.37	4.89	4.40	3.87	3.53
June	7.00	2.07	4.75	3.72	3.88	1.66	3.05	3.74	4.02
July	1.06	.38	4.58	2.70	5.51	1.62	3.08	2.50	3.92
August	1.65	.59	7.96	1.53	10.51	4.10	1.68	4.00	4.41
September	2.33	.81	1.22	3.67	1.98	12.41	7.53	4.28	3.21
October	4.43	.21	1.16	6.38	1.07	.52	1.96	2.38	2.70
November	1.93	.66	1.38	5.94	.05	2.91	4.04	2.54	2.40
December	2.70	1.83	2.23	3.47	2.09	3.89	1.02	2.55	3.20
Total	39.32	17.93	36.12	47.61	45.37	43.79	41.34	38.78	40.35

[1] This average is from the Weather Bureau station at College Park, Md., which is about 5 miles from Beltsville.

GROWTH OF THE PASTURES

CONDITIONS AFFECTING GROWTH

Pasture A came up to a good stand in the fall of 1928, but made slow growth as part of the pasture was heavily infested with chickweed, which retarded the grass growth and reduced the stand. On November 21 these areas were sprayed with iron sulphate solution, but the results were not entirely satisfactory, probably due to the low temperatures and extremely high winds immediately after spraying.

Pasture A suffered rather severe injury in the winter of 1928–29, it being estimated that 50 percent of the original stand was winter-killed, recovery was slow during the spring, and chickweed continued to retard the grass growth. To improve the grass stand, an additional seeding of one-half the original grass seed mixture was broadcast on March 13, 1929, along with the seeding of clover and lespedeza. A cultipacker was used to cover the seed and to set the plants which had been heaved during the winter.

The spring-seeded pastures, B and C, came up to a good germination and made rapid spring growth. By July 1 the stand and growth on these pastures was equal to that of pasture A.

The pastures were clipped once in early spring to reduce the chickweed growth and to thicken the turf before grazing was started, June 1. Recovery was rapid after mowing and good growth continued until late summer when lack of moisture was a limiting factor. The ryegrasses and meadow fescue furnished most of the pasturage during the spring and early summer, with redtop, timothy, orchard grass, and Kentucky bluegrass increasing as the season progressed. The legumes were suppressed by the dense grass growth early in the season and by the dry weather in late summer.

When it became apparent that the original seeding of lespedeza had been crowded out by the dense grass growth, 6 pounds of common lespedeza and 4 pounds of Korean lespedeza per acre were seeded in March 1930. Lespedeza germinated well but by late spring it was again crowded out by a thick stand of grass. At the time grazing was started this season the ryegrasses and meadow fescue were 8 inches high with Kentucky bluegrass, timothy, and orchard grass approximately 4 inches. The ryegrass was largely the perennial species, the Italian ryegrass having gone out late in 1929. After the middle of June the pastures did not make any growth because of the drought. The cattle remained on them until September 22, at which time they were obtaining practically no pasturage. It did not seem likely that the pastures would survive such severe drought and high-temperature conditions. In April 1931, however, all pastures had practically recovered except two areas where perennial ryegrass predominated. This grass suffered more from the drought than any other species, and the plants that survived recovered very slowly. By the middle of summer Kentucky bluegrass was established in most of these areas. By the end of the 1931 season the plant cover was as dense as it had been before the drought.

The greatest changes in botanical composition began to appear during the season of 1931, between the fertilized pastures (A and B) and the unfertilized pasture (C). Kentucky bluegrass increased rapidly on the fertilized pastures but some perennial ryegrass remained, while on the unfertilized pasture the perennial ryegrass disappeared almost completely with Kentucky bluegrass, orchard grass, and redtop making up an equal percentage of the cover. The clovers did not recover from the drought of 1930, while lespedeza had not become sufficiently established to add materially to the pasturage on either the fertilized pastures or the unfertilized pasture.

A good spring growth was obtained in 1932. The unfertilized pasture was about 10 days later than the fertilized pastures, with redtop more prominent on the former and Kentucky bluegrass and orchard grass making up most of the cover on the latter. During July and August the grass growth was very slow. Lespedeza furnished 35 percent of the herbage on the unfertilized pasture during the summer months, this being the first year that this legume had been prominent in the mixture. It was not present on the fertilized pastures except in small areas where the grass stand was thin. It is believed that the heavy nitrogen fertilization, which produced a dense turf and growth, suppressed the lespedeza.

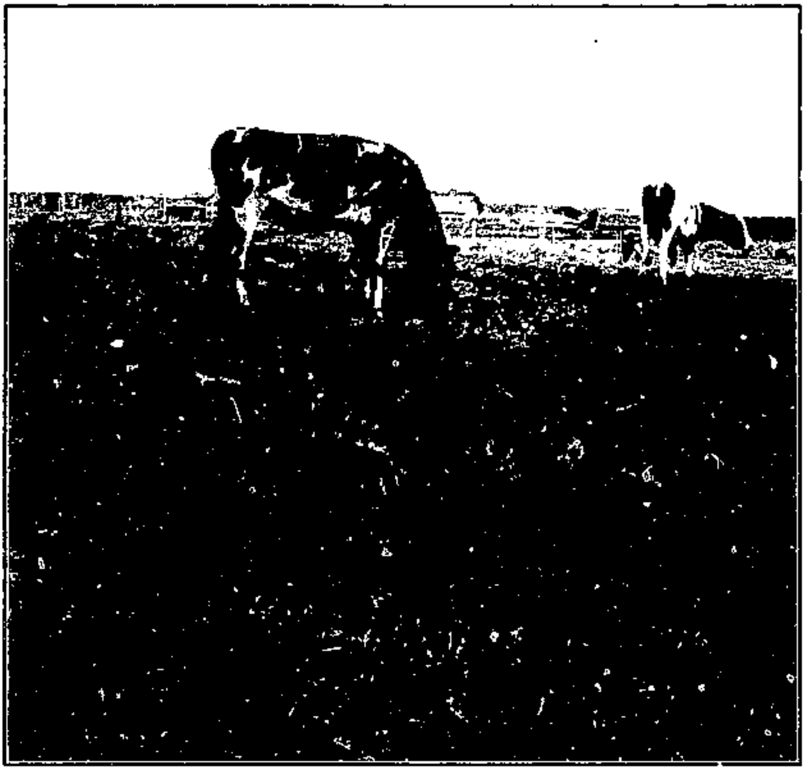

FIGURE 4.—The unfertilized continuously grazed pasture, showing the thick stand of lespedeza, 1933.

In 1933 climatic conditions were ideal for pasturage during the entire season except for a short period in late fall. The fertilized pastures were ready for grazing approximately 2 weeks earlier than the unfertilized pasture. After July 1 this latter pasture furnished as much grazing per acre and, for some periods, more than either of the fertilized pastures. Its comparatively good showing was largely due to the predominance of lespedeza (fig. 4), which was estimated to form 65 to 75 percent of the herbage during August, September, and October. When the pasture yields for these months were calculated in terms of total digestible nutrients, the unfertilized pasture furnished almost 300 pounds more nutrients per acre than the fertilized pastures. Grazing started equally early on all pastures in 1934. The dense growth of lespedeza during the 1933 season, it is believed, was the principal factor in the increase in the early growth of the unfertilized pasture. The lespedeza was not as prominent during the summer months of 1934 as in 1933, probably due to the dense grass growth in early spring. The pastures made rather slow growth in July and part of August, but recovered late in August and made excellent growth, furnishing the best fall pasturage since 1929.

All pastures were ready for grazing at about the same time again in the spring of 1935, and made good growth most of the season except for a short period in August, when lack of moisture reduced production. Lespedeza furnished about 50 percent of the herbage during the summer months of this year on the unfertilized pasture.

RELATIVE AMOUNTS OF GROUND COVER SUPPLIED BY DIFFERENT GRASSES AND LEGUMES

PLANT POPULATION IN THE PERMANENT QUADRATS

Table 2 shows the relative changes in the character of the pastures during the experiment, as determined from the readings of the permanent quadrats on pastures A–2, A–3, A–4, and pastures B and C. The percentage of area considered as being occupied by each kind of grass or legume, the weeds, and the percentage of bare ground, was calculated from the average of the readings made in the spring and fall of each year except 1929, when plant populations were determined by counting the individual plants.

Table 2.—*Initial stands, and the percentages of bare ground and of ground cover supplied by different grasses and legumes, for a period of 7 years, on pastures rotation grazed, continuously grazed, fertilized, and unfertilized*

PASTURE A–2

Item	Plants per square foot in initial stand, 1929 [1]		Area of bare ground or plant cover					
			Rotationally grazed, fertilized			Continuously grazed, fertilized		
	Spring	Fall	1930 [2]	1931	1932	1933	1934	1935
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Bare ground			13.2	28.0	10.2	5.3	5.5	2.8
Kentucky bluegrass	3	3	20.4	53.4	75.9	84.0	83.7	92.5
Canada bluegrass	0	[3] T	.0	.3	.9	.0	.0	.0
Timothy	7	8	23.2	9.0	.5	1.4	2.6	.3
Orchard grass	2	3	8.3	6.6	11.5	8.7	0.0	2.4
Redtop	1	2	9.4	1.3	.7	.0	1.3	.6
Italian ryegrass	3	0	2.4	.0	.2	.0	.0	.0
Perennial ryegrass	3	8	16.1	.7	.1	.3	.0	.0
Meadow fescue	2	2	4.4	.7	.0	.0	.0	.0
Clovers	4	3	.9	.0	.0	.2	.3	.0
Lespedeza	3	T	.0	.0	.0	[3] T	.0	.0
Weeds	4	T	1.7	.0	.0	.1	.6	1.4

PASTURE A–3

Item	Spring	Fall	1930	1931	1932	1933	1934	1935
Bare ground			8.7	32.5	7.9	3.7	7.3	6.0
Kentucky bluegrass	4	5	28.3	54.4	71.4	86.3	77.6	77.8
Canada bluegrass	0	0	.0	1.7	6.7	.3	.9	.0
Timothy	6	4	11.7	5.9	.9	.0	.3	.0
Orchard grass	2	3	4.0	2.6	2.8	.8	.9	.1
Redtop	2	3	10.9	.0	.3	.0	.1	.3
Italian ryegrass	3	T	3.3	.0	3.1	.0	.0	.0
Perennial ryegrass	2	7	10.3	1.7	4.1	2.7	2.1	4.0
Meadow fescue	2	2	1.7	.3	.0	.0	.0	.0
Clovers	7	7	19.7	.0	.4	.3	.4	1.9
Lespedeza	11	0	.0	.0	.0	.0	.0	.0
Weeds	7	1	1.4	.0	2.4	5.9	10.4	9.9

See footnotes at end of table.

TABLE 2.—*Initial stands, and the percentages of bare ground and of ground cover supplied by different grasses and legumes, for a period of 7 years, on pastures rotation grazed, continuously grazed, fertilized, and unfertilized*—Continued

PASTURE A-4

Item	Plants per square foot in initial stand, 1929		Area of bare ground or plant cover					
			Rotationally grazed, fertilized			Continuously grazed, fertilized		
	Spring	Fall	1930	1931	1932	1933	1934	1935
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Bare ground			25.0	49.9	23.9	14.5	7.2	6.8
Kentucky bluegrass	1	3	22.3	24.0	45.1	59.8	60.2	67.7
Canada bluegrass	0	0	.0	.0	2.8	.0	.0	.0
Timothy	3	3	10.8	11.9	3.3	2.7	2.1	1.0
Orchard grass	3	2	6.3	7.9	0.7	7.1	3.0	1.7
Redtop	1	1	1.4	.4	.9	.1	.2	.0
Italian ryegrass	3	1	7.8	.0	3.5	.9	.0	.0
Perennial ryegrass	3	6	15.9	2.1	9.3	3.3	.0	1.6
Meadow fescue	1	2	5.3	3.4	.0	.0	.0	.0
Clovers	4	2	5.2	.1	.4	9.5	14.8	13.5
Black medic	0	0	.0	.0	.0	.0	2.9	2.4
Lespedeza	4	0	.0	.0	.0	(4)	(5)	1.1
Weeds	2	[3] T	[3] T	.3	1.1	2.1	3.6	4.2

PASTURE B

	Spring	Fall	Continuously grazed, fertilized			Rotationally grazed, fertilized		
Bare ground			21.7	21.9	9.4	9.2	8.1	9.4
Kentucky bluegrass	3	3	33.3	36.6	49.9	67.4	46.6	51.0
Canada bluegrass	0	0	.0	.0	3.9	.3	.0	.0
Timothy	0	1	7.1	4.6	.4	1.6	1.1	.5
Orchard grass	5	4	7.8	12.1	13.0	3.2	2.2	2.0
Redtop	1	2	8.3	11.8	11.9	6.0	7.9	7.1
Italian ryegrass	4	1	3.3	.0	.2	.0	.0	.0
Perennial ryegrass	3	5	12.1	8.6	6.5	.0	2.1	4.4
Meadow fescue	2	1	5.6	3.5	.0	.0	.0	.0
Clovers	5	2	.7	.3	.3	1.9	6.2	7.8
Lespedeza	1	0	.0	.2	(6)	4.9	10.6	7.3
Weeds	6	T	.1	.4	4.5	5.5	9.2	10.5

PASTURE C

	Spring	Fall	Continuously grazed, not fertilized					
Bare ground			15.5	24.0	13.0	8.9	14.4	8.1
Kentucky bluegrass	3	1	39.4	26.3	41.9	52.8	51.4	60.8
Canada bluegrass	0	0	.0	.0	.6	.0	.0	.0
Timothy	3	1	3.9	2.6	.9	3.4	3.7	1.8
Orchard grass	6	4	7.2	18.6	21.9	14.9	7.1	4.1
Redtop	1	3	13.9	11.4	11.1	10.5	8.3	7.8
Italian ryegrass	4	1	5.6	.6	.3	.7	.0	.0
Perennial ryegrass	4	5	12.8	6.4	8.0	4.7	.9	2.1
Meadow fescue	3	2	1.7	8.1	.0	.0	.0	.0
Clovers	5	[3] T	[3] T	.0	.0	.0	.3	.3
Lespedeza	2	0	.0	.0	.0	.0	8.6	11.1
Weeds	5	[3] T	[3] T	.0	1.4	4.1	5.3	3.9

[1] Pasture A, fertilized and rotationally grazed; pasture B, fertilized and continuously grazed; pasture C, not fertilized but continuously grazed.
[2] Spring count only.
[3] T=Trace.
[4] 1¼ plants.
[5] 10 plants.
[6] 2.3 plants.

Plants of each species of the mixture sown were present in 1929 on all the pastures, and there was a complete cover of herbage on all quadrats, except the one that had been located in pasture A–4, on an area selected to observe the character of subsequent growths where the plant cover had been reduced by winter killing. The percentage of bare ground in relation to grass cover was highest in the spring of 1931, following the severe drought of 1930, but with more favorable rainfall in the spring and summer of 1931 the grass cover had increased 50 to 75 percent by the fall of that year. It was the only year when striking changes were recorded between the fall and spring estimates.

During other years the variations in cover between spring and fall were influenced by the presence of crabgrass in summer, which reduced the cover of desirable grasses, and the slow recovery during fall, of such grasses as orchard grass, timothy, and redtop. Favorable climatic conditions for the growth of white clover during certain seasons also contributed to some differences in the cover between spring and fall.

While comparisons of the seasonal results (table 2) obtained on the permanently marked quadrats with those on the random-selected areas (table 3) indicate considerable variation in the plant cover, the changes in the permanent quadrats and the random areas from year to year show a trend that is quite similar for all pastures. On the pastures receiving fertilizer, Kentucky bluegrass rapidly became the predominating grass to the virtual exclusion of other grasses. On the unfertilized pasture Kentucky bluegrass also predominated, but with orchard grass and red top contributing a substantial proportion of the grass cover. Timothy and perennial ryegrass persisted to a minor extent in all pastures after the first few years. The reduction in stand of annual lespedeza was influenced more by the heavy fertilizer applications than was the white Dutch clover.

COMPARATIVE RESULTS OBTAINED FROM RANDOM-SELECTED AREAS

The average percentages of ground cover for different grasses or legumes as obtained from the random-selected areas in 1933 and 1935, are given in table 3, for comparison with the data in table 2.

TABLE 3.—*Botanical analysis of random-selected areas (1933 and 1935)*

Item	Bare ground or plant cover					
	1933			1935		
	Pasture A	Pasture B	Pasture C	Pasture A	Pasture B	Pasture C
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Bare ground	5.9	13.1	18.4	7.1	9.3	9.0
Kentucky bluegrass	65.3	58.4	45.3	60.1	70.1	46.0
Timothy	2.2	2.2	9.1	.4	.3	1.7
Redtop	1.6	.9	1.9	2.0	3.3	5.0
Orchard grass	6.0	14.7	12.0	2.2	4.3	13.7
Perennial ryegrass	1.8	1.8	----------	.8	----------	----------
Clovers	13.2	3.6	6.5	12.8	2.6	----------
Lespedeza	(1)	(2)	(3)	.5	3.2	21.0
Weeds	4.0	5.3	6.9	5.1	0.9	3.6

[1] 1 plant per square foot.
[2] 2 plants per square foot.
[3] 8 plants per square foot.

When the estimates of ground cover, based on the random-selected areas of pasture A (table 3) are compared with the estimates based on the three permanent quadrats in this pasture (table 2) for the same years, the greatest difference is in the percentage for Kentucky bluegrass and clover (mostly white Dutch). The random-selected areas showed a significantly higher average percentage of these species than the permanent quadrats.

When a similar comparison is made between the permanent quadrat and the random-selected areas in pasture B and in pasture C, a greater variation between species as well as between different years is shown than was the case for pasture A. Moreover, in 1933 the permanent quadrat, both in pasture B and in pasture C, showed a relatively higher percentage of Kentucky bluegrass than the random-selected areas, while in 1935 the percentage was reversed. This would indicate that in pastures B and C the permanent quadrat was not located on a representative area of the pasture, and that a greater number should be used to obtain an accurate botanical analysis. The data based on random areas only, for the years 1933 and 1935 (table 3) show that at the end of the experiment the only significant difference in plant population between pasture A, which was grazed continuously the last three pasture seasons (1933–35) and pasture B, which was grazed rotationally the last three seasons, was a higher percentage of white clover in pasture A. The same condition was true in 1933, when the grazing practices in the two pastures were reversed.

UNIFORMITY OF GRAZING

One of the advantages claimed for rotation grazing is that the pasturage is grazed more uniformly so that fewer bunches of grass are left ungrazed. Observations for 6 years showed that there is practically no difference in this respect between pastures grazed in rotation and pastures grazed continuously.

CLIPPING THE PASTURES

In June, every year, after some of the grasses had grown up in clumps and formed seeds, the pastures were clipped to get rid of this ungrazed grass and to permit a new and more palatable growth to take its place. Much of the newly mown grass was eaten by the cattle, but any that became bleached by the sun and leached by the rains was apparently avoided entirely. In only one of the six seasons was the yield of clippings sufficient to justify making them into hay and removing them from the fields. In the other five seasons the clippings were allowed to lie in the pastures just as they were mowed.

Only one-half of each of the pastures was clipped in 1935. The purpose of this was to see whether the ungrazed clumps would be eaten eventually, and whether there would be any difference at the end of the season in the uniformity with which the clipped and unclipped portions were grazed. The cattle ate the clumps of tall grass on the unclipped half little by little, and at the same time clumps were reappearing on the clipped half. At the end of the season, it would have been difficult for one to tell which half had been clipped.

The clumps of grass developed for the most part because of the droppings of the cattle. The young growth on such places was refused after it was mowed in the same way as the more mature growth was refused before it was mowed. Clipping is also desirable as a means of controlling weeds, but there is no evidence that clipping of heavily grazed pastures, free of weeds, will serve any useful purpose.

YIELDS OF HERBAGE AS ESTIMATED FROM HAND-HARVESTED AREAS

The annual yields of herbage, expressed in pounds of dry matter, for the experimental pastures, as determined from the yields of hand-harvested areas, are shown in table 4.

TABLE 4.—*Annual yield of herbage per acre (dry-matter basis) on the unfertilized pasture and on different parts of fertilized pastures, according to the form in which nitrogen was applied*[1]

Year	Rotationally grazed, fertilized with—		Continuously grazed, fertilized with—		Continuously grazed, not fertilized, pasture C
	Sodium nitrate, pasture A	Ammonium sulphate, pasture A	Sodium nitrate, pasture B	Ammonium sulphate, pasture B	
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1930	[2] 2,771	[2] 2,771	[2] 2,869	[2] 2,869	2,447
1931	[2] 6,183	[2] 6,183	[2] 6,379	[2] 6,379	5,157
1932	3,535	2,435	[2] 4,163	[2] 4,163	2,823
	Pasture B	Pasture B	Pasture A	Pasture A	Pasture C
1933	2,912	3,140	4,756	4,354	4,291
1934	1,537	1,828	3,078	3,018	2,365
1935	1,559	2,035	2,968	3,174	2,558
Average	3,083	3,065	4,036	3,993	3,274

[1] Average yield on rotation-grazed fertilized pastures for 6-year period was 3,074 pounds per acre; on continuously grazed fertilized pasture, 4,015 pounds.
[2] Yield not taken by individual treatments of nitrate of soda and sulphate of ammonia.

Theoretically, rotation grazing should give an increased production of herbage. From the data given in table 4, however, calculations show that the yield of herbage (dry-matter basis) on rotation-grazed fertilized pasture was only 76.6 percent as much as that on continuously grazed fertilized pasture for the 6-year period.

Observations of herbage and nutrient yields as determined with grazing animals (pp. 25–6) show that pasture A was naturally more productive than pasture B, yet the estimates based on hand-harvesting methods indicate that during the first 3-year period when pasture A was under rotation grazing it produced only 89.0 percent as much herbage (table 4) as pasture B when continuously grazed; during the last 3-year period when the grazing treatments were reversed, pasture B produced 60.9 percent as much as pasture A.

The data showing the yield of herbage undoubtedly were influenced by the difference in the frequency of harvesting by hand. When pastures A and B were under rotation grazing, yields were taken on an average every 17 days, while under continuous grazing the yields were taken every 30 days except the period of flush growth in the spring. This shorter interval between dates of hand-harvesting will give a lower total annual yield, as many previous experiments have indicated. Another factor that makes the figures for the rotation pasture less than they should have been was that the growth made during the 8-day period when the cattle were grazing a pasture was not determined, since the quadrats were not fenced. This growth would be sufficient, especially in the spring, to increase the total yield of herbage materially.

Under continuous grazing the unfertilized pasture produced 81.5 percent as much as the fertilized pasture. The form in which nitrogen was applied seemed to make little difference. On pasture A nitrate of soda produced 6.2 percent more herbage than sulphate of ammonia, while on pasture B sulphate of ammonia produced 5.1 percent more herbage than nitrate of soda.

CHEMICAL COMPOSITION OF THE HERBAGE

Table 5 shows the average chemical composition of the herbage harvested at various periods from the fertilized pastures (A and B) during the 3-year period, 1933–35, when pasture A was grazed continuously and pasture B was rotationally grazed. Table 5 also shows the composition of that harvested from the unfertilized pasture C in the same 3-year period. The herbage was plucked by hand, as described under Estimation of Herbage Yields from Harvested Quadrats, with an effort to obtain samples representative of that consumed by the cattle. The analyses of the herbage from the rotation-grazed fertilized pasture represent composite samples harvested from the six units of pasture B during each complete rotation of the cattle over all six units. Each unit received on an average eight grazing rotations during the pasture season. The analyses of herbage from the continuously grazed fertilized pasture—that is, pasture A when continuously grazed—represent composites of samples taken in the six different areas at each date of harvest. Those for the pasture that was continuously grazed but not fertilized (pasture C) were taken from two different areas at each date of harvest.

TABLE 5.—*Average chemical composition of the herbage (dry-matter basis) on the three different pastures during the 3-year period, 1933–35*

ROTATION-GRAZED, FERTILIZED PASTURE B

Form in which nitrogen was applied, and period of analysis	Ash	Ether extract	Crude fiber	Crude protein	"True" protein	Non-protein nitrogen	Nitrogen-free extract	Calcium	Phosphorus
Sodium nitrate:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
First rotation	8.81	4.71	21.77	18.62	16.03	1.95	46.73	0.48	0.47
Second rotation	8.77	3.95	26.48	17.33	14.50	2.13	44.18	.38	.48
Third rotation	10.01	5.17	24.25	19.20	16.66	1.91	42.00	.52	.50
Fourth rotation	9.42	5.34	24.70	15.05	13.43	1.22	45.00	.57	.47
Fifth rotation	8.74	5.26	24.46	14.43	12.75	1.26	47.53	.60	.44
Sixth rotation	8.06	5.21	23.23	19.72	16.59	2.35	44.50	.55	.50
Seventh rotation	9.16	5.69	22.30	21.03	18.60	1.83	42.41	.43	.56
Eighth rotation	10.49	5.24	21.55	18.74	16.54	1.66	44.53	.48	.50
Average	9.18	5.07	23.59	18.02	15.64	1.79	44.73	.50	.49
Ammonium sulphate:									
First rotation	8.55	4.86	22.19	18.79	16.01	2.10	46.31	.48	.48
Second rotation	9.02	4.00	28.60	18.25	15.09	2.37	40.91	.37	.50
Third rotation	10.02	5.11	25.40	18.58	16.26	1.74	41.40	.48	.51
Fourth rotation	9.41	5.17	20.14	14.12	12.42	1.26	45.57	.51	.47
Fifth rotation	8.99	5.43	25.78	13.34	11.87	1.09	46.83	.50	.47
Sixth rotation	8.53	5.24	23.85	18.99	16.76	1.67	43.95	.48	.51
Seventh rotation	8.96	5.68	23.95	20.03	17.84	1.65	41.93	.46	.58
Eighth rotation	10.03	5.13	22.91	18.22	16.28	1.46	44.19	.42	.50
Average	9.19	5.08	24.85	17.54	15.32	1.07	43.89	.46	.50

TABLE 5.—*Average chemical composition of the herbage (dry-matter basis) on the three different pastures during the 3-year period, 1933–35*—Continued

CONTINUOUSLY GRAZED, FERTILIZED PASTURE A

Form in which nitrogen was applied, and period of analysis	Ash	Ether extract	Crude fiber	Crude protein	"True" protein	Non-protein nitrogen	Nitrogen-free extract	Calcium	Phosphorus
Sodium nitrate:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
April	8.51	4.87	23.32	20.31	16.97	2.52	43.82	0.61	0.50
May	9.10	3.63	27.73	17.30	13.34	2.97	43.22	.48	.49
June	9.15	4.76	25.19	15.97	13.21	2.07	45.50	.68	.46
July	8.38	5.54	23.35	17.31	14.94	1.78	46.00	.62	.48
August	8.27	5.92	24.44	20.32	17.08	2.44	41.85	.58	.52
September	8.95	5.60	21.83	23.00	19.13	2.91	41.60	.66	.52
October	10.16	5.03	17.30	22.93	20.09	2.14	45.29	.57	.46
Average	8.93	5.05	23.31	19.59	16.39	2.40	43.90	.60	.49
Ammonium sulphate:									
April	8.31	4.79	23.13	20.42	16.95	2.62	44.22	.66	.49
May	8.58	3.60	28.62	15.97	12.74	2.45	44.01	.45	.49
June	8.40	4.95	25.14	16.96	14.33	1.98	45.19	.68	.45
July	7.90	5.45	24.65	15.07	13.40	1.25	47.35	.58	.45
August	7.98	5.77	24.04	21.20	17.54	2.75	42.01	.54	.50
September	8.60	5.57	22.34	22.11	17.90	3.17	42.42	.66	.55
October	9.39	4.98	18.76	20.22	17.90	1.74	47.23	.52	.45
Average	8.44	5.02	23.81	18.85	15.82	2.28	44.63	.58	.48

CONTINUOUSLY GRAZED, UNFERTILIZED PASTURE C

Period of analysis	Ash	Ether extract	Crude fiber	Crude protein	"True" protein	Non-protein nitrogen	Nitrogen-free extract	Calcium	Phosphorus
April	8.39	4.57	24.51	15.93	13.61	1.76	47.19	0.50	0.46
May	9.54	3.46	28.39	12.87	10.57	1.73	46.30	.44	.41
June	8.96	4.79	25.75	14.88	12.76	1.60	46.15	.75	.45
July	7.06	5.42	21.85	18.62	16.05	1.93	47.70	.92	.43
August	7.36	5.70	21.57	20.63	17.55	2.31	45.50	.84	.46
September	7.92	5.81	21.45	21.92	18.69	2.43	43.71	.80	.49
October	8.97	4.44	20.41	17.84	16.04	1.36	48.78	.72	.42
Average	8.31	4.88	23.42	17.53	15.04	1.87	46.48	.71	.45

The fertilized pastures produced herbage higher in crude protein early in the season than the unfertilized pasture (table 5). As the growth of anual lespedeza increased early in July on the latter pasture, the percentage of crude protein in the herbage increased rapidly, and continued to maintain a comparatively high level until the end of the season. As a result, the average seasonal composition of the herbage on this pasture compares quite favorably with that of the herbage on the fertilized pastures. The average percentage of crude protein was higher and the crude fiber lower for herbage on the continuously grazed fertilized pasture than for that on the rotation-grazed fertilized pasture, although the herbage was harvested more frequently on the latter pasture. The averages for crude fiber content of all samples were 23.56 percent for the continuous pasture and 24.22 percent for the rotation pasture; those for crude protein were 19.22 percent for the continuous pasture and 17.78 percent for the rotation pasture.

The calcium and phosphorus content was sufficiently high at all times for the nutritional requirements of the cattle. The amount of calcium, which was lowest during May, varied more during the season than the phosphorus content, which was quite uniform.

These data indicate that under the conditions of this experiment the herbage on a pasture grazed continuously is as high in feeding value, as indicated by its chemical composition, as that on a similar pasture grazed in rotation, when both pastures are fertilized in the same manner and grazed with similar groups of cattle. Also, with herbage from an unfertilized pasture in which annual lespedeza maintains an optimum stand and growth along with desirable grasses, it appears that the composition will be equally as high in feed nutrients in the summer and fall as with herbage from a fertilized pasture.

PASTURE YIELDS AS MEASURED WITH DAIRY CATTLE

Results of the work with dairy cattle in this investigation are contained in tables 6 and 7. Table 6 shows the dates and days of grazing, the supplementary feed, production of milk, gain or loss in weight, nutrients required, nutrients credited to pasture, and the percentage of total nutrients required that were furnished by the pasturage. Table 7 shows the yields of digestible nutrients by months for the different pastures. The data in both tables are stated on an acre basis. The averages in table 7 are also shown graphically in figure 5.

TABLE 6.—*Record on a per-acre basis, of grazing, supplementary feed, production of milk, and butterfat, gains or losses in live weight, digestible-nutrient requirements, and nutrients credited to pastures when rotation-grazed and fertilized, when continuously grazed and fertilized, and a pasture continuously grazed but not fertilized*

Year	Pasture	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—				Proportion of total nutrient requirements supplied in supplementary feeds per acre		Digestible nutrients credited to pasture per acre
		Date begun	Date ended	Days			Concentrates eaten— By cows	Concentrates eaten— By heifers	Hay eaten— By cows	Hay eaten— By heifers	Milk	Butterfat	Cows	Heifers	For maintenance	For milk production	For gain in weight	Total			
				No.			*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Pct.*	*Lb.*
ROTATION-GRAZED, FERTILIZED																					
1930	A	Apr. 15	Sept. 22	161	108	67	698	246	203	7	3,094	127.35	+18	+52	1,428	1,103	193	2,724	810	29.7	1,914
1931	A	Apr. 28	Oct. 11	167	120	119	897	504	294	0	4,081	145.53	+2	+98	2,019	1,321	240	3,580	1,189	33.2	[1] 2,600
1932	A	Apr. 16	Oct. 18	186	126	126	657	310	0	0	3,194	110.12	−2	+88	2,149	1,006	219	3,374	717	21.3	2,657
1933	B	Apr. 14	Oct. 18	188	135	134	821	49	0	0	3,781	131.23	+3	+69	2,345	1,199	178	3,722	642	17.2	3,080
1934	B	Apr. 24	Oct. 31	191	138	138	1,164	218	[2] 178	0	3,671	139.43	+2	+118	2,250	1,238	270	3,758	1,056	28.1	2,702
1935	B	Apr. 23	Oct. 18	179	109	109	908	255	[2] 356	[2] 82	3,150	126.37	+42	+101	1,724	1,102	357	3,183	940	29.5	2,243
Average	------	Apr. 20	Oct. 15	179	123	115	857	264	------	-------	3,495	130.00	+11	+88	1,986	1,162	243	3,390	892	26.3	2,533
CONTINUOUSLY GRAZED, FERTILIZED																					
1930	B	Apr. 15	Sept. 22	161	80	62	501	249	157	8	2,462	94.68	+19	+60	1,296	836	208	2,340	643	27.5	1,697
1931	B	Apr. 28	Oct. 11	167	108	107	533	443	323	0	2,819	106.46	−44	+113	1,771	944	119	2,834	890	31.4	[1] 2,073
1932	B	Apr. 16	Oct. 18	186	107	106	644	273	0	0	2,897	108.68	−53	+112	1,826	975	98	2,899	678	23.4	2,221
1933	A	Apr. 14	Oct. 18	188	131	129	797	57	0	0	3,642	132.72	+27	+71	2,222	1,193	265	3,680	637	17.3	3,043
1934	A	Apr. 24	Oct. 31	191	132	132	1,052	330	[2] 137	0	3,302	125.74	+13	+127	2,168	1,114	327	3,609	1,057	29.3	2,552
1935	A	Apr. 23	Oct. 18	179	120	120	999	309	[2] 340	[2] 77	2,953	119.40	+18	+104	1,891	1,036	289	3,216	1,032	32.1	2,184
Average	------	Apr. 20	Oct. 15	179	113	109	754	277	------	-------	3,012	114.61	−3	+98	1,862	1,016	218	3,096	823	26.6	2,295
CONTINUOUSLY GRAZED BUT NOT FERTILIZED																					
1930	C	Apr. 15	Sept. 22	161	75	53	546	182	161	9	2,309	84.89	−27	+24	1,047	762	1	1,810	630	34.8	1,180
1931	C	Apr. 28	Oct. 11	167	77	76	422	253	239	0	2,309	87.96	−14	+70	1,266	779	111	2,156	624	28.9	[1] 1,659
1932	C	Apr. 26	Oct. 18	176	73	73	359	77	0	0	1,731	63.99	−3	+68	1,128	573	139	1,840	323	17.6	1,517
1933	C	Apr. 27	Oct. 18	175	103	101	722	20	0	0	3,152	120.58	+35	+107	1,839	1,069	375	3,283	549	16.7	2,734
1934	C	Apr. 24	Oct. 31	191	118	118	1,111	382	[2] 200	0	3,156	124.09	+45	+122	1,891	1,091	405	3,387	1,138	33.6	2,249
1935	C	Apr. 23	Oct. 18	179	97	97	836	278	[2] 216	[2] 56	2,757	113.66	+48	+106	1,556	980	392	2,928	876	29.9	2,052
Average	------	Apr. 24	Oct. 15	175	90	86	666	199	------	-------	2,569	99.19	+14	+83	1,454	876	237	2,567	690	26.9	1,898

[1] Includes nutrients in hay that was cut from pastures, but not fed to cows in this experiment: 209 pounds, pasture A, 129 pounds, pasture B, and 127 pounds, pasture C.
[2] Silage.

TABLE 7.—*Quantities of digestive nutrients per acre obtained from the experimental pastures, by months*

ROTATION-GRAZED, FERTILIZED

Year	Pasture	Yield of total digestible nutrients per acre						
		April	May	June	July	August	September	October
		Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1930	A	443	996	264	88	82	40	0
1931	A	0	691	406	212	384	478	220
1932	A	183	1,077	455	412	181	171	179
1933	B	269	1,095	318	313	400	472	204
1934	B	123	752	290	269	205	409	655
1935	B	151	768	381	133	296	278	238
Average		195	896	352	238	259	308	249

CONTINUOUSLY GRAZED, FERTILIZED

Year	Pasture	April	May	June	July	August	September	October
1930	B	460	771	233	123	63	46	0
1931	B	0	633	314	182	346	455	12
1932	B	115	903	334	338	149	188	194
1933	A	330	799	433	435	331	562	153
1934	A	100	708	327	235	129	331	661
1935	A	140	660	383	318	177	286	211
Average		191	757	337	272	199	311	205

CONTINUOUSLY GRAZED, UNFERTILIZED

Year	Pasture	April	May	June	July	August	September	October
1930	C	251	515	200	68	103	44	0
1931	C	0	501	281	119	324	273	30
1932	C	58	629	199	237	187	130	77
1933	C	83	747	189	387	482	584	282
1934	C	75	506	207	261	235	302	453
1935	C	108	501	288	278	329	317	240
Average		96	577	243	225	272	285	180

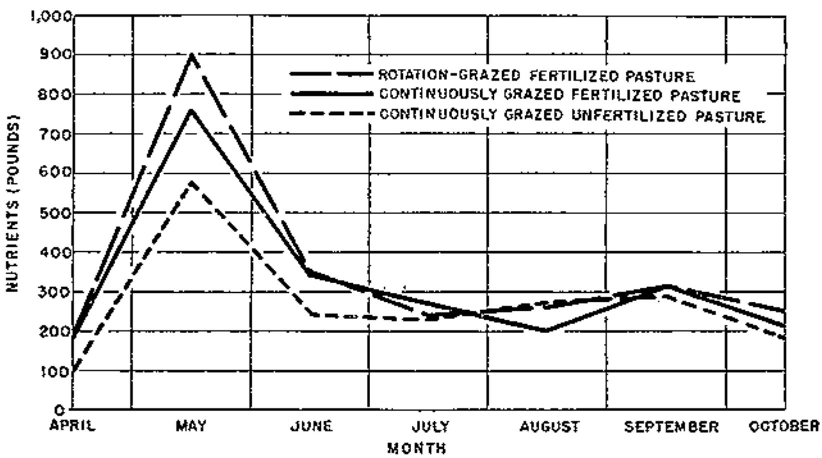

FIGURE 5.—Comparative monthly yields of total digestible nutrients as measured by grazing dairy cattle.

The supplementary feed (table 7) for the most part was concentrates, although a small amount of hay was fed the first 2 years and a small amount of silage the last 2 years. A little less than 27 percent of the total amount of nutrients required was provided by the supplementary feeds. The exact percentages for the different pastures were as follows: Rotation-grazed, fertilized, 26.3; continuously grazed, fertilized, 26.6; continuously grazed but not fertilized, 26.9. The ratio of grain fed to milk produced by the cows on the different pastures for the 6 years was 1:4.1; 1:4.0, and 1:3.9, respectively.

YIELDS OF MILK AND GAINS OR LOSSES IN LIVE WEIGHT

The average daily production per cow was 28.4 pounds of milk testing 3.72 percent butterfat on the rotation-grazed fertilized pasture; 26.7 pounds testing 3.81 percent on the continuously grazed fertilized pasture; and 28.5 pounds testing 3.86 percent on the continuously grazed unfertilized pasture. The average yields of milk for the season on the acre basis were 3,495, 3,012, and 2,569 pounds for the three pastures, respectively (table 6).

The average gains in weight of cows and heifers together for the season on an acre basis were very nearly the same for the three pastures. These were 99, 95, and 97 pounds, respectively.

GRAZING AND SUPPLEMENTARY FEEDING

The date cattle were first turned on the fertilized pastures in the spring varied with the different years, from April 14 to April 38, the average date for the 6 years being April 20 (table 6). In four of the six years, cattle were turned on both the unfertilized pasture and the fertilized pastures on the same date. In two of the years, grazing started 10 and 13 days later on the unfertilized pasture than on the fertilized pastures. While grazing was started on the unfertilized pasture only 4 days later than on the fertilized pastures, on the average, it is probable that the growth on the fertilized pasture was a little more than 4 days in advance of that on the unfertilized pasture, but probably not more than 10 days in advance. The early spring growth on the unfertilized pasture is attributed to the nitrogen stored the previous season by the lespedeza, which acted in the same way as the nitrogen applied in the form of fertilizer.

The length of the grazing season for all pastures varied with the different years from 161 to 191 days, with an average of 179 days for the fertilized pastures and 175 days for the unfertilized pasture.

The number of days' grazing supplied to the heifers was only slightly less than the number of days' grazing that was supplied to the cows. The total number of days' grazing per acre supplied to both cows and heifers combined was 238 for the rotation-grazed fertilized pasture; 222 for the continuously grazed fertilized pasture; and 176 for the continuously grazed unfertilized pasture. As the average weight of the cows and heifers combined lacked less than 50 pounds of being 1,000 pounds, which is the standard weight for estimating the unit days (*18*) of grazing, the sum of figures given for days' grazing by cows and heifers will also approximate the unit days of grazing.

COMPARATIVE YIELDS OF NUTRIENTS

The average quantity of digestible nutrients credited to rotation-grazed fertilized pasture for 6 years was 2,533 pounds per acre per season, and that credited to the continuously grazed fertilized pasture was 2,295 pounds (table 6).

Apparently rotation grazing at Beltsville resulted in a 10.4-percent increase in yield of digestible nutrients. Rotation grazing with dairy cattle increased the yield of digestible nutrients 8.9 percent at the Western Washington Experiment Station (*8*) and 1 percent at the Virginia Agricultural Experiment Station (*9*). On the other hand, two experiments (*3*, *14*) with beef cattle showed that continuous grazing was superior to rotation grazing in the amount of beef produced per acre.

The fertilizers used and the quantities applied per acre were stated under Plan of Investigation (p. 9). The pastures that received fertilizer were heavily treated during the first 3 or 4 years of the experiment, but were less liberally treated in the remaining years. As previously described, the amount of nitrogen fertilizer applied in 1930 was reduced on account of the drought. Also, fewer applications were made in subsequent years than at first because it was found that applications later than June did not benefit the growth of grass materially for the rest of the season.

The comparison of pasture yields to determine the influence of fertilizers should properly be made between pastures B and C, as was explained in the plan of investigation (p. 5). Since pasture B was grazed in rotation the last 3 years, however, and pasture C was grazed continuously every year, the yields of pasture B for the last 3 years must be adjusted to a continuously grazed basis. This adjustment was made by dividing the 3-year yields of pasture B by the factor 1.104, since the ratio of continuous to rotation grazing yields was 1.00:1.04. The yield for fertilized pasture then became 2,210 pounds of digestible nutrients per year per acre, as compared with 1,898 pounds for unfertilized pasture. The application of fertilizers increased the yield 16.4 percent. It is thought that the increase due to the application of fertilizer would have been somewhat greater if the kinds of plants that made up the herbage in the unfertilized field had been the same as those in the fertilized field. The yields of the unfertilized pasture were no doubt greatly improved by the growth of common lespedeza, which came into the unfertilized pasture to a much greater extent than it came into the fertilized pasture. It is not known at present whether the lespedeza could be depended upon to come into other pastures in this latitude, when they are managed similarly to this unfertilized pasture.

The combined effect of rotation grazing and the application of fertilizers was also determined by comparing the yields of pastures B and C. In making this comparison, the yields of pasture B for the first 3 years were multiplied by 1.104 to adjust them to the rotation-grazed basis. The relative yields of the two pastures, after this adjustment was made for B, are 2,440 pounds per year per acre for the rotation-grazed fertilized pasture and 1,898 pounds for the continuously grazed unfertilized pasture. This indicates that the increases due to fertilization and rotation grazing was 28.6 percent.

MONTHLY YIELDS OF DIGESTIBLE NUTRIENTS

Table 7 and figure 5 were prepared to show the yields of digestible nutrients by months throughout the season. The purpose was to determine whether either rotation grazing or the application of fertilizers tended to make the yields from month to month any more uniform. The unfertilized pasture yielded at the most uniform rate throughout the season. This was because the peak growth in May was less than that of the other pastures and because the common lespedeza increased the yields from July on. Rotation grazing had little or no influence on the uniformity of yields from month to month.

It is admitted that the variations in yields from month to month cannot be measured with the greatest accuracy by the methods followed, because it was impossible to have the pastures all grazed to the same degree of closeness at the end of each month. Furthermore, the pastures were all grazed shorter as the season progressed. For this reason, the growth early in the season was greater and that later in the season was less than the results indicate.

ECONOMIC COMPARISON OF RESULTS

DID ROTATION GRAZING PAY?

To determine the relative economy of rotation grazing and continuous grazing, the quantity of the additional digestible nutrients obtained by rotation grazing must be converted to the equivalent in a feed or feeds of known market value and of similar milk-producing ability. The value of such feed or feeds must then be compared with the cost of fencing the pasture into the smaller pastures, and perhaps also the cost of providing shade and water in each pasture. In this investigation the rotation grazing resulted in an additional yield per acre of 238 pounds of digestible nutrients. This quantity of digestible nutrients would be contained in 473 pounds of alfalfa hay or 339 pounds of wheat bran. For example, the average cost of raising 473 pounds of alfalfa hay is $2.36.[4] The average purchase price of 473 pounds of No. 1 alfalfa at Beltsville, for the years 1931–35, was $5.22.[5] The average purchase price of 339 pounds of wheat bran for the past 10 years was $4.71.[6] Whether these values per acre of pasture would be sufficient to compensate a farmer for the expense of fencing his pasture into six subdivisions is something that cannot be answered categorically. Another thing that must be borne in mind is that the pastures in this investigation were at least twice as productive as the average bluegrass pasture. The same percentage increase for rotation grazing applied to pastures only one-half so productive as the pastures in this investigation, would make the value of the increased nutrients only half as much as stated above. It is doubtful, therefore, if rotation grazing can be advocated for pastures of less than medium productivity unless the fencing costs and other expenses incident to the subdivision of the pasture can be kept very low.

On the other hand, if the pasture is above the average in productivity and an inexpensive type of fence is used, it appears that it would pay to cross-fence the pasture into a number of subdivisions. The electric fence offers one means of lowering the cost of fencing.

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[4] Average of costs from farm surveys in New York and Ohio $9.97 a ton.
[5] $22.07 a ton.
[6] $27.77 a ton at Philadelphia.

Under the conditions of this investigation it is estimated that the value of the increased pasturage greatly exceeded what cross-fencing with an electric fence would have cost.

Because of the location of the pastures and the inaccessibility of water and shade, six subdivisions of the pasture may be too many to be practicable on many of the dairy farms of this country. An investigation is now in progress to compare a three-pasture rotation with continuous grazing. The rotation pastures are being grazed 1 week in every 3.

DID THE HEAVY APPLICATION OF FERTILIZERS PAY?

It appears that the question of whether heavy applications of fertilizers pay can be answered satisfactorily for conditions similar to those at Beltsville. However, the information obtained at Beltsville concerning the use of fertilizers will not be as widely applicable as the information obtained about rotation grazing. The kinds and quantities of fertilizers to use are dependent to a great extent upon the soil and climatic conditions. Naturally, these vary widely in different parts of the United States.

The cost of the fertilizer applied per acre during the 6 years was as follows: 1930, $11.92; 1931, $12.19; 1932, $9.75; 1933, $7.14; 1934, $2.88; 1935, $2.88; and total for the 6 years, $46.76.

Since the total cost for the 6-year period was $46.76, the average cost per acre per year was $7.79. In return for this expense the quantity of digestible nutrients obtained was 312 pounds. This quantity of nutrients would be contained in 620 pounds of alfalfa hay or 444 pounds of wheat bran. If alfalfa hay could have been bought or raised for less than $25.14 a ton or wheat bran could have been bought for less than $35.09 a ton, it would have been better to use these feeds to provide this quantity of digestible nutrients than to have obtained it from pasture by the application of fertilizers.

The application of fertilizers of the kinds and in the amounts specified in this investigation did not pay under the conditions prevailing at Beltsville. One reason for this, and perhaps the principal one, is that common lespedeza came into the unfertilized pasture and materially increased the yield. Neither common lespedeza nor any other legume comprised any considerable part of the herbage of the fertilized pastures.

The phase of this investigation concerned with the use of fertilizers is being continued. In addition, a series of plots in a separate pasture are being devoted to the problem of finding out what kinds and quantities of fertilizers will be profitable. It is certain that pastures will in time decline in fertility and in productivity unless as much plant food is returned to the soil as is removed by the grazing animals. For this reason, it appears that judicious applications of fertilizers should be profitable. The question is what kinds and amounts to apply.

DID THE HOHENHEIM SYSTEM PAY?

The combined increase due to rotation grazing and the use of fertilizers was 542 pounds of total digestible nutrients per acre. This quantity of nutrients would be contained in 1,078 pounds of alfalfa hay or 772 pounds of wheat bran. The average cost of raising 1,078 pounds of alfalfa hay is $5.37;[7] the purchase price of this quantity of No. 1 alfalfa hay is $11.90;[8] and 772 pounds of wheat bran, $10.72.[9] If from these prices is deducted $7.79, the cost of the fertilizer, it can be seen that the Hohenheim system, under the conditions of this experiment, is of doubtful economic value, and this is particularly the case if the comparison is made between the cost of the fertilizer for the increased yields of pasture nutrients and the cost of obtaining an equal quantity of nutrients in home-grown alfalfa hay, rather than in purchased hay or bran.

SUMMARY

Three fields of 12, 4, and 4 acres, respectively, in a good state of productivity were used in an investigation of the Hohenheim system of pasture management for dairy cattle.

A good 2-year-old stand of alfalfa on all the fields was plowed under, and the fields were seeded with a complex pasture mixture of grasses and legumes.

One pasture was divided into six equal units, heavily fertilized each year with a complete fertilizer, and the units were grazed in rotation; another pasture was fertilized in a similar manner but was grazed continuously; the third pasture was unfertilized and grazed continuously.

After 3 years the method of grazing the first two pastures was reversed, and the experiment with all three pastures was continued for another 3 years.

Except for 1 dry year, 1930, the climatic conditions were not very different from the average of 48 years.

On the two fertilized pastures the growth of the grasses suppressed the legumes, and in a few years Kentucky bluegrass was predominating. Orchard grass and redtop were the most prominent of the other grasses remaining.

On the unfertilized pasture most of the grazing in spring was furnished by Kentucky bluegrass, orchard grass, and redtop; and in summer by common lespedeza.

Ungrazed clumps were as prominent in a pasture that was grazed in rotation as in a pasture that was grazed continuously.

The yields of herbage harvested by hand from protected spots were greater on continuously grazed pasture than on rotation-grazed pasture. The more frequent harvesting of the herbage is thought to have reduced the yield of rotation-grazed pasture. This result shows some of the difficulties that may be encountered, and indicates the necessity for exercising particular care in measuring the yields of hand-harvested, caged areas, if such areas are to be used as the basis for measuring grazing yields.

The results obtained indicate that rotation grazing by dairy cows and heifers increased the yield of total digestible nutrients 10.4 percent; that heavy fertilization increased the yield 16.4 percent; and that both rotation grazing and heavy fertilization combined increased the yield 28.6 percent.

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[7] Same as footnote 4, p. 29.
[8] Same as footnote 5, p. 29.
[9] Same as footnote 6, p. 29.

The fact that common lespedeza came into the unfertilized field to a much greater extent than into the fertilized fields is no doubt responsible in large measure for the relatively good showing of the former.

Heavy fertilization failed to improve the uniformity of carrying capacity throughout the grazing season.

It appears likely that on most dairy farms in the United States, an increase of 10 percent in the yield of nutrients obtained from a pasture by rotation grazing would not be sufficient to justify the construction of permanent division fences of the usual type and to provide the necessary shade and water in each pasture. It is sufficient, however, under many conditions to justify the construction of a cheaper type of fence.

The application of large quantities of a complete fertilizer was not profitable.

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