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Tennessee roughage experiments with dairy cattle

Norman Ray Thompson

To the Graduate Council:

I am submitting herewith a thesis written by Norman Ray Thompson entitled "Tennessee roughage experiments with dairy cattle." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

C. E. Wylie, Major Professor

We have read this thesis and recommend its acceptance:

Marshall C. Hervey, S. A. Hinton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 1, 1942

To the Committee on Graduate Study:

I am submitting to you a thesis written by Norman Ray Thompson entitled "Tennessee Roughage Experiments with Dairy Cattle". I recommend that it be accepted for nine quarter hours credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Dairying.

C. E. Wylie
Major Professor

We have read this thesis
and recommend its acceptance:

Marshall C. Hervey

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Accepted for the Committee

H P Smith
Dean of the Graduate School

TENNESSEE ROUGHAGE EXPERIMENTS

WITH DAIRY CATTLE

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

Norman Ray Thompson

August, 1942

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--Norman R. Thompson

TABLE OF CONTENTS

PAGE

PAGE

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The development of cattle raising in all countries is characterized sooner or later by the cultivation of improved grasses and legumes for forage. The introduction of clovers from the Netherlands was said to be a great step forward in the English agriculture. The spread of alfalfa, originally a desert plant of southwestern Asia, then introduced in succession to Greece, Italy, Spain, the western parts of the Americas, and finally the humid regions, has benefited the livestock industry perhaps more than any other plant except corn. Likewise, the use of other legumes such as sweet clover and lespedeza has aided dairying. The same may be said for many of the improved grasses.

The use of roughages for feeding dairy cattle has undergone several changes. Native pastures were supplemented with grass hays very early. The high yields and high protein contents of legume hays have led, more recently, to their frequent although not general use in place of grass hays. Silages had their start in the early days--when hay quality was probably poorer than today. General use of legume hays and improvements in harvesting have removed most of the advantage in feeding value which silages once may have posessed. The development of pasture crops and systems, particularly in the South, has recalled attention to the original, and still best source of roughage for dairy cows, namely pastures.

Several factors make study of roughages for dairy cattle in the South especially desirable. The climate, the soils and topography, the growth of dairying, the need for more dairy products in the Southern diet and the present war emergency are all factors. These will be discussed briefly with especial reference to the State of Tennessee.

Tennessee is in a region of heavy rainfall, averaging about 50 inches a year (62). The climate is mild, about 60° F. is the average annual temperature, and the soil is frozen for only a few days each winter. These conditions favor rapid erosion, also the rapid loss of soluble calcium and phosphates. A program of soil conservation is indicated, and the long growing season of 170 to 225 days favors development of an extensive system of forage crops, both for erosion control and for feed.

In general, the soils of Tennessee vary greatly in fertility (62). Those on the western Plateau Slope and those of the Central Basin are very productive. The broken topography and lower fertility of regions such as the Valley of East Tennessee, for instance, make them less productive and therefore better adapted to enterprises such as dairying than to grain and cash crops.

Numbers of milk cows and manufacturers of dairy products have increased faster in the South of late years than in the Northern Dairy Region (26). The trend is especially pronounced in recent months (1941-42). In order to meet the need for additional products for Lend-Lease export, the Federal Government has asked the South to increase production more than would be possible in other regions.

Before the present war emergency, shipments of dairy products from the South to principal Northern markets were relatively small (26). The further fact that shipments did not increase in the past decade, this in spite of increasing production, suggests that home consumption was on the increase. There is evidence, however, that still more dairy products are needed before the Southern diet contains optimal, in some cases minimal, amounts for good health and growth.

PART I

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Importance of the Problem; Experiments with Roughages for Dairy Cattle

As of January 1, 1942, there were 26 million milk cows in the United States (87). The U. S. Farm Census for 1935 (88) showed one billion acres in farm land, of which 517 million were in pasture and another 68 million in hay crops. The growing of roughages, then, employs more than 50 percent of all farm land in the United States. Further evidence of the importance of the roughage problem is found in the numerous hay, silage, and pasture experiments at many stations. Work with hays includes feeding values of hay crops, digestibility, mineral and vitamin values, and use of silages and concentrates to supplement hays. Experiments with silages include feeding values of silage crops, feeding values as compared to hay and pasture, and on whether or not silage is needed in dairy rations. Pasture studies include those on yields, on feeding values of pasture crops, on cultural practices such as irrigation and use of fertilizers, on rotation systems, and on development of year-round pastures. Several workers have shown the possibilities of all-roughage rations for dairy cattle. Others have attempted to grow cattle on rations of concentrates alone, with unsuccessful but interesting results.

It would seem, from the numerous experiments, that little remains to be done. On the contrary, however, we need to study local situations much further and to develop a universal appreciation of the great feeding value of young, rapidly growing forage plants.

Dairy Cattle Need Roughages

Dairy cattle not only need, but commonly are given roughage as their main source of nutrients. Pastures are used, almost without exception, wherever and whenever available. Hay is the principal feed for non-pasture periods, with silage quite frequently given. Attempts to grow cattle on milk and concentrates have failed in every instance, and further investigations have revealed several nutritive needs of dairy cattle that only rough feeds can supply.

Roughage for Calves. Davenport (15) tried to raise four calves on diets of skim milk and equal parts of corn and oats. Each calf developed a ravenous appetite at first, followed by enlargement and stiffening of the joints and later by dizziness and difficult locomotion. The calves finally became indifferent to feed. One calf was given roughage at six months and became normal again at eight.

McCandlish (64) tried growing calves on milk alone, on milk and grain, and on milk and alfalfa hay. Those on milk showed depraved appetite, joints weak and later becoming stiff, skin sensitive when touched, and an emaciated condition due to lack of body fat. The milk-and-grain group developed similar symptoms, but even more rapidly than the milk group. One calf finally died from non-specific septicemia. Calves on milk and alfalfa hay grew satisfactorily, while adding alfalfa to either the milk or milk-and-grain rations would bring calves on such rations back to normal. Meade and Regan (65) raised calves to 19 months of age without roughage when cod liver oil and alfalfa ash were added to the ration. Huffman (49) cites work at the Minnesota Station in which adding cod liver oil to a concentrate ration did not furnish factors found in roughage. He also reports work at the Michigan Station in which mineral supplements failed to prevent convulsions in calves due to lack of roughage. Herman (43) reports that calves fed on milk plus cod liver oil and mineral supplements made supernormal growth, but would live only to 12 or 15 months of age.

What These Experiments Revealed. Davenport (15) suggested that roughages were necessary for the proper physiologic functioning of the digestive system of ruminants. McCandlish (64) thought that the beneficial effects of alfalfa were to increase the calcium content of the ration and to furnish bulk. He did not believe that alfalfa added any appreciable amounts of vitamins which might have been absent in the other rations.

Huffman (49) showed that the bulk characteristic of roughages was not an essential factor. Experiments on vitamin A deficiency in cattle (5, 35, 55, 60, 68, 69) show symptoms which are strikingly like those resulting from absence of roughage in the ration. These symptoms include edema and incoordination of the legs, anorexia, respiratory infections, calves born dead or weak, and spasms and increased rate of respiration, followed frequently (in young growing animals) by death. Kuhlman, Gallup, and Weaver (59) found that low blood calcium or phosphorus values generally preceded or coincided with vitamin A deficiency symptoms. Both good quality roughages (31, 35, 36, 51, 53, 55, 60, 68, 85, 93) and cod liver oil (5, 35, 55, 59, 68) have been used to supply vitamin A. The work by Herman (43) suggests that other factors in addition to minerals and vitamin A (and D) are needed by cattle and supplied by rough feeds.

Factors Supplied by Rough Feeds. Huffman (50), in his extensive review of the literature, shows that roughages are generally adequate in several factors known to be essential to cattle, in vitamins A and D, in quality of protein, in fat (minimal, however), and in calcium. He points out that phosphorus may be deficient in some cases, and that iodine, iron, copper, and cobalt may be low in roughages grown in certain areas. Sun-cured hay supplied vitamin D, necessary for proper calcification in growing calves (46, 89). Thus roughages supply a number of known factors, and apparently some unknown factors as well, that are needed by cattle.

Roughages Commonly Fed

1. Pastures

Pasture, originally the only roughage, is still of primary importance to dairy cattle. Morrison (70) lists 21 legumes and 33 cultivated grasses as being used for pasture purposes in the United States. The native grasses in this country furnished most of the pasture in earlier days. Later, as more land was cleared and brought under cultivation, efforts were made to use new crops for pasture. New cultural practices were employed and seasonal factors were investigated. Rotation systems, fertilizers, and irrigation were tried. Attempts were made to fill in the low periods of the pasture season with special crops, and to extend the season at both ends. Studies of the feeding value of pastures have led to a renewed appreciation of their importance, too. Some experiments and reports will be discussed.

Pasture Yields and Consumption. Woodward (101) reports that cows will consume up to 150 pounds of grass a day, which is equivalent to 30-35 pounds of dry matter. In the experiments quoted, Holstein cows averaged 110 pounds, Jerseys 106 pounds of grass daily. The experiments showed that a yield of 2,500 pounds or more of grass per acre (at one cutting) was needed for cows to graze their fill. This yield is much less than is commonly secured from crops grown for hay, but fully as high as may be secured from good grass pasture. Faires, Dawson, Lamaster, and Wise (24) found that permanent pasture over a 5-year period yielded 1253 pounds total digestible nutrients per acre for the entire season. This would be roughly equal to three cuttings of 2,000-2,500 pounds of grass. Gorton (30), from a survey of 205 farms in eastern Oregon, reports that irrigated bluegrass carried an average of 0.85 animal units per acre, mixed tame grass 1.33. A similar survey of 88 coast farms (not irrigated) showed carrying capacities ranging from 0.50 unit for mixed grass to 1.25 units for Reed canary. Probably those pastures carrying less than 1.00 animal unit per acre would not provide growth luxuriant enough for a cow to graze her fill.

Irrigated Pastures. Ewalt and Jones (22) report that it is profitable to establish and irrigate Ladino clover and grass pastures for dairy cattle under Oregon conditions. Ladino clover pastures yielded the equivalent of 4.37 tons alfalfa hay a year for a four-year period. Ladino clover and grass yielded the equivalent of 4.8 tons alfalfa. The use of 300 pounds superphosphate per acre secured the equivalent of 6.4 tons as compared to 3.7 tons without fertilizer. Trumble (86) recommends the use of superphosphate, seeding of grass and clover mixtures, and frequent rotation of pastures under conditions in southern Australia. Beruldsen (8) urges farmers not to over-graze and to rotate pastures frequently.

All-Year Pastures. Faires, Dawson, Lamaster, and Wise (24) used a whole series of crops--soybeans and pearl millet, millet alone, oats-barley-rye-vetch, Italian rye grass and crimson clover, and corn stover with velvet beans--to provide continuous grazing for dairy cows.

Etheridge, Helm, and Brown (21) recommend Korean lespedeza, winter barley and bluegrass for an all-year pasture system under Missouri conditions. Neel (73) recommended Balbo rye and crimson clover for late fall and early spring pasture in Tennessee. Hazelwood (39) describes all-year pasturing, with and without concentrates, at the West Tennessee Station. Limited numbers of cows were used. Crimson clover for late fall, winter, and early spring, plus Sudan grass and mixed permanent pasture the rest of the year, provided an almost unbroken succession of pasture crops.

Dorrance and Rather (19) report that alfalfa may be used for pasture, and that it gave even better returns in milk production than did hay from the same area. Finnell (25) reports on the use of winter barley and winter wheat for fall and spring pasture in the High Plains region of western Oklahoma. Jeter (52) describes winter pasturing in the flats and coves of western North Carolina. A mixture of orchard grass, bluegrass, timothy and clover was seeded on new land following two years of corn.

Steers on such pasture made greater gains than on dry feed.

Limitations of Pasture as Feed. Morrison (70) states that "good pasture alone will provide sufficient nutrients for body maintenance and the production of 10 to 20 pounds of milk or more, depending on its richness". He makes recommendations for feeding concentrates to cows on pasture which allow for varying pasture qualities. Woodward (101) showed that cows on good pasture would consume enough nutrients to produce a maximum of about one pound of butterfat a day. Sims (82) reports that Jersey cows on machine-dried hay and pasture grass averaged 6,335 pounds of milk and 329 pounds butterfat in a lactation. The same cows averaged 9,656 pounds of milk and 527 pounds fat on the same roughage plus liberal concentrate allowances such as are given to cows on official test. Hazelwood (39) states that cows on pasture alone with hay and silage produced 5,885 pounds of milk and 342 pounds of butterfat as compared with 6,659 pounds milk and 373 pounds fat when concentrates were given. In later work at the same station, a cow that had produced 14,481 pounds of milk and 1,002 pounds fat under official test conditions, came back with 9,814 pounds milk and 632 pounds fat in 365 days on roughage alone.

2. Hays

Next to pasture, hay crops are our most important source of roughages for dairy cattle. The crops used for pasture are, for the most part, used for hay with good results. Low growing plants and very young, succulent plants are cut and cured with some difficulty, however, and so are not used frequently.

Quality of Hay. Huffman (50) states that young plants are higher in protein, lower in cellulose and lignin, and have a higher coefficient of digestibility than older plants. Morrison (70) gives values of over 17% protein and 64.7% total digestible nutrients on an air-dried basis for young actively growing pasture grass, compared to about 7% protein and 51.7% total digestible nutrients for ordinary mixed hay. Likewise, the calcium and phosphorus contents of dried young grass are significantly higher than for hay. These facts suggest that the quality and feeding value of hay vary greatly, depending on stage of growth when the crop is cut.

Quality of hay may be affected further by manner of harvesting and storing. Huffman (50) states that losses may occur from respiration in the freshly-cut plant before drying, from mechanical losses in handling, from exposure to rains and from fermenting in storage. The sum of such losses may reach 40%, or even higher if the hay "browns" in the mow. Total losses when hay is artificially dried are significantly less. Gordon and Hurst (29) in experiments at Jeanerette, Louisiana, found the cost of machine-drying too high except for very large growers. Weaver and Wylie (90), using a low cost barn drier, made hay that was one grade better than the same hay dried in the field. The barn-dried hay averaged 2.5 percent more leaves and 19 percent more color, was higher in vitamin A value, and gave results slightly superior to good field-dried hay in feeding trials with dairy heifers.

Uses and Limitations of Hays. Morrison (70) states that legume hay is especially valuable in feeding dairy cows, because it provides generous supplies of high quality proteins, of calcium, and of vitamins

A and D. He further states that feeding of concentrates is generally desirable, especially under Corn Belt conditions and those farther east. Early experiments (37) with legume hays showed that such hays supplied more protein than grass or mixed hays, thus permitting a saving in amount of high protein concentrates. Hodgson and Knott (47) found alfalfa hay superior to mixed hay and grass silage as a ration for cows in milk when no concentrates were given. Meigs and Converse (66), however, report that cows would eat more of a mixture of alfalfa and timothy than of either alone.

Hay Alone. Experiments with cows given full-grain, limited grain, and all-roughage rations (17, 18, 33, 34, 39, 40, 41, 56, 63, 72, 81, 82, 95, 99) show that cows on all-roughage rations will produce about 60% as much milk as on full feed. The limited-grain group in some experiments produced more in proportion to grain fed than those groups on full-grain. This in turn indicates a higher physiological efficiency for the limited-grain rations, and suggests that combinations of roughages and concentrates may supply necessary factors not present in either alone. In Table I it will be noted that some of the best results from all-roughage rations were secured at Western Stations where alfalfa hay was the principal roughage. Huffman (50) states that, while cows fed alfalfa alone in the Western experiments appeared to make exceedingly good use of the total digestible nutrients, the productive energy of alfalfa varies and grain should probably be fed to cows in medium and high milk production. It should be noted in Table I that cows generally did not exceed 300 pounds butterfat production on all-roughage rations.

TABLE I

RESULTS FROM FEEDING FULL-GRAIN, LIMITED GRAIN, AND ALL-ROUGHAGE RATIONS TO DAIRY COWS

Station	Full grain		Limited grain		All roughage	
	Milk	Fat	Milk	Fat	Milk	Fat
	Per cow per lactation					
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Summary*	18746	654			11416	405
Utah**	10349	348			9029	288
Montana**	15793	544	16407	576	13295	464
Nevada	10352	359	9163	326	8644	304
Wyoming			10180	325	9386	310
Tennessee	6442	376	6265	367		
Tennessee	9656	527			6333	329
California	7389	324			6058	245
Oregon	7208	278			5696	214
Oregon			7181	322	5875	266
Louisiana	6806	252	6576	264	4531	216

* Work at Federal Stations, to 1936

** Federal Stations

Physiologic and Economic Factors. Autrey (3) reports a higher physiologic efficiency for all-roughage rations than for either limited or full grain. This observation is confirmed or indicated by others (18, 33, 40, 45, 72). Cows on full-grain rations consume more dry matter and total digestible nutrients than do limited-grain or all roughage groups (2, 72, 99). Cows on all-roughage rations lose more weight early in the lactation, reach a peak in milk production earlier and may be less persistent than cows fed concentrates (18, 33, 34, 40, 41, 63, 81, 95, 99). Whether or not grain feeding is profitable depends both on the quality and cost of roughage and concentrates and the price of butterfat. Autrey (3) concluded that it pays to feed grain under Iowa conditions. Lush (63) reports similar findings for Louisiana. Headley (41) found that cows under Nevada conditions produced more economically on roughage alone.

3. Silages

Crops Used. Early experiments (11, 12, 23, 44, 57, 91) showed that adding silage to the dairy ration would secure small but apparently significant increases in milk production. Some later experiments (13, 27, 47, 84, 97) do not agree. As a result of the early experiments, however, use of silage in dairy rations became a standard practice, particularly in the Northern Dairy Region. The writer has seen old stone silos in upper Wisconsin that must have been at least 30 or 40 years old. Corn was used most frequently in the early days. Woll and Humphrey (98) made trials of soybean silage without preservatives, at the Wisconsin Station about 1904. Reed and Fitch (79), at the Kansas

Station, reported in 1917 the successful ensiling of alfalfa alone, alfalfa with corn chop, and alfalfa with molasses. The experiments with alfalfa silage are too numerous to discuss in detail here, but several studies (48, 74, 80) show good results from feeding alfalfa silage to dairy cows.

Recent experiments (6, 75) with soybeans alone for silage gave good results. The same can be said for corn and soybeans in combination (4, 58, 92). Ragsdale and Herman (78) list 10 legumes, 9 grasses and 4 cereals that are commonly used for silage in the Middle West.

Bender and Bosshart (7) state that "In general,..... all crops which can be made into hay can be stored as grass silage".

Factors in Preserving. Bender and Bosshart (7) list six methods of preserving silages, in addition to natural fermentation. Reed and Fitch (79) found molasses more satisfactory than corn chop in making alfalfa silage. Bohstedt and co-workers (9) found corn meal to be an effective preservative for grass silage when added at the rate of 150-200 pounds per ton of green forage. In several experiments (16, 54, 61, 74) mineral acids have been used successfully as preservatives. Lepard and co-workers (61) showed that phosphoric acid grass silage did not affect the alkaline reserve of the blood, even when fed as the only roughage. Huffman (50) states that about 10% of the dry matter is lost in the silo. Newlander and co-workers (74) give losses of 11% and 14% for 36- and 24-foot silos, respectively. Davies, Botham, and Thompson (16) found the loss of nutrients to be greatest from natural fermentation and significantly less from the use of either mineral acids (A. I. V. process) or molasses. The same workers recommend molasses as being most practical to use. Carotene losses in making silage are less than in making hay (53, 80) under ordinary conditions. Good hay may be equal or superior, however, in carotene content to some silages (36, 48). Bender and Bosshart (7) state that silages made with preservatives have especially high vitamin A values. This statement agrees, in substance, with a report by Taylor and co-workers (85).

Use of Silage. The reason why silage gave such good results in early experiments (11, 12, 23, 44, 57, 91) was not investigated for some time. More recent studies on the problem (10, 27, 32, 38, 42, 77) show that water content alone is not a factor. Hay and silage made from the same crop have given almost identical results in feeding trials with dairy cows. Likewise, wet beet pulp gave results no better than dry pulp, when cows had free access to water. Pratt and White (76) report slightly greater dry matter consumption with heavy feeding of silage than with light. Hodgson and Knott (47) found that cows would eat more dry matter on a ration containing U. S. No. 2 alfalfa hay than on mixed hay and grass silage. Pratt (77) found that cows would eat less dry matter in wet beet pulp than dry, but more in wet silage than in dehydrated. Apparently, the value of silage in the dairy ration is not due to its moisture content, but to whatever additional nutrients it may possess that are not found in ordinary to poor grades of hay.

Interrelations of Feeds for Dairy Cattle

Silage vs. Hay vs. Pasture. It should be noted that one crop may be used for hay, for silage, or for pasture. As stated above, the difference between hay and silage made from the same crop is very small, assuming that care is taken to conserve most of the nutrients in each. The differences, however, between pasture on the one hand and hay or silage on the other may be significant. Dawson and Graves (17) found that with cows on rations restricted to roughage, those on pasture produced on the average seven percent more than the non-pasture groups. Graves, Dawson, and Kopland (32) found the dry matter in hay and silage made from immature pasture herbage to be apparently superior for milk production to the dry matter in alfalfa hay. Huffman (50) shows that young pasture grass is higher in protein, lower in fiber, and has higher coefficients of digestibility than found in hays. The good results secured by Hazelwood (39) with cows on all-roughage rations may be related to the fact that about three-fourths of the nutrients were secured from pasture.

Roughages vs. Concentrates. As stated earlier, roughages are indispensable for dairy cattle because they furnish factors, known and unknown, that are not available in concentrates. Also, the efficiency of nutrient utilization appears to be higher on all-roughage rations than those with grain. Huffman (50) points out that roughages may be low in phosphorus, a deficiency which can be supplied either by mineral supplements or by high-protein concentrates. Willard (94) found no advantage in feeding grain to yearling heifers when given alfalfa hay and irrigated pasture, but found it desirable in a later study (96) to feed grain to calves up to nine months. Monroe (67) found that some grain was necessary to keep heifers growing well and in a normal state of fleshing unless high quality hay was fed. With cows in milk, the results of some experiments with full-grain vs. limited grain vs. all-roughage rations (63, 72) indicate somewhat more efficient use of nutrients when a moderate amount of concentrates is fed.

PART II

EXPERIMENTAL

EXPERIMENTAL

The work reported here includes four major experiments. The objects of the individual experiments are somewhat diverse, but their final aim is to develop a sound roughage program which will use to best advantage the climatic, soil, and economic factors related to dairying in Tennessee.

Silage Experiments at Knoxville. The work reported includes trials of corn, alfalfa, and Lespedeza sericea silages for the winters of 1939-40 and 1940-41, also corn, alfalfa, and soybean silages for the winter of 1941-42. The latter year constitutes an original investigation by the author. Data for the first two years were already on file.

Winter Pasture Experiment at Columbia. The four years of work reported consist of trials with conventional winter rations that include silage, vs. rations with small grain pasture and with permanent and small grain pastures in place of silage. Trials were started usually in November and extended into the following April. The data for four winter seasons, 1937-38 to 1940-41, were already on file at Knoxville.

Irrigated Pasture Experiment at Columbia. This experiment includes trials of irrigated pastures vs. non-irrigated pastures for the summer season. Trials were begun in May or June and extended into September or October. The data for four seasons, 1938, 1939, 1940, and 1941, were already on hand at Knoxville.

Limited Grain and All-Year Pasture at Jackson. This experiment followed similar work with limited numbers of cows at the same station. Cows were pastured most of the year and fed hay and/or silage only during the days when pastures were short or not available. Concentrates were fed in limited amounts to certain cows for one or two lactations, followed by no concentrates during succeeding lactations. The data for four whole years, June 1937 to May 1941, were already on file.

SOYBEAN AND ALFALFA SILAGE TRIALS AT KNOXVILLE; WINTER OF 1941-42

The experimental work reported here was done in the winter of 1941-42. It represents the third year of cooperative silage investigations by the Department of Dairying of the University of Tennessee, and the Tennessee Valley Authority*.

<u>Plan of Experiment, 1941-42</u>. Jersey cows were divided into three groups, with four cows in each group. Silage was fed to the milking cows in each group somewhat according to individual milk production and so that the total for each group was the same. As much hay was fed as each group would consume. Feed not eaten was weighed back.

The cows were weighed at monthly intervals on three successive days, and the average taken. Production was computed as the actual milk production, times the average of one-day tests at the beginning and end of each month. The experiment was continued for 150 days. It should be noted that the experimental periods were all 30 days in length, instead of being calendar months.

The experiment was planned to observe feed consumption, changes in body weight, milk and butterfat production, and to note any differences in results between groups. Feed consumption data by individual cows were not kept, thus limiting any complete analysis of the results to group aveages.

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* The Tennessee Valley Authority furnished two 6' x 20' experimental silos and the 80% phosphoric acid.

Feeds. Corn silage used in the experiment was put up in 14' x 50' silos and used both for experimental cows and the rest of the herd. Alfalfa for silage was cut in mid-June when in full bloom and ensiled with 60 pounds of blackstrap molasses and 20 pounds of 80% phosphoric acid per ton. Soybeans were cut at the end of September when well matured and ensiled with molasses and phosphoric acid, as above. Both alfalfa and soybean silages were stored in 6' x 20' experimental silos. The alfalfa silage kept well and was eaten readily. The soybean silage did not pack well in the small silo and became somewhat moldy. Analyses by Mr. G. A. Shuey, Experiment Station Chemist (Table VII), showed pH values of 4.42 and 4.40 for alfalfa and soybeans, respectively. The alfalfa silage was somewhat higher in moisture than the soybean, and lower in fat and carbohydrates.

The hay fed varied from mixed grass-and-legume to pure lespedeza. At the beginning of the experiment all hay was ground. Later it was fed whole. Grain mixture for the corn silage group contained 100 pounds corn, 100 pounds oats, 100 pounds wheat bran, and 200 pounds cottonseed meal, with a calculated digestible protein content of 19.4 percent. Grain mixture for the alfalfa and soybean silage groups contained 200 pounds corn, 100 pounds oats, 100 pounds wheat bran, and 50 pounds cottonseed meal, with 11.8 percent digestible protein. The reason for varying the grain mixture between groups was to equalize the protein intake as nearly as possible. Average analyses of alfalfa and soybean silages show more digestible protein than in corn.

Selection of Cows. Individuals were grouped according to previous records, body weight, stage of lactation, milk production at time of starting experiment, and dates bred. The resulting groups were within 200 pounds of one another in initial weight. All cows that milked during the experiment showed one or more indications of mastitis. Samples taken monthly showed high leucocyte counts in many cases. Two cows showed streptococci at times; one showed staphylococci. One cow, in the corn silage group, that showed streptococci was treated with a silver oxide preparation and went dry sooner than planned. One cow, in the soybean silage group, developed a staphylococcic infection in three quarters following calving and produced much less than normal for the last 30 days of the experiment.

The cows on corn silage were designated as Group I; those on alfalfa silage as Group II; those on soybean silage as Group III. In the text and tables which follow, the groups will be referred to in this manner.

Conduct of Experiment. Each group was kept in a large box stall and removed only for milking, for weighing, for cleaning the stalls, or for exercise. Cows were milked three times daily, in the milking parlor, except the last six weeks when they were milked twice a day. Silage and hay were fed once a day, concentrates twice.

Three cows calved during the experiment, three went dry. Each group had one or two dry cows most of the time. One dry cow died near the end of the first month and was replaced by another. The experiment started December 2, 1941, and ended April 30, 1942. (Both dates are inclusive.)

TABLE II

FEED CONSUMED BY EXPERIMENTAL GROUPS; SILAGE EXPERIMENT
1941-1942

Item	Amount fed	Amount refused	Amount consumed	Total digestible nutrients supplied*
	lbs.	lbs.	lbs.	lbs.
Group I:				
Hay	8,825	180	8,645	4,409
Silage (corn)	12,000	0	12,000	2,244
Grain	2,092	0	2,092	1,189
Total....................................				8,189
Group II:				
Hay	8,824	140	8,684	4,429
Silage(alfalfa)	11,840	6	11,834	1,680
Grain	2,092	0	2,092	1,561
Total....................................				7,670
Group III:				
Hay	8,762	76	8,686	4,430
Silage(soybean)	12,000	189	11,811	2,031
Grain	2,092	0	2,092	1,561
Total....................................				8,022

* Total digestible nutrient values used are based on average analyses (Morrison), with adjustments for moisture content in the case of alfalfa and soybean silages.

<u>Feed Consumption</u>. Table II shows the amounts of feed given, refused and consumed by each group and the total digestible nutrients supplied. Hay consumption was surprisingly close for the groups, while grain for each was the same. Silage consumption was practically the same, except that the soybean silage was moldy and somewhat less palatable, although nearly as much was eaten as of the others. This lack of relation between palatability and total amount eaten is noted by Huffman (50). The total digestible nutrient intake was low for the alfalfa silage group because of the high moisture content of the alfalfa silage.

<u>Maintenance of Body Weight</u>. Table III shows both individual and group weights by months from beginning to end of the 150-day experimental period. Figure 1 shows graphically the changes in body weight. It will be noted that all cows but three lost weight the first month, regardless of groups. It should be noted also that Groups I and II gained weight after the first month, while Group III remained at about the same level throughout. These differences probably are not significant, however, because of the differences between groups in stages of lactation.

Figure 2 shows that Groups I and II were in advanced stages of lactation when started on experiment, while Group III was earlier. It is normal for a cow to lose weight early in lactation and to regain weight after the sixth month and during the dry period.

The monthly losses and gains shown in Table III represent differences between weighings for successive months. These data are used in computing physiological efficiency.

TABLE III

BODY WEIGHTS OF COWS IN SILAGE EXPERIMENT
1941-1942

	Initial weight	1st. month	2nd. month	3rd. month	4th. month	End of experiment	Monthly losses***	Monthly gains***
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Group I:								
Louise	799	725	785	791	811	870	74	145
Venus	893	878	928	837*	851	856	15	69
Sunshine	992	992	1040	1056	1087	1150	0	158
Fanny	892	834	932	956	949	1035	65	208
Total	3576	3429	3685	3640	3698	3911	154	580
Group II:								
Lily	833	811	842	841	862	897	23	87
Joy	976	960	1021	1052	1065	1148	16	188
Fancy Flo	868	874	910	936	933	971	3	106
Susie	---	718**	710	716	743	762	8	52
Daisy	914	---	---	---	---	---	---	---
Total	3591	3363	3483	3545	3603	3778	50	433
Group III:								
Duchess	935	842	868	849	887	894	112	71
Pansy	810	804	719*	666	704	715	59	49
Rose	789	711	727	708	731	775	97	83
Sultane	1016	1026	1066	1098	1068	1011	30	82
Total	3550	3383	3380	3321	3390	3395	298	285

* Drop in weight from preceding month is due to calving.

** Started second month to replace Daisy.

*** Changes in body weight between monthly weighings. Losses due to calving not included.

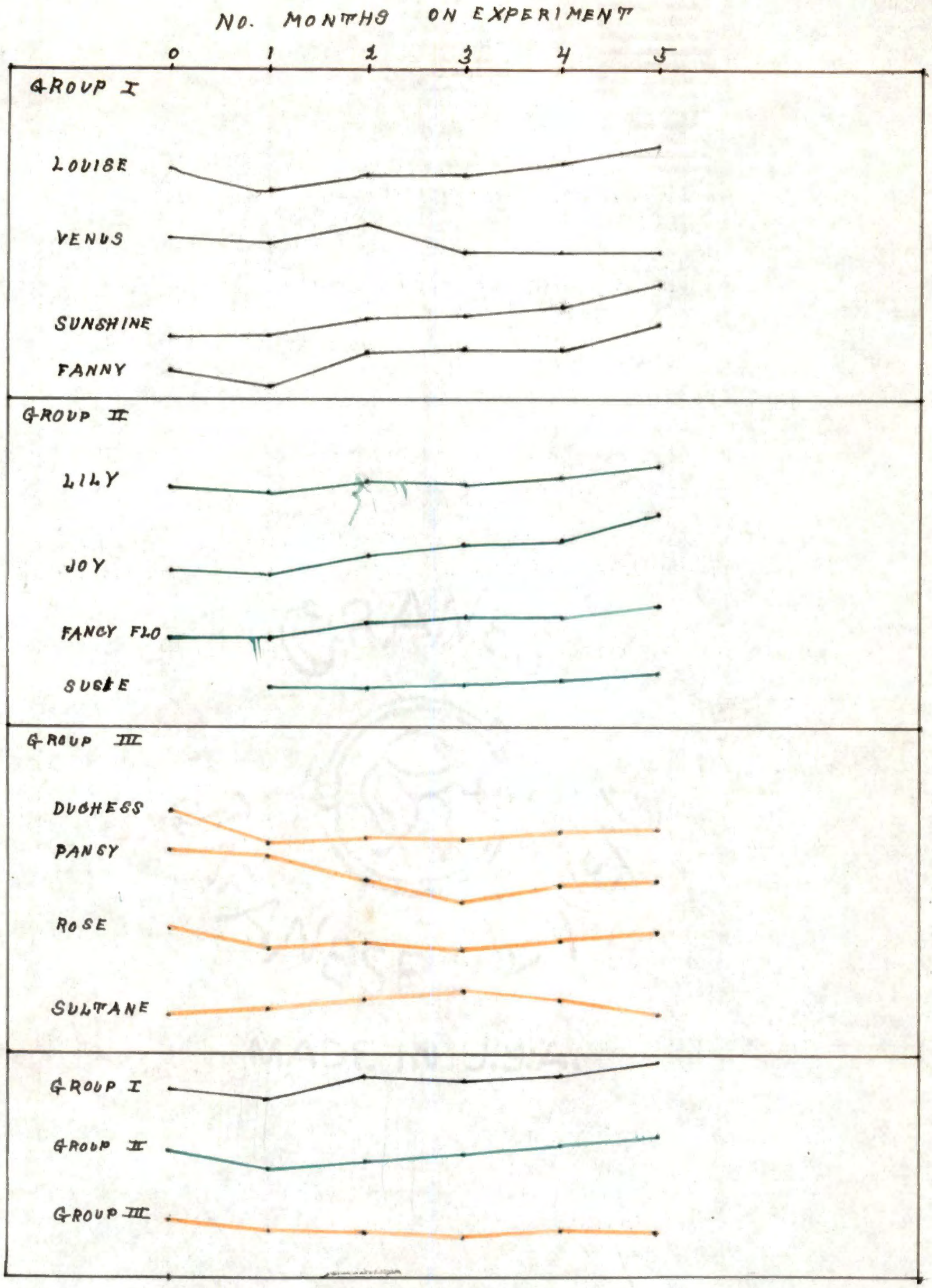

Figure 1. Graph showing changes in body weight during experiment; silage experiment at Knoxville, 1941-42.

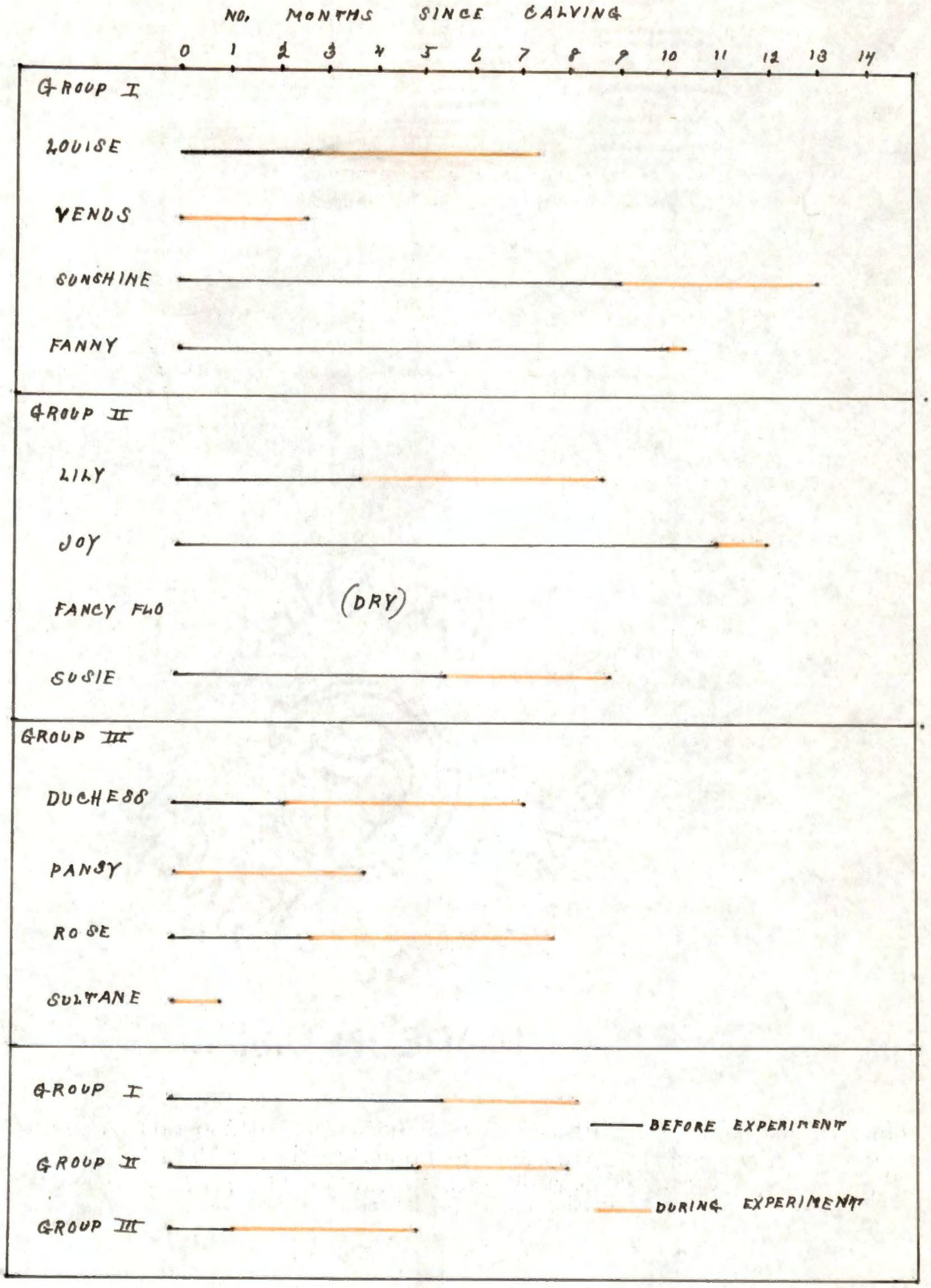

Figure 2. Graph showing what part of lactation cows were in milk during experiment, also average for groups; silage experiment, 1941-42.

Production. Table IV shows the milk and butterfat production for each group. Group III produced about 50 percent more than the others, both in actual and four percent fat-converted milk.

Figure 2 shows graphically the stage of lactation and number of months milked for each cow during the experiment. When production is reduced to a cow-day basis (Table V) the differences between groups are not very great, and the variations in stage of lactation between groups probably account for most of the differences. It will be noted that Group I had milked on the average 164 days when started on experiment; Group II, 152 days; and Group III only 38 days.

Physiological Efficiency. Nutrient intake and requirements are shown in Table VI. In arriving at the values shown, Morrison's standards and average analyses (70) were used. Weight losses (excluding those due to calving) were considered as equivalent to supplying extra nutrients, while weight gains were considered as requiring additional nutrient. The values of 2.75 pounds total digestible nutrients for one pound loss in weight and 3.53 pounds for one pound gain, as recommended by Knott, Hodgson, and Ellington (58), were used. The soybean silage group showed the lowest physiological efficiency by producing only 2.19 pounds of 4% milk per pound of total digestible nutrients above maintenance. The other two groups did somewhat better by producing 2.58 pounds of 4% milk with corn silage and 2.74 pounds with alfalfa.

Autrey (3) reports that cows on full feed at the Iowa Station produced 3.20 pounds of 4% milk for each pound total digestible nutrients above maintenance. Graves and co-workers (33) report that cows at the

TABLE IV

PRODUCTION OF EXPERIMENTAL GROUPS; SILAGE EXPERIMENT
1941-1942

	No. days in milk		Production		
	Before experiment	During experiment	Milk	Fat	4% F.C.M.
			lbs.	lbs.	lbs.
Group I (corn silage)					
Louise	75	150	1,980.9	88.4	2,118
Venus	Dry	78	1,265.1	59.8	1,403
Sunshine	275	120	1,338.3	89.5	1,878
Fanny	304	10	71.6	3.7	84
Total	---	358	4,655.9	241.4	5,483
Group II (alfalfa silage)					
Lily	113	150	2,251.3	123.1	2,747
Joy	332	34.3	338.7	19.0	420
Fancy Flo	Dry	Dry	---	---	---
Susie	165	108.3	1,651.4	90.2	2,014
Total	---	292.7	4,241.4	232.3	5,181
Group III (soybean silage)					
Duchess	68	150	2,879.3	156.3	3,496
Pansy	Dry	118.7	1,916.2	94.0	2,176
Rose	83	150	1,767.7	104.3	2,272
Sultane	Dry	30	286.6	12.0	295
Total	---	448.7	6,849.8	366.6	8,239

TABLE V

COMPARISON OF MILK PRODUCTION BETWEEN EXPERIMENTAL GROUPS; SILAGE EXPERIMENT, 1941-1942

Group	Ave. No. days in milk when started on experiment	No. cow days milked during experiment	Total production 4% milk	4% milk per cow per day
	days	days	lbs.	lbs.
I. Corn silage	164	358	5483	15.3
II. Alfalfa silage	152	292.7	5181	17.7
III. Soybean silage	38	448.7	8239	18.4

TABLE VI

NUTRIENT INTAKE VS. REQUIREMENTS; EFFICIENCY OF NUTRIENTS FOR MILK PRODUCTION; SILAGE EXPERIMENT 1941-1942

Item	Group		
	I. Corn silage	II. Alfalfa silage	III. Soybean silage
	lbs. T.D.N.	lbs. T.D.N.	lbs. T.D.N.
Nutrients supplied:			
Hay	4409	4429	4430
Silage	2244	1680	2031
Grain	1536	1561	1561
Weight losses*	420	137	814
Total nutrients available	8609	7807	8836
Nutrients required:			
Maintenance**	4439	4385	4067
Weight gains	2048	1529	1006
Total	6487	5914	5073
Left for milk production	2122	1893	3763
Pounds 4% milk	5483	5181	8239
Ratio: T.D.N. to 4% milk	1:2.58	1:2.74	1:2.19

* Equivalent to supplying extra nutrients.

** Based on average weight during experimental period. (It is assumed that all groups used nutrients both for maintenance and for weight gains with equal efficiency).

Federal Stations produced 2.71 pounds of milk testing 3.49% on full feed for each pound total digestible nutrients.

In computing physiological efficiency as above, it is assumed that all cows are equally efficient in the use of nutrients for maintenance and for increases in body weight, and that the same cows are not equally efficient in the use of nutrients for milk production. Some cows may use nutrients more efficiently for one purpose than for another. There may be differences between individual cows in one or more of the three uses. Also, cows may use nutrients for milk production with varying efficiency at different levels of production. However, the data in Table VI indicate that Group III used nutrients less efficiently in some manner, whether for maintenance or milk production, than the other groups.

GROUP I - CORN SILAGE

Figure 3. Silage experiment group, 1941-42, at end of experimental period.

GROUP II - ALFALFA SILAGE

Figure 3 (cont'd.). Silage experiment groups, 1941-42, at end of experimental period.

GROUP III - SOYBEAN SILAGE

Figure 3 (cont'd.). Silage experiment groups, 1941-42 at end of experimental period.

TABLE VII

ANALYSES OF ALFALFA AND SOYBEAN SILAGE; SAMPLES TAKEN FEBRUARY 2, 1942*. SILAGES MADE FROM 1941 CROPS

	Alfalfa silage		Soybean silage	
	On 73.21% moisture basis	On water-free basis	On 68.81% moisture basis	On water-free basis
	%	%	%	%
Moisture in fresh silage	73.21		68.81	
pH value of fresh silage	4.42		4.40	
Ash (mineral matter)	2.54	9.50	3.32	10.63
Crude fat (either extract)	1.10	4.13	1.54	4.89
Crude protein (% N x 6.25)	5.49	20.50	5.52	17.65
Crude fiber	8.51	31.79	10.21	32.74
Nitrogen-free extract	9.15	34.08	10.60	34.07

* Analyses by Mr. G. A. Shuey, Experiment Station Chemist.

SILAGE TRIALS AT KNOXVILLE; WINTERS OF 1939-40 AND 1940-41

Procedure. These experiments were started with the dairy herd at Knoxville in the fall of 1939. The procedure differs but little from that for 1941-42. Lespedeza sericea was used instead of soybeans. Alfalfa and sericea were ensiled with molasses and phosphoric acid. First-cutting alfalfa in early bloom and first-cutting sericea were used in 1939. Corn was ensiled in the usual manner, without preservatives. Table VIII shows the chemical analyses of silages put up in 1939. It should be noted that sericea silage was almost equal to alfalfa in protein but somewhat higher in fiber.

Cows were divided into groups of four, according to breed, size, stage of lactation, previous production, and condition. Two Holsteins and two Jerseys per group were used in 1939-40, one Holstein and three Jerseys in 1940-41. Silage was fed at the rate of 20 pounds a day per cow, grain at 10 pounds per cow. As much hay was fed as each group would eat. Feed not eaten was weighed back and the weights recorded.

Results. Tables IX and X show the results for 1939-40 and 1940-41, respectively. The sericea silage was consumed less completely than the others. Hay consumption was about the same for all groups. The sericea silage group produced slightly more 4% fat-converted milk the first year, but somewhat less the second year than the corn and alfalfa silage groups. Likewise, the sericea group lost weight the first year, but gained the second.

In computing nutrient intake and requirements, T.D.N. values of

TABLE VIII

PROXIMATE CHEMICAL ANALYSES OF CORN, ALFALFA, AND SERICEA SILAGES PUT UP IN 1939*

	Corn silage %	Sericea silage %	Alfalfa silage %
Moisture	75.82	68.79	75.54
Dry matter	24.18	31.21	24.46
pH value		5.99	4.43
Ash (mineral matter)	1.55	1.97	2.42
Crude protein (NX 6.25)	1.46	4.33	4.47
Crude fat (ether extract)		0.64	0.65
Crude fiber	6.46	10.28	8.86
Nitrogen-free extract	14.11	13.99	8.06

* Analyses by Mr. G. A. Shuey, Tennessee Experiment Station Chemist.

TABLE IX

RESULTS OF SILAGE FEEDING EXPERIMENT, 150 DAYS; WINTER OF 1939-40*

	Group I corn silage	Group II sericea silage	Group III alfalfa silage
No. cows	4	4	4
Ave. wt. per cow at beginning, lbs.	1,151	1,125	1,119
Ave. wt. per cow at end, lbs.	1,155	1,168	1,108
Gain or loss per cow, lbs.	4	43	- 11
Grain consumed, lbs.	6,000	6,000	6,000
Hay feed, lbs.	12,754	13,231	13,259
" refused, lbs.	316	78	114
" consumed, lbs.	12,448	13,153	13,145
Silage fed, lbs.	12,000	12,000	12,000
" refused, lbs.	0	113.5	45
" consumed, lbs.	12,000	11,886.5	11,955
Total milk produced, lbs.	15,933.1	14,261.4	17,183.3
" butterfat produced, lbs.	698.0	600.1	717.1
" 4% F.C.M., lbs.	16,843	14,706	17,630
" cow-days in milk	532	541	540
4% F.C.M. per cow-day, lbs.	31.7	27.2	32.6
Nutrient intake vs. requirements:			
T.D.N. supplied by feed, lbs.	12,888	13,229	13,236
T.D.N. for maintenance, lbs.	5,370	5,262	5,362
" " milk production, lbs.	5,457	4,765	5,712
Total requirements, lbs.	10,827	10,027	11,074
Ratio: T.D.N. supplied, above maintenance, to 4% milk	1:2.24	1:1.85	1:2.24

* From Mimeographed Report No. 63, Department of Dairying, University of Tennessee.

TABLE X

RESULTS OF SILAGE FEEDING EXPERIMENT, 150 DAYS; WINTER OF 1940-41*

	Group I corn silage	Group II sericea silage	Group III alfalfa silage
No. cows	4	4	4
Ave. wt. per cow at beginning, lbs.	1,015	1,049	1,038
Ave. wt. per cow at end, lbs.	1,034	1,010	1,018
Gain or loss per cow, lbs.	19	- 39	20
Grain consumed, lbs.	6,000	6,000	6,000
Hay feed, lbs.	11,443	11,159	11,075
" refused, lbs.	149	90	132
" consumed, lbs.	11,294	11,069	10,943
Silage fed, lbs.	12,000	12,000	12,000
" refused, lbs.	2	754	5
" consumed, lbs.	11,998	11,246	11,995
Total milk produced, lbs.	14,460.6	13,831.6	15,326.6
" butterfat produced, lbs.	684.6	657.1	669.3
" 4% F.C.M., lbs.	16,054	15,388	16,170
Total cow-days in milk	563	529	562
4% F.C.M. per cow-day, lbs.	28.5	29.1	28.8
Nutrient intake vs. requirements:			
T.D.N. supplied by feed, lbs.	12,300	12,057	12,120
T.D.N. for maintenance, lbs.	4,818	4,962	4,940
" " milk production, lbs.	5,201	4,986	5,239
Total requirements, lbs.	10,019	9,948	10,179
Ratio: T.D.N. supplied, above maintenance, to 4% milk	1:2.15	1:2.17	1:2.25

* From original data, on file with the Department of Dairying, University of Tennessee.

75% for grain, 51% for hay, and 17% for silages were used. All groups for both years consumed approximately 2,000 pounds more nutrients per group than required, according to Morrison's standards (70). The physiological efficiency of the three groups (ratio of T.D.N. above maintenance to 4 percent fat-converted milk) was quite comparable each year, except that the sericea group showed less efficient use of nutrients than the others in 1939-40.

SILAGE VS. WINTER PASTURE
MIDDLE TENNESSEE EXPERIMENT STATION*

The experiments reported here consist of trials of conventional winter rations that included silage vs. rations with small grain pasture and with small grain and permanent pastures in place of silage.

The main object of the investigation was to compare winter pasture with corn silage for feeding dairy cows through the winter season. The experiment was started at the Middle Tennessee Experiment Station in 1937 and continued for four years.

Procedure. Cows were divided into three groups according to body weight, age, previous records, and dates bred. Group I was fed alfalfa hay, corn silage, and a grain ration of equal parts corn-and-cob meal, ground oats, and cottonseed meal. Group II was fed hay and grain, and turned on rye pastures whenever weather and pasture permitted. Group III was fed hay and grain, turned on rye pasture whenever available, and pastured on bluegrass some time in addition.

All groups were fed as much hay as they would eat. Corn-and-sorghum silage was fed at the rate of 30 pounds a day per cow to Group I. Grain mixture was fed at a rate of one pound for every three pounds of milk. All groups were milked twice daily. Cows were weighed monthly on three successive days and the average taken. Group II was kept in a dry lot when rye pasture was not available. Groups II and III

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* From data on file with the Department of Dairying, University of Tennessee, Knoxville.

were kept inside when weather did not permit pasturing.

Daily milk records were kept. Butterfat production was computed from the actual milk produced and the test for one day during the month.

The cows used were shifted from group to group for succeeding seasons, but no attempt was made to follow a definite reversal system. However, a sufficient number of changes were made to avoid much of the error that might arise from keeping cows in the same groups continuously.

Table XI shows the number of days of pasture obtained each season. It should be noted that the winter of 1939-40 was unusually severe and much less grazing was secured that season than usual. The winter pasture vs. silage trials usually were started in November and extended through March.

Feed Consumption. Table XII shows the amounts of feed consumed by each group. Group II ate the most hay in every instance. Group III ate more hay than Group I in two out of four years, and about the same the other two years. Apparently the hay consumption of both Groups II and III was influenced by the amount of feed available from pasture. Grain consumed was determined, of course, by milk production and could vary only as the groups behaved in this respect.

Changes in Body Weight. Table XIII shows the changes in average body weight per cow in each group from beginning to end of each experimental period, and the same data is shown graphically in figure 4.

TABLE XI

NUMBER OF DAYS PASTURE EACH WINTER FOR GROUPS ON PASTURE; SILAGE VS. WINTER PASTURE

Year	Group II	Group III		
	Rye pasture	Rye pasture	Permanent pasture	Total
	days	days	days	days
1937-1938	81	81	60	141
1938-1939	71	71	63	134
1939-1940	15	15	95	110
1940-1941	88	86	41	127

TABLE XII

FEED CONSUMPTION OF EXPERIMENTAL GROUPS; SILAGE VS. WINTER PASTURE EXPERIMENT

		Group I, silage	Group II, rye pasture	Group III, rye and permanent pasture
		lbs.	lbs.	lbs.
1937-38	Hay	15,829	22,837	17,517
(163 days)	Silage	27,606	----	----
	Grain	5,081	6,040	5,263
1938-39	Hay	13,056	16,216	13,724
(136 days)	Silage	22,848	----	----
	Grain	5,576	4,987	5,061
1939-40	Hay	12,960	21,850	19,524
(162 days)	Silage	20,250	----	----
	Grain	3,817	3,939	4,281
1940-41	Hay	15,762	16,979	15,218
(151 days)	Silage	17,475	----	----
	Grain	5,042	5,543	5,954

TABLE XIII

CHANGES IN AVERAGE BODY WEIGHT PER COW; SILAGE VS. WINTER PASTURE EXPERIMENT

Group	Initial weight	Months on Experiment					
		1	2	3	4	5	6
	lbs.	lbs	lbs	lbs	lbs	lbs	lbs
1937-38							
I	916	897	843	878	888	885	861
II	856	824	829	814	811	786	865
III	840	818	818	796	809	768	808
1938-39							
I	888	911	933	885	906	902	*
II	844	842	852	832	814	878	
III	929	859	879	840	837	881	
1939-40							
I	828	826	852	849	873	893	869
II	947	902	933	910	965	931	909
III	830	835	874	873	850	828	825
1940-41							
I	803	807	827	817	834	859	*
II	801	782	813	787	816	806	
III	749	742	758	751	755	748	

* Experiment ended before sixth month.

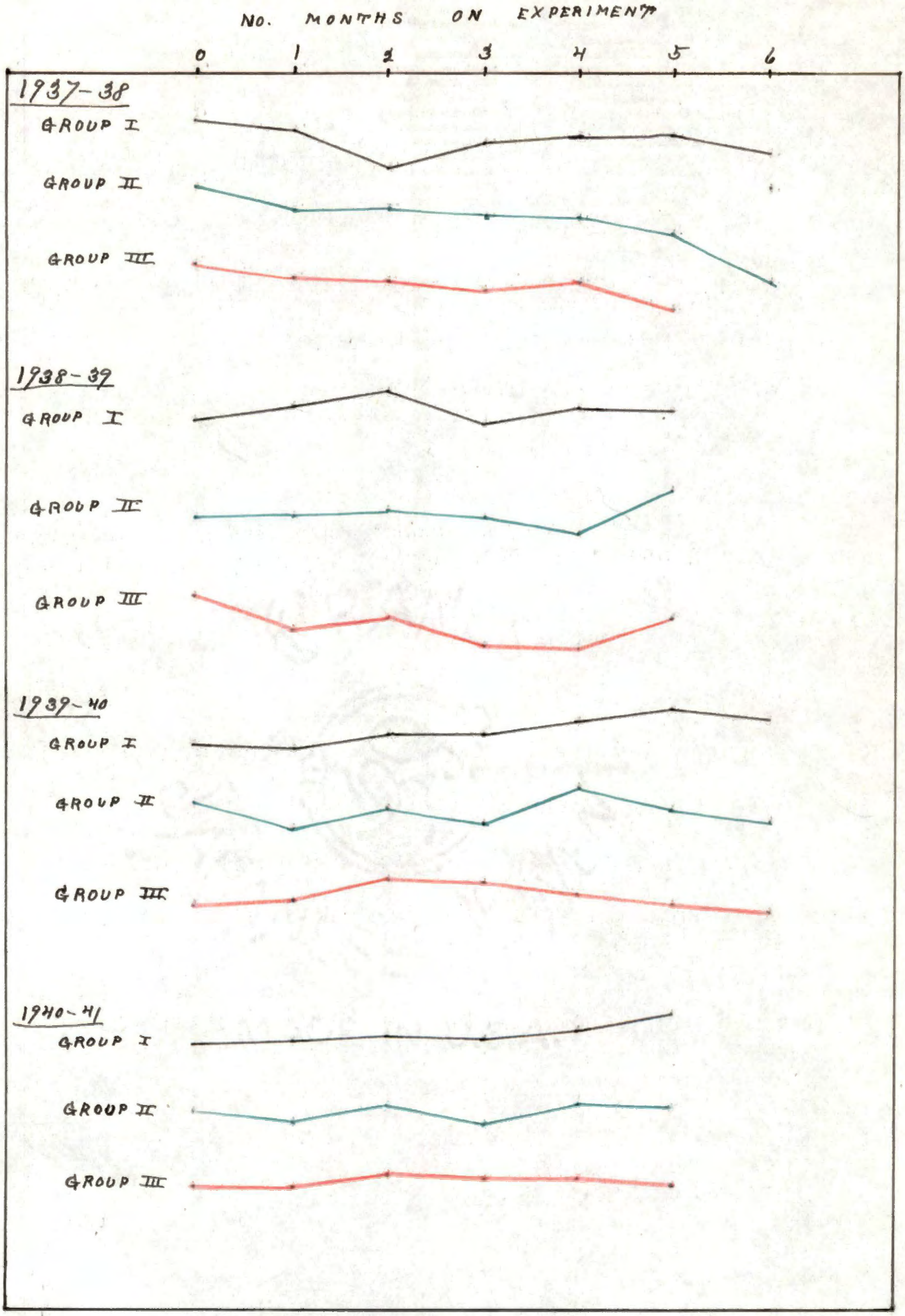

Figure 4. Graph showing changes in average body weight of groups; silage vs. winter pasture experiment.

Table XIV shows the total gains and total losses of cows in each group between successive monthly weighings, after deducting losses due to calving. (Calving losses were assumed to be equal to the difference between monthly weighings before and after calving). An analysis of the variance in body weight of individual cows (Table XV), based on differences between first and last months of experiment, shows the difference between groups to be not significant. Thus, the rations fed did not have any significantly different effects on maintenance of body weight.

Milk and Butterfat production. Table XVI shows the average number of days in milk for each group at the start of the experimental period, also the average number of days milked during the period.

Table XVII shows the milk and butterfat production of each group for each year. It should be noted that Group III produced the most per cow per day in three out of four years, also the most per group in all years. At least a part of the difference may be explained by greater persistence of lactation from month to month, as shown in figure 5. The differences in persistence are highly significant, as the analysis of variance reveals (Table XVIII).

Nutrient Intake vs. Requirements. The method recommended by Knott, Hodgson, and Ellington (58) was used in computing the nutrient balance (Table XIX). Hay was figured at 50.3 percent total digestible nutrients, corn-and-sorghum silage 16.9 percent, and grain mixture 75.7 percent. Weight losses were assumed to be equivalent to supplying

TABLE XIV

SUM OF GAINS AND LOSSES IN BODY WEIGHT OF COWS BETWEEN SUCCESSIVE MONTHLY WEIGHINGS; SILAGE VS. WINTER PASTURE EXPERIMENT*

		Group I, silage	Group II, rye pasture	Group III, rye and permanent pasture
		lbs.	lbs.	lbs.
1937-38				
	Gains	685	825	520
	Losses	660	810	435
1938-39				
	Gains	545	575	495
	Losses	435	280	325
1939-40				
	Gains	450	600	285
	Losses	170	560	390
1940-41				
	Gains	600	490	445
	Losses	190	415	275

* Losses due to calving have been deducted.

TABLE XV

ANALYSIS OF VARIANCE IN BODY WEIGHT BASED ON DIFFERENCES BETWEEN FIRST AND LAST MONTHS OF EXPERIMENT; SILAGE VS. WINTER PASTURE

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	69	232,436	
Between groups	2	5,333	2,666
Between years	3	24,385	8,128
Between cows regardless of groups or years	64	202,718	3,167

"F" values

$$F\ (\text{Groups}) = \frac{3167}{2666} = 1.19\ (\text{not significant})$$

$$F\ (\text{Years}) = \frac{8128}{3167} = 2.57\ (\text{not significant})$$

TABLE XVI

AVERAGE NUMBER OF DAYS IN MILK AT START OF EXPERIMENT, AND AVERAGE NUMBER OF DAYS MILKED DURING EXPERIMENT SILAGE VS. WINTER PASTURE

Group	Days in milk at start per cow	Days in milk during experiment per cow
1937-38		
I Silage	180	137
II Rye pasture	144	154
III Rye and permanent pasture	162	156
1938-39		
I Silage	173	117
II Rye pasture	156	129
III Rye and permanent pasture	185	120
1939-40		
I Silage	203	149
II Rye pasture	259	153
III Rye and permanent pasture	200	159
1940-41		
I Silage	96	138
II Rye pasture	88	131
III Rye and permanent pasture	115	136
Average, 4 years		
I Silage	163	135
II Rye pasture	162	142
III Rye and permanent pasture	165	143

TABLE XVII

PRODUCTION OF EXPERIMENTAL GROUPS; SILAGE VS. WINTER PASTURE EXPERIMENT

	Group I, silage	Group II, rye pasture	Group III, rye and permanent pasture
1937-38			
Ave. No. cows	6.0	6.83	5.67
Cow-days in milk	823	1,054	886
Total milk, lbs.	15,666.7	18,553.6	16,138.2
Total butterfat, lbs.	948.1	1,086.5	992.4
4% F.C.M., lbs.	20,486	23,727	21,335
4% F.C.M. per cow, lbs.	3,414	3,474	3,763
4% F.C.M. per cow-day, lbs.	24.9	22.5	24.1
1938-39			
Ave. No. cows	6.0	5.8	5.4
Cow-days in milk	703	751	649
Total milk, lbs.	15,962.7	14,315.7	15,146.0
Total butterfat, lbs.	918.3	883.2	822.2
4% F.C.M., lbs.	17,925	16,885	18,360
4% F.C.M. per cow, lbs.	2,988	2,911	3,400
4% F.C.M. per cow-day, lbs.	25.5	22.5	28.3
1939-40			
Ave. No. cows	5	5	5
Cow-days in milk	746	763	795
Total milk, lbs.	11,187.6	11,796.0	13,207.9
Total butterfat, lbs.	687.7	701.9	801.1
4% F.C.M., lbs.	14,795	15,248	17,298
4% F.C.M. per cow, lbs.	2,959	3,050	3,460
4% F.C.M. per cow-day, lbs.	19.8	20.0	21.8
1940-41			
Ave. No. cows	6	6	6
Cow-days in milk	827	788	813
Total milk, lbs.	15,249.4	16,623.2	17,462.1
Total butterfat, lbs.	930.3	895.5	961.0
4% F.C.M., lbs.	20,050	20,089	21,400
4% F.C.M. per cow, lbs.	3,342	3,348	3,567
4% F.C.M. per cow-day, lbs.	24.2	25.5	26.3

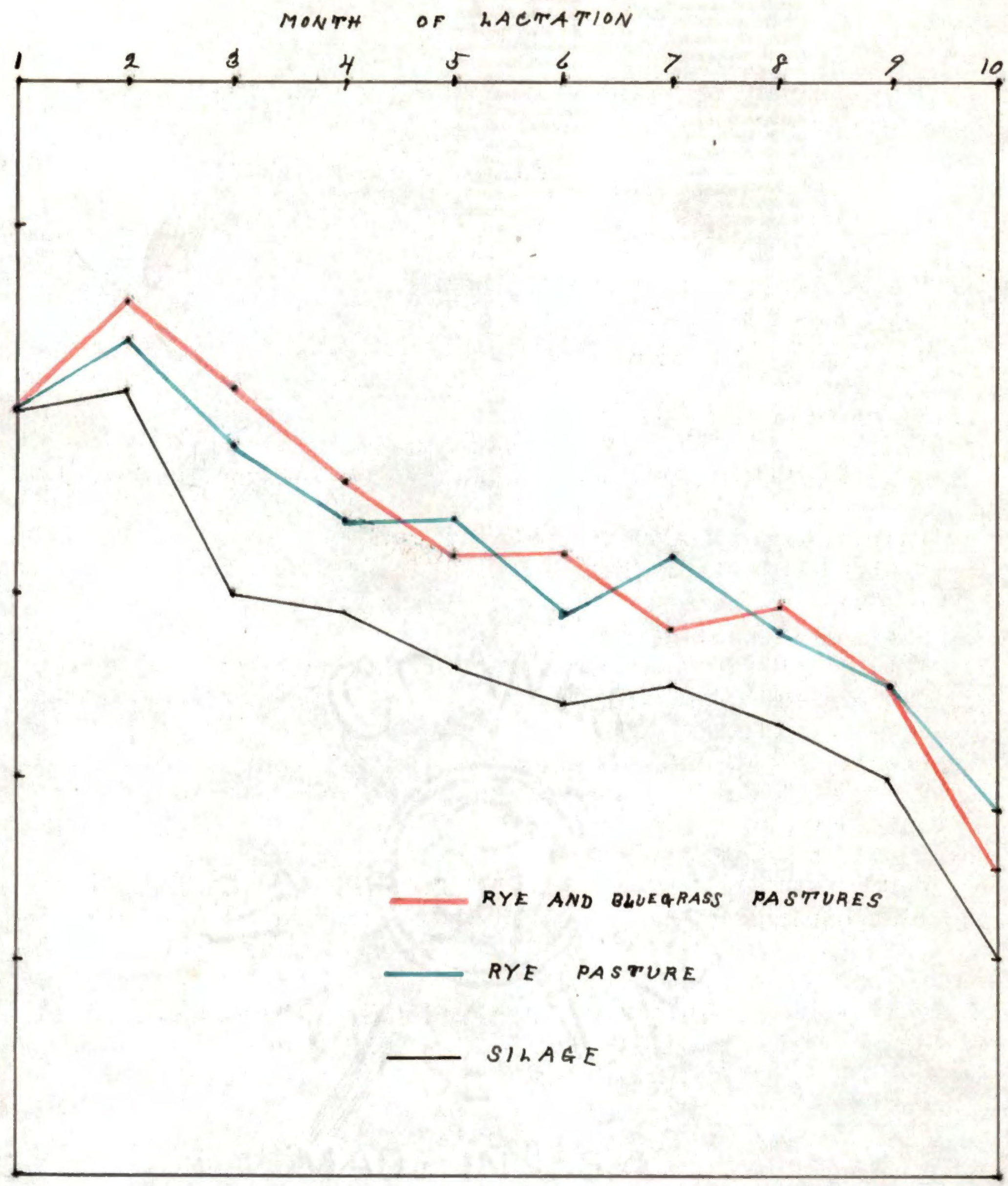

Figure 5. Composite lactation curves showing relative persistence in milk production of experimental groups over 4-year period; silage vs. winter pasture experiment.

TABLE XVIII

ANALYSIS OF VARIANCE IN PERSISTENCY OF MILK PRODUCTION OF EXPERIMENTAL GROUPS OVER A 4-YEAR PERIOD; SILAGE VS. WINTER PASTURE

Source of variation	Sum of squares	Degrees of freedom	Mean square
Total	10.1619	335	
Between groups	2.754	2	1.377**
Between years	2.121	3	.707**
Between cows regardless of groups or years	5.287	328	.01612

"F" values

$$F \text{ (Groups)} = \frac{1.377}{.01612} = 85.4^{**}$$

$$F \text{ (Years)} = \frac{.707}{.01612} = 43.9^{**}$$

** Highly significant

TABLE XIX

NUTRIENT INTAKE VS. REQUIREMENTS; SILAGE VS. WINTER PASTURE EXPERIMENT

	Group I, silage	Group II, rye pasture	Group III, rye and permanent pasture
	Lbs. TDN	Lbs. TDN	Lbs. TDN
1937-38			
Nutrient intake:			
Hay	7,963	11,483	8,810
Silage	5,162	------	------
Grain	3,847	4,572	3,984
Pasture*	------	3,127	3,383
Weight losses**	1,802	2,211	1,188
Total	18,774	21,393	17,365
Nutrient requirements:			
Maintenance	7,113	7,826	6,208
Milk production	6,637	7,688	6,913
Weight gains**	2,418	2,912	1,836
Total	16,168	18,426	14,957
1938-39			
Nutrient intake:			
Hay	5,865	7,280	6,155
Silage	3,815	------	------
Grain	3,765	3,370	3,830
Pasture*	------	2,863	4,466
Weight losses**	1,188	764	887
Total	14,633	14,277	14,338
Nutrient requirements:			
Maintenance	5,456	5,361	5,221
Milk production	5,808	5,471	5,949
Weight gains**	1,924	2,030	1,747
Total	13,188	12,862	12,917

* Total digestible nutrients not furnished by other feeds were assumed to come from pasture.

** Differences between weighings for successive months of experiment.

TABLE XIX (CONT'D.)

NUTRIENT INTAKE VS. REQUIREMENTS; SILAGE VS. WINTER PASTURE EXPERIMENT

	Group I, silage	Group II, rye pasture	Group III, rye and permanent pasture
	Lbs. TDN	Lbs. TDN	Lbs. TDN
1939-40			
Nutrient intake:			
Hay	6,520	10,991	9,821
Silage	3,422	-----	-----
Grain	2,889	2,982	3,241
Pasture*	-----	-1,082	- 720
Weight losses**	464	1,529	1,065
Total	13,295	14,420	13,407
Nutrient requirements:			
Maintenance	5,626	5,968	5,500
Milk production	4,794	4,940	5,605
Weight gains**	1,589	2,118	1,006
Total	12,009	13,026	12,111
1940-41			
Nutrient intake:			
Hay	7,928	8,540	7,655
Silage	2,953	-----	-----
Grain	3,817	4,196	4,507
Pasture*	-----	683	1,791
Weight losses**	519	1,127	751
Total	15,217	14,546	14,704
Nutrient requirements:			
Maintenance	5,700	5,445	5,328
Milk production	6,496	6,509	6,934
Weight gains**	2,118	1,730	1,571
Total	14,314	13,684	13,833

* Total digestible nutrients not furnished by other feeds were assumed to come from pasture.

** Differences between weighings for successive months of experiment.

extra nutrients at the rate of 2.73 pounds T.D.N. for each pound lost. Similarly, gains in weight were figured as requiring 3.53 pounds T.D.N. for each pound increase in body weight. In addition, it was found that Group I (silage) ate more nutrients than apparently required, 16.1 percent more the first year, 11.0 percent more the second, 10.7 percent the third, and 6.3 percent the fourth. Based on this finding, the calculated nutrient intakes of Group II and III were increased above the calculated requirements by the same percentages for the respective years. The differences between total intake and nutrients furnished by hay and grain were assumed to come from pasture.

The data for 1938-39 show certain discrepancies. The nutrients supplied by hay and grain alone exceeded the requirements. The apparent result was that the few days of pasture for that season showed a negative value. What seems more likely is that the cows did not use the nutrients supplied by hay and grain as efficiently as expected.

IRRIGATED PASTURE AT THE MIDDLE TENNESSEE EXPERIMENT STATION*

This project was started in the summer of 1938 as a cooperative project with the Tennessee Valley Authority. The object of the experiment was to study the value of irrigated pasture for dairy cattle at the Middle Tennessee Experiment Station. Data were on hand for the years 1938 to 1941, inclusive.

Plan of Experiment. Jersey cows were selected according to age, body weight, previous records, and stage of lactation and divided as near equally as possible into two groups. One group was pastured on a 3 1/4-acre lot of irrigated pasture, containing bluegrass, Bermuda grass, and white clover. The other group was pastured on a similar lot that was not irrigated. Each cow in either group was fed five pounds a day of the same grain mixture as used for the herd. Alfalfa hay was fed when pasture became short. No hay and very little grain were fed in the summer of 1941.

Cows were milked twice a day. Butterfat production was computed from the daily milk weights and monthly one-day tests. Cows were weighed monthly.

The experiment started with June the first year, and May the following three years, and ended in September or October.

Pasture Treatment. The irrigated plot was watered one or more times a month except in those months when rainfall was unusually heavy. Table XX shows the amounts of rainfall and of irrigation water for each year. Water

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* From data on file with the Department of Dairying, University of Tennessee, Knoxville.

TABLE XX

INCHES OF RAINFALL AND IRRIGATION WATER ON IRRIGATED AND CHECK PLOTS; IRRIGATED PASTURE EXPERIMENT

Year	Plot	Days	Rainfall	Irrigation water
			inches	inches
1938	Irrigated	153	18.12	8
	Check	153	18.12	-
1939	Irrigated	169	18.39	9.2
	check	169	18.39	---
1940	Irrigated	168	14.96	16
	Check	168	14.96	--
1941	Irrigated	143	12.08	23
	Check	143	12.08	--

for irrigation was pumped from a nearby stream by electric motor-driven pumps. An overhead rotating sprinkler system was used to distribute the water. No additional treatment, besides irrigation, was given any plot.

The pastures were inspected twice a month to note height of grasses and proportions of the grasses and white clover.

Results. Results of the trials for 1938, 1939, 1940, and 1941 are shown in Table XXI. Production, persistence of lactation, changes in body weight, and nutrient intake vs. requirements have been examined. All figures, unless otherwise noted, are group totals. "Cow days milked during experiment" equals the sum of days in milk for all cows in the group. Although not shown in the table, irrigation increased the percentages of white clover and bluegrass somewhat and reduced the percentages of Bermuda grass and weeds. However, Bermuda dominated the scene after mid-June.

Milk and Butterfat Production. When reduced to a cow-day in milk basis, the irrigated pasture group produced slightly more the first two years, and the same and slightly less, respectively, the last two. A comparison of the average daily milk production between the first and last months for both irrigated and non-irrigated pasture groups (Table XXI) shows no large or consistent differences in decline in milk yield.

Maintenance of Body Weight. Examination of the losses and gains between monthly weighings (Table XXI) shows that the irrigated pasture group made greater net gains for 1938 and 1939 than the check group, but

TABLE XXI

RESULTS FROM IRRIGATED PASTURE EXPERIMENT, 1938

	Irrigated	Not irrigated
Ave. No. cows	4.8	4.8
Ave. No. days in milk at start	56	48
Cow days milked during expt.	712	743
Total milk, lbs.	16,108.7	16,804.2
Total fat, lbs.	873.9	896.3
4% F.C.M., lbs.	19,552	20,166
4% F.C.M. per cow-day, lbs.	27.5	27.2
Initial weight per cow, lbs.	882	920
Gains between weighings, lbs.	215	280
Losses " " "	370	705
Nutrients* required for		
Maintenance, lbs.	5,141	5,413
Live weight gains, lbs.	759	988
Milk production, lbs.	6,335	6,534
	12,235	12,935
Nutrients* supplied by		
Alfalfa hay, lbs.	932	932
Concentrates, lbs.	2,411	2,422
Live weight losses, lbs.	1,010	1,925
Pasture, lbs.	7,882	7,656
	12,235	12,935
Portion of nutrients supplied by pasture	64.4%	59.2%
Actual milk per cow per day:		
First month (June), lbs.	24.8	26.0
Last month (October), lbs.	14.7	14.5

* Total digestible nutrients.

TABLE XXI (CONT'D)

RESULTS FROM IRRIGATED PASTURE EXPERIMENT, 1939

	Irrigated	Not irrigated
Ave. No. cows	6.67	6.67
Ave. No. days in milk at start	54	31
Cow days milked during expt.	1,023	958
Total milk, lbs.	19,609.8	18,425.7
Total fat, lbs.	1,058.2	926.3
4% F.C.M., lbs.	23,717	21,265
4% F.C.M. per cow-day, lbs.	23.2	22.2
Initial weight per cow, lbs.	821	903
Gains between weighings, lbs.	545	690
Losses " " "	685	995

	Irrigated	Not irrigated
Nutrients* required for		
Maintenance, lbs.	7,552	8,150
Live weight gains, lbs.	1,924	2,436
Milk production, lbs.	7,684	6,890
	17,160	17,476
Nutrients* supplied by		
Alfalfa hay, lbs.	1,401	1,401
Concentrates, lbs.	3,851	4,018
Live weight losses, lbs.	1,870	2,716
Pasture, lbs.	10,038	9,341
	17,160	17,476
Portion of nutrients supplied by pasture	58.5%	53.5%
Actual milk per cow per day:		
First month (May), lbs.	26.1	24.6
Last month (October) lbs.	13.9	15.6

* Total digestible nutrients.

TABLE XXI (CONT'D.)

RESULTS FROM IRRIGATED PASTURE EXPERIMENT, 1940

	Irrigated	Not irrigated
Ave. No. cows	6.64	5.53
Ave. No. days in milk at start	64	70
Cow days milked during expt.	1,070	902
Total milk, lbs.	21,943.1	17,231.1
Total fat, lbs.	1,127.2	986.4
4% F.C.M., lbs.	25,685	21,668
4% F.C.M. per cow-day, lbs.	24.0	24.0
Initial weight per cow, lbs.	832	846
Gains between weighings, lbs.	400	365
Losses " " "	570	275

	Irrigated	Not irrigated
Nutrients* required for		
Maintenance, lbs.	7,496	6,143
Live weight gains, lbs.	1,412	1,288
Milk production, lbs.	8,322	7,027
	17,230	14,458
Nutrients* supplied by		
Alfalfa hay, lbs.	2,053	1,629
Concentrates, lbs.	4,158	3,039
Live weight losses, lbs.	1,556	751
Pasture, lbs.	9,463	9,039
	17,230	14,458
Portion of nutrients supplied by pasture	54.9%	62.5%
Actual milk per cow per day:		
First month (May), lbs.	26.8	27.3
Last month (October), lbs.	15.5	15.2

* Total digestible nutrients.

TABLE XXI (CONT'D)

RESULTS FROM IRRIGATED PASTURE EXPERIMENT, 1941

	Irrigated	Not irrigated
Ave. No. cows	6.0	4.4
Ave. No. days in milk at start	129	126
Cow days milked during expt.	849	626
Total milk, lbs.	13,974	10,675
Total fat, lbs.	756.6	699.6
4% F.C.M., lbs.	16,939	13,264
4% F.C.M. per cow-day, lbs.	20.0	21.2
Initial weight per cow, lbs.	770	740
Gains between weighings, lbs.	105	295
Losses " " "	415	210
Nutrients* required for		
Maintenance, lbs.	5,903	3,871
Live weight gains, lbs.	371	1,041
Milk production, lbs.	5,488	4,298
	11,762	9,210
Nutrients* supplied by		
Alfalfa hay, lbs.	----	----
Concentrates, lbs.	644	470
Live weight losses, lbs.	1,133	573
Pasture, lbs.	9,985	8,167
	11,762	9,210
Portion of nutrients supplied by pasture	84.9%	88.7%
Actual milk per cow per day:		
First month (May), lbs.	19.9	21.7
Last month (September), lbs.	11.2	12.7

* Total digestible nutrients.

smaller net gains for 1940 and 1941. All cows in either group were milking in the early part of their lactations during the experiment. Cows under such conditions may be expected to lose weight regularly, and the effect of ration on weight maintenance is easily noted.

Nutrients Supplied by Pasture. It will be noted from Table XXI that the irrigated pasture supplied somewhat more total digestible nutrients each year than the non-irrigated plot of the same size. The calculations were made according to the method of Knott, Hodgson, and Ellington (58), using standards and average analyses from Morrison (70). In percentage of total nutrient intake supplied by pasture, the irrigated pasture led for 1938 and 1939, but was behind for the last two years. The omitting of alfalfa hay from the ration and reducing of the concentrates fed in 1941 had the effect of increasing the percent of nutrients secured from pasture, but it greatly reduced both total nutrient intake and also milk production.

Significance of the Results. The smallness of differences and lack of consistency between groups for the four years of experiment suggest that there was no significant difference in production of individual cows on either kind of pasture. Data on individual feed consumption were not available, and the variances in body weight and in milk production were not computed, but it is likely that there was more difference within, than between groups. In order to have significant individual differences, it would be necessary for the group means to be consistently apart in the same direction and for individual cows in each group to not vary greatly from the group means.

It should be noted, however, that the irrigated plot carried more cows than the non-irrigated plot during the summers of 1940 and 1941, and that the irrigated plot produced more milk than the other plot in each of these two years. The effect of irrigation was to provide somewhat more feed per acre, and thus make it possible to carry more cows per acre and secure more milk per acre than from the non-irrigated plot. The increase in milk production was secured by employing more cows rather than by increasing production of individual cows.

ALL-YEAR PASTURING WITH AND WITHOUT CONCENTRATES AT THE WEST TENNESSEE EXPERIMENT STATION*

The work reported is a continuation of previous work with limited numbers of cows at the West Tennessee Station. Results up to 1937 showed 88 percent as much milk and 92 percent as much butterfat on hay, silage, and pasture as with roughage plus 1,979 pounds of concentrates per cow for complete lactations (39). With these results, the experiment was extended to include more cows.

Procedure. Older cows were continued on all-roughage rations, this being Group I. Heifers were entered two months before expected date of first calving in Group II and fed concentrates, in addition to roughage, both while dry and during the lactation. Four pounds of concentrates a day usually were given during the dry period. The rate while milking was generally less than the conventional figure of one pound to three pounds milk. Following one lactation with concentrates, cows in Group II were switched to Group I on all-roughage rations. The data on hand extend from June 1937 to May 1941, and in that time seven cows completed one or more lactations in each of both groups.

Hay and silage were given both groups whenever pasture was short or not available. Mixed grass and legumes were used for the permanent pasture, generally through May, June, and early July, also in early fall. Crimson clover with or without ryegrass was used from November to April, inclusive. Sudan grass furnished grazing in July and August.

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* From data on file with the Department of Dairying, University of Tennessee, Knoxville.

Tables XXII and XXIII show the number of pasture days from each crop each year, also the total pasture days for the year, and by months. The seasonal distribution is shown in Figure 6.

Cows in both groups were weighed monthly. Daily milk weights were kept, and butterfat production was computed from daily milk weights and monthly one-day fat tests. All cows were milked twice daily.

Feed Consumption. Table XXIV shows the amounts of feed consumed by seven cows during lactations when grain was fed and during the following lactations on roughage alone. The quantities of hay and silage were not greatly different for the two lactations.

Silage feeding extended from November to March the first and second years. In 1939 and in 1940, silage feeding started in September. Hay consumption was low during the pasture season, dropping to one pound a day in some months. Judging by monthly data on milk production and changes in body weight, crimson clover during April furnished the most nutrients per acre of all pastures. By the same evidence, permanent pasture during late summer and early fall furnished the least. When turned on crimson clover in April, cows generally would come up in milk production and, in some cases, show fairly large increases in body weight.

Maintenance of Body Weight. Figure 7 shows the changes in body weight from beginning through end of lactations for the same seven cows, both when fed grain and on roughage alone. It is obvious that on all-roughage rations the cows lost more weight the first two months of

TABLE XXII

AMOUNTS OF PASTURE SUPPLIED BY EACH CROP;
ALL-YEAR PASTURING EXPERIMENT

Year	Pasture days			
	Permanent pasture	Sudan grass	Crimson clover	Total
1937-38	191	15	136	342
1938-39	156	28	30	214
1939-40	123	---	30	153
1940-41	184	---	178	362

TABLE XXIII

PASTURE DAYS BY MONTHS; ALL-YEAR PASTURING EXPERIMENT

Month	1937-38	1938-39	1939-40	1940-41	Average
June	30	30	30	30	30
July	31	31	31	30	31
August	31	31	31	31	31
September	30	30	0	30	22
October	31	31	0	31	23
November	27	0	0	30	14
December	25	0	0	30	14
January	22	0	0	31	13
February	25	0	0	26	13
March	29	0	0	31	15
April	30	30	30	30	30
May	31	31	31	31	31
	342	214	155	362	267

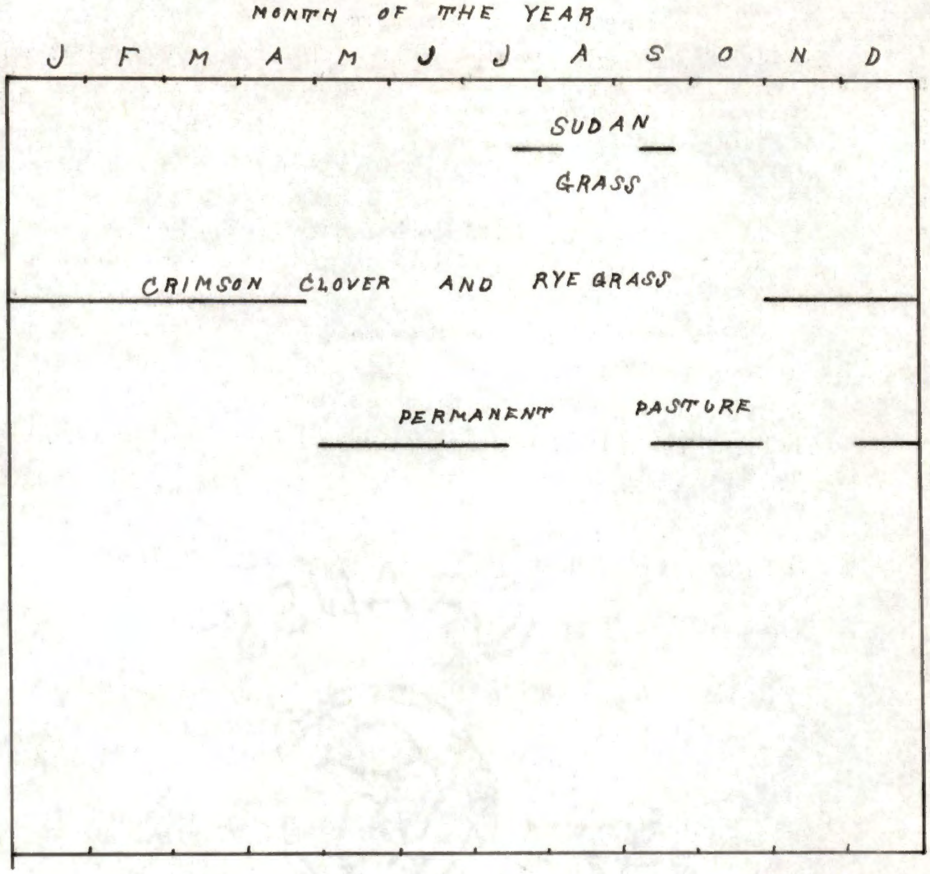

Figure 6. Seasonal distribution of pasture secured from various crops, West Tennessee Experiment Station

TABLE XXIV

COMPARISON OF PERFORMANCE OF SAME SEVEN COWS WHEN GIVEN LIMITED-GRAIN AND ALL-ROUGHAGE RATIONS FOR SUCCESSIVE LACTATIONS

	On limited-grain ration Ave. per cow	On roughage alone Ave. per cow
Feeds given:		
Hay, lbs.	3,117	3,195
Silage, lbs.	4,329	4,491
Grain, lbs.	1,623	----
Pasture days	199	199
Production data:		
Days milked	336	324
Milk, lbs.	7,744	6,288
Fat, lbs.	406.6	314.1
4% F. C. M., lbs.	9,197	7,226
4% F. C. M. per cow-days, lbs.	27.4	22.3
Initial body weight, lbs.*	822	859
Monthly losses, lbs.**	382	456
Monthly gains, lbs.**	660	653

* Beginning of lactation.

** Differences between weighings for successive months.

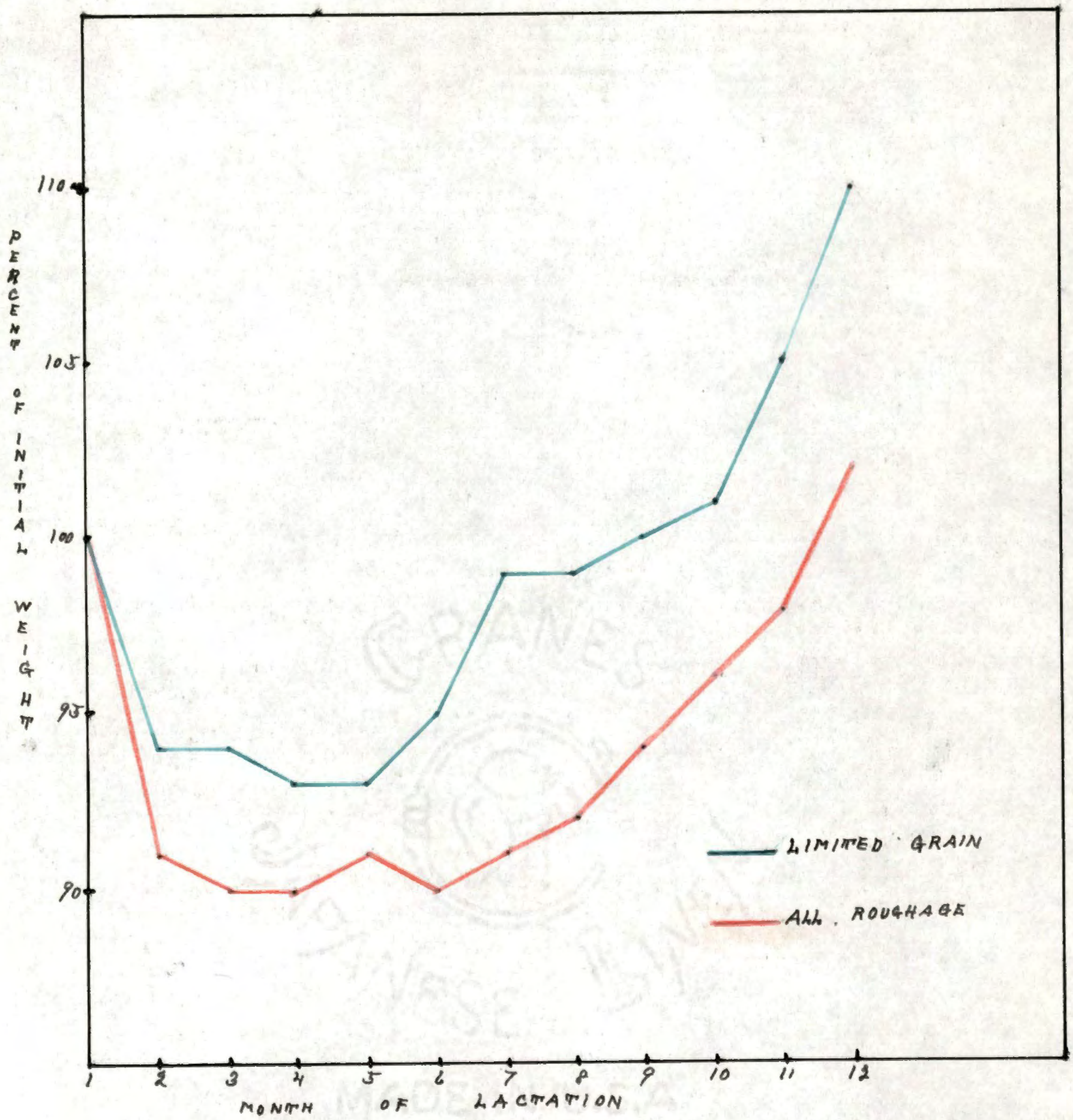

Figure 7. Graph showing changes in body weight from beginning to end of lactation; all-year pasturing experiment.

lactation and remained lower until later in lactation than on roughage plus grain. These results agree with those from other experiments (18, 33, 34, 40, 41, 63, 81, 95, 99).

The striking increases in weight from the tenth to the twelfth months, particularly in the lactations when grain was fed, are due to the fact that the cows were in their first, second, or third lactations and still growing.

Production. Table XXIV shows the production of the seven cows, both with and without concentrates. The same cows produced 81 percent as much milk and 77 percent as much butterfat on roughage alone as with grain. When given concentrates, the cows milked longer than when not.

Figure 8 shows that with concentrates the cows reached a peak the second month of lactation rather than the first, and continued at a higher level in succeeding months than with roughage alone. This increased persistency of lactation when grain is fed agrees with other reports (2, 18, 33, 34, 41, 63, 95, 99).

Health and Condition of Cows. Except for heavy losses in weight the first six months of lactation, the all-roughage rations seemed to have no undesirable effect on health or condition of the cows. The records show no evidence of breeding troubles, since cows calved regularly throughout the four years of the experiment.

Nutrients Supplied by Pasture. Table XXV shows the average nutrient requirements per cow, based on Morrison's standards (70), and the estimated amounts furnished by each feed. It was assumed that the

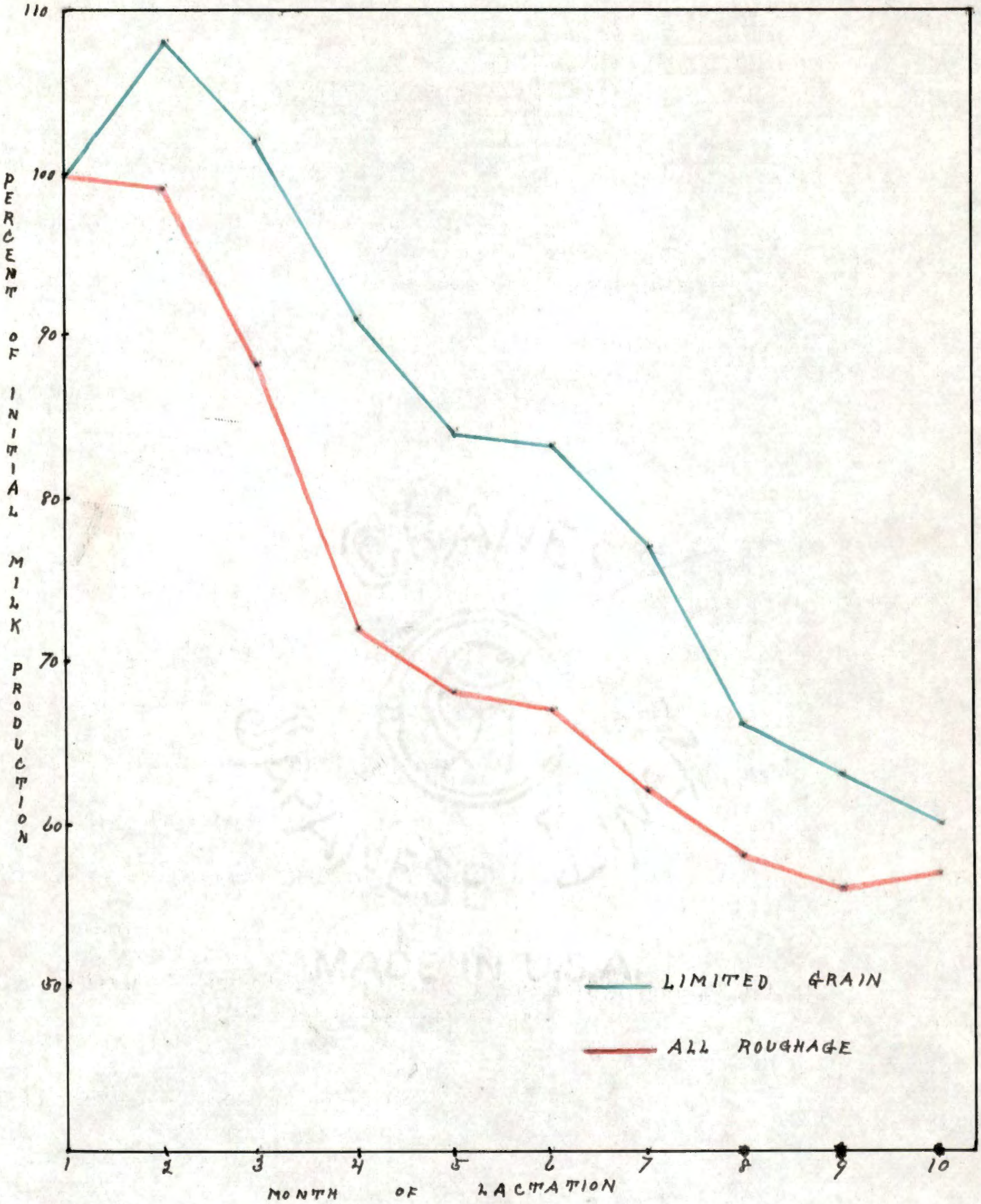

Figure 8. Graph showing persistency of lactation; all-year pasturing experiment

TABLE XXV

COMPARISON OF PERFORMANCE OF SAME SEVEN COWS WHEN GIVEN LIMITED-GRAIN AND ALL-ROUGHAGE RATIONS FOR SUCCESSIVE LACTATIONS; NUTRIENT INTAKE VS. REQUIREMENTS

	Limited grain	Roughage alone
	Lbs. per cow	Lbs. per cow
T. D. N. requirements:		
Milk production	2,980	2,341
Maintenance	2,244	2,242
Gains in weight	660	653
Total	5,884	5,236
T. D. N. supplied:		
Hay	1,590	1,630
Silage	779	808
Grain	1,201	---
Losses in weight	382	456
Pasture (estimated)	1,932	2,342
Total	5,884	5,236

cows ate only their actual requirements and that the extra nutrients above those supplied by other feeds came from pasture. Since cows sometimes do eat more than their actual requirements, it is safe to say that pasture furnished at least the amounts shown. Ewalt and Jones (22) reported actual pasture yields by the clip-plot method to be 8 percent higher than by the method used here.

Cows on roughage alone received 47 percent of their nutrients from pasture, those on limited grain and roughage 33 percent. This is somewhat lower than the figures of 74 and 52 percent, respectively, from previous work at the same station.

DRYING HAY IN THE BARN

This work, which was begun at Knoxville in 1934 and is still in progress, has been reported in Tennessee Bulletin No. 170 (90). The results, as mentioned earlier in this paper, have been highly satisfactory. Hay has been produced that was somewhat superior to field-dried hay, both in quality and in feeding value. The method is relatively inexpensive and appears to be quite practical for most farmers to use. For further details the reader is referred to the above bulletin.

DISCUSSION OF RESULTS

Accuracy of Results. In evaluating the results of feeding experiments with dairy cows, it should be remembered that we are dealing with biological material which is inherently variable. In simpler words, no two cows are exactly alike. Beyond these inherent differences, environment may affect greatly a cow's performance. It follows that the production of any cow is a combined result of heredity and environment. In selecting cows for experiment, we can attempt to equalize groups on the basis of past performance, and we can try to control the environmental factors. The repeatability of past performance is not perfect, however. Copeland (14) found correlation values of 0.59 to 0.71 for two consecutive records by the same cow. This means that different records of the same cow may vary 20% or more from one another.

Environmental factors are numerous and not easy to determine or control. Stage of lactation of the different cows at the start of an experiment may affect their performance in the following weeks. The cows in the winter pasture experiment reached a peak in milk production in the second month of lactation. If cows in the third month were selected for one experimental group, and cows just fresh for another group, the results in terms of milk production might differ between groups from this cause alone. Levels of feeding alone affect the results. It would be entirely possible to give cows enough supplementary feed alone for maintenance and milk production, in which case the test feeds would furnish only unnecessary surplus nutrients. In the irrigated pasture experiment, hay and grain were fed the first three years, but no hay and very little grain the fourth year. In this experiment, however, the order of results did not change with a reduction in the amounts of supplementary feeds.

Body reserves may affect the performance of cows, especially in short-time experiments. The cows when on all-roughage at the West Tennessee Station drew more on their body reserves in the first four months of lactation than during the same months of preceding lactations in which the same cows were given concentrates. Cows on experiments employing a reversal system may carry over positive or negative residual effects, in the form of differences in body weight, from one period to the next. Autrey (3) claims to have accounted for these residual effects by suitable experimental design and proper statistical treatment of the results.

In starting an experiment, it is generally thought desirable to use fairly large numbers of animals and, by determining group averages, to reduce the variability in results arising from individual differences in cows. The tendency in interpreting data from such experiments is to consider the group averages only. However, cows within each group may not react the same way or to the same extent from experimental treatment. The differences between cows within groups may be great enough, in some cases, to render the differences between group averages almost meaningless.

The silage experiments at Knoxville showed that gains and losses in body weight, including calving losses, should be considered in computing nutrient requirements. The gains in weight during later months of lactation, both body weight and the developing fetus, require extra feed. Likewise, the losses in body weight during earlier months of lactation supply extra nutrients over and above what a cow may consume in the form of feed.

Conclusions. The results of the silage experiments at Knoxville showed that physiologic efficiency of a ration tends to vary inversely with the level of feeding. The physiologic efficiency (ratio of T.D.N. above maintenance to 4% fat-converted milk) was higher for the winter of 1941-42, when limited amounts of grain were fed, than for the two winters previous.

The winter pasture vs. silage trials at Columbia showed that both rye pasture alone and rye plus permanent pastures would maintain milk production at a somewhat higher level than would corn silage. The results with crimson clover pasture at the Jackson station are similar. Cows turned on crimson clover pasture in April after having been on hay and silage through the winter came up in milk production.

The all-year pasturing work at Jackson showed that the same cows fed limited amounts of concentrates used a larger portion of their total nutrient intake for milk production than when fed roughage alone. In effect, these particular cows produced milk with greater efficiency when given grain than on a lower level of feeding. Whether or not the feeding of still more concentrates would have given further increase both in total milk production and in efficiency of milk production is not known.

The results with irrigated pasture at Columbia suggest that other factors than water supply should be investigated. In the Oregon and

Australian experiments cited (8, 22, 86), fertilizers were used and various combinations of crops were tried. Some crops may respond more effectively to irrigation than others. Water is not the only food material that plants need, and fertilizers may supply other factors also necessary. It may be possible to supply too much water to crops in regions of normally heavy rainfall, thus interfering with formation of nitrates by bacterial action in the soil and tending to remove soluble nitrates, phosphates, and other plant food materials by leaching.

The experiments in general show that nutrient balance computations as used to determine yields of pasture may not be reliable at high levels of feeding. The apparently negative value of pasture at the Columbia Station in the winter of 1939-40 can be explained best by assuming that the cows were fed more than enough hay and grain alone to supply their needs, and that pasture represented excess nutrients. In such cases, pasture yields should be checked by some other method, such as clip plots, besides the total digestible nutrient method.

The results of feeding trials with silages at Knoxville show that alfalfa, soybeans, and sericea can be preserved successfully and fed to milking cows with good results. The sericea silage appeared to be less palatable than corn and alfalfa silages. The work with winter pastures at Columbia shows them to be somewhat superior to corn silage for milk production, also capable of saving up to one-fourth in hay or an equivalent amount of silage through the winter season.

The experiments with irrigated bluegrass, Bermuda, and white clover pasture at Columbia show that it may be advantageous to apply irrigation water, even in seasons of normal rainfall, in trying to increase yields of that particular pasture combination on the particular soil used. The results, in terms of milk production per cow, were consistently negative for each of the four years, both with and without fairly generous amounts of supplementary hay and grain. The results, in terms of milk production per acre, showed an advantage for irrigation in the seasons of 1940 and 1941 when enough cows were put on the irrigated plot to use all the available growth. The results might or might not be the same with different soil types, with fertilizers, with other crops than bluegrass, Bermuda, and white clover, or in a season of sub-normal rainfall over a period of several weeks. The separate or combined effects of these factors remain to be investigated. One positive result from the irrigated pasture experiments was to show that good permanent pasture may supply nutrients equal to 2 to 3 tons of hay per acre in a single season.

The work on all-year pasturing at the Jackson Station showed that cows capable of producing 400 pounds of butterfat a year with limited amounts of concentrates would produce about three-fourths as much on good hay, silage, and pasture alone. The limiting factor seemed to be that cows on roughage alone did not reach a high peak in production, even with the help of body reserves. If dry matter intake remains constant, the T.D.N. intake on an all-roughage ration is lower than when concentrates are fed, and the T.D.N. from roughage may have less net energy value for milk production than the T.D.N. from concentrates. Whether or not to feed concentrates, and how much to feed, would depend on (1) maximum ability of the cow, (2) the prices of grain and butterfat, and (3) what crops, roughages or grains, will produce the most nutrients and net energy per acre. If cows can produce 300 pounds butterfat a year on roughage, then it may not pay to feed concentrates to cows whose maximum ability to produce is around 300 pounds. However, the higher producing cows may make good use of generous amounts of grain. The difference in the Jackson experiment of 92 pounds butterfat per cow per lactation between all-roughage rations and rations with concentrates would bring $56. at current prices, while the 1,623 pounds of concentrates fed per cow per lactation should cost much less. The fact that roughages generally produce more nutrients per acre than do grains would favor feeding of roughage alone, but the high efficiency of high-producing cows may cause feeding of generous amounts of concentrates to be most profitable with such cows.

SUMMARY

1. Alfalfa, sericea, and soybeans were ensiled with molasses and phosphoric acid and fed to dairy cows. Alfalfa and soybean silages gave results fully equal to those from corn silage. Sericea silage gave results slightly inferior to those from corn silage, apparently because it was consumed less readily than the other silages.

2. Cows were divided into groups and fed (1) conventional winter rations of hay, corn silage, and grain, and (2) hay and grain with winter pasture in place of corn silage. Winter pasture was found equal to corn silage in maintaining body weight and superior to corn silage in maintaining milk production.

3. Irrigated permanent pasture consisting of bluegrass, Bermuda, and white clover was compared with non-irrigated pasture of the same composition. Cows on the irrigated plot did not produce significantly greater amounts of milk per cow than cows on the non-irrigated plot. The irrigated plot produced more milk per acre than the non-irrigated plot when enough cows were put on it to consume all the available feed.

4. Cows were fed hay, silage, grain, and pasture throughout one or more lactations, followed by all-roughage rations in succeeding lactations. Cows when fed only hay, silage, and pasture produced less total milk, also reached a peak in milk production somewhat earlier and were less persistent than when fed grain in addition. Cows on all-roughage rations lost more weight the first two months of lactation and remained lower in body weight till a later stage of lactation than when grain was fed.

Seven cows produced an average of 7,744 pounds of milk and 406 pounds fat in complete lactations when grain was fed, but only 6,288 pounds milk and 314 pounds fat in the immediately following lactations on roughage alone.

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