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To the Committee on Graduate Study:

I submit herewith a thesis written by Guy Robert Kirk and entitled "A Pasture Program for Tennessee", and recommended 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 Agriculture.

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At the request of the
Committee on Graduate Study,
we have read this thesis,
and recommend its acceptance.

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Accepted for the Graduate
Committee

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A PASTURE PROGRAM FOR TENNESSEE

- O -

A THESIS

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

By

GUY ROBERT KIRK

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INTRODUCTION

When it is considered that out of 19,085,837 acres of land in farms in Tennessee, 5,643,998 acres are in pasture, one readily sees the importance of pasture in the State. Of the total acreage in farm land, 15 per cent is in plowable pasture.

The farmers of Tennessee have long used their pasture land as a source of free feed. The necessity for replacing the fertility removed by grazing animals has not been considered. Very little attention has been given to reseeding pastures which are running out. Livestock have been allowed to graze at will, often times, completely denuding the landscape. Weeds and other undesirable plants have been allowed to come into pastures, in many cases completely taking them, without any attempt to control their advances.

After considering the importance of pastures in Tennessee, and the pasture management practices the farmers are following, one readily comes to the conclusion that there is a great need for pasture improvement in the State. It is with this thought in mind that this paper has been written. An attempt has been made to set up a sound pasture program for the State, based upon proven, sound, scientific principles.

Henry A. Wallace, Secretary of Agriculture, has the following to say about the future of pastures in the United States:

> "I suspect that we are going to revise some of our thinking about pastures. We usually find them on the poorest parts of our farms. They are, as a rule, compared

with those of other countries, of low productivity. We must make them more productive eventually to justify our going back to a grassland economy. The right grasses, the right legumes, proper mixtures, innoculation, fertilization, careful use - all these, and more, are necessary to get and maintain good pastures." (35)[1]

(1) Numbers refer to reference citations in Bibliography.

PART I

PASTURE PRINCIPLES AND DEVELOPMENTS

CHAPTER I

THE IMPORTANCE OF PASTURE ON THE FARM

Pasture and Farm Income

The problem of land use economics is of vital importance to every farmer. He is constantly confronted with the problem of deciding on the number of acres he will give to the various enterprises on his farm. His problem is to decide what combination of enterprises and acreage or number of units of each will be most profitable to him, both in farm income and labor income. It is the purpose of this discussion to present data, from various sections of the United States, showing the influence of pasture on farm income.

A survey of 70 dairy farms in Washington County, Indiana, in 1928 (2)[1] showed the farm and labor income to be higher on those farms having the highest percentage of farmed area in pasture, with a decrease in farm and labor income as the percentage of farmed area in pasture became less. It also showed the farms that had the largest percentage of land in pasture to have the least number of acres in crops, the largest total farm receipts, the largest livestock receipts, and the least labor costs. Table I shows a comparison between the farms having the highest, medium, and lowest percentage of farmed area in pasture.

(1) Numbers refer to reference citations in Bibliography.

TABLE I. EFFECTS OF A HIGH PROPORTION OF FARM AREA IN PASTURE (2)
(Survey of 70 Farms in Washington Co. Ind. 1928)

	Highest one-third	Medium one-third	Lowest one-third
Percentage of farmed area in pasture. #	56	36	24
Number of Farms	23	24	24
Farm Efficiency Factors -			
Size of farm (acres)	152	164	154
Crop acres per farm	63	74	84
Crop index	91	103	83
Operating expenses per acre	$10.05	$13.98	$13.36
Receipts per $1.00 feed fed	1.34	1.26	1.24
Farm Receipts -			
Cattle	$1,260	$1,041	$780
Sheep	193	29	48
Hogs	463	549	492
Poultry	326	391	395
Crop sales	154	222	244
Total farm receipts	$2,527	$2,407	$2,073
Farm Expenses -			
Labor	$175	$183	$196
Fertilizer and seed	123	176	165
Feed purchased	352	339	286
Taxes	235	257	239
Other	222	202	120
Total farm expenses	$1,107	$1,127	$1,006
Farm income	$1,420	$1,280	$967
Labor income	928	794	572

Farmed area is the total pasture and crop land.

A study made of the 1936 records of twenty Henderson County farms in the University of Tennessee Extension Farm Management Office is as follows: The records of twenty farms having acreages between 150-200 were selected. The total acreage of pasture and hay was determined, and the farms were divided into two equal groups, group 1 having a low pasture and hay acreage and group 2 having a high pasture and hay acreage. It was found that Group 1 (the low pasture and hay acreage group) had the smallest farm income, the smallest livestock receipts, the largest acreage of cotton, and the largest acreage of crops

(excluding pasture and hay). Table II shows a comparison between the two groups.

TABLE II. EFFECT OF LARGE ACREAGE OF PASTURE AND HAY ON TWENTY FARMS IN HENDERSON COUNTY, TENNESSEE, 1936

	Group 1 Low pasture and hay acreage	Group 2 High pasture and hay acreage
Number of records studied	10	10
Average farm acreage	170	177.5
Average acreage of pasture and hay	36.4	66.2
Average acreage of crops (excluding pasture and hay)	57.7	51.7
Average acreage of cotton	16.1	14.5
Average corn acreage	26.2	25.9
Average livestock receipts	$244.20	$521.00
Average farm income	$844.00	$1,180.00

Although the material presented in Table II is for one year only, it does indicate that the farms having the most pasture and hay, along with more livestock and livestock products to sell, are the most profitable farms.

It is generally known that dairying is more profitable during the summer than during the winter, providing a good pasture is available for grazing. E. G. Misner made a study in New York (23), covering six counties, showing cost and returns from pasture compared with winter feeding. He found that the cost of pasture and supplementary feed was $0.097 per cow per day during the pasture period, while the cost of feed per cow per day during the winter was $0.38. The returns from

the milk per cow per day was $0.34 for both seasons. This shows a loss of $0.04 per day per cow during the winter and a gain of $0.243 per cow per day during the pasture season. These data show a loss to the farmer during the winter. However, he was not actually losing money due to the fact that he was producing his own roughage. These data do show clearly that dairying is more profitable during the pasture season than during the winter.

Wylie and Neel of the Tennessee Experiment Station (50) found that, in the South, it is possible to continue the grazing season throughout the year. In a four year experiment, 1932-36, they found that if good grazing was provided throughout the year that it was more profitable to feed dairy cows a half grain ration (one pound of grain to six pounds of milk) than it was to feed them a full grain ration (one pound of grain to three pounds of milk) with only summer pasture. They also found that by proper management of pastures that over 300 days of grazing could be provided per year. Table III shows a comparison of performance and requirements of cows fed a full grain ration on summer pasture, and cows fed a half grain ration on all-year pasture.

These data indicate that, in the South, if good all-year pasturage is provided, the profits ordinarily received from dairying during the summer months may be continued, to a certain extent, throughout the year.

The discussion so far has dealt only with the presence of pasture on the farm as related to farm income. The problem of improving pastures already established and their relation to

TABLE III. EFFECT OF ALL-YEAR PASTURE FOR DAIRY COWS ON COST OF MILK (50)
(Tenn. Experiment Station 1932 - 36)

	Group 1 Full grain (1:3) and summer pasture	Group 2 Half grain (1:6) and all year pasture
Number of Cows	7	7
Days on pasture	198	346
Feed cost per cow per year	$55.37	$44.53
Value of butterfat per cow per year	$129.42	$127.13
Feed cost per cwt. milk	0.835	0.677
Feed cost per pound of fat	0.143	0.116
Income over cost of feed per cow per year	$73.96	$82.59

farm income is of importance. The farmer wants to know if it will be profitable to him to improve his pastures.

In the fall of 1931 a pasture in Louisiana (3) was divided into two equal parts. One part was disced and seeded with six pounds White Dutch Clover, nine pounds Red top, and nine pounds Italian rye grass per acre. In 1933, the half that had been disced and seeded produced 264.8 pounds of beef per acre while the untreated half, which was mowed only, produced only 148.6 pounds per acre. This shows an increase of 115.2 pounds of beef which more than pays for improving the pasture. The increase in production in the future would be a clear profit. This experiment indicates that the farm income may be increased by improving the pasture.

Nelson found in Arkansas (30), while working with permanent pastures, that an application of a complete fertilizer early in the season and a second application of nitrogen in June increased the carrying capacity of permanent pastures from 1.73 animals per acre up to 2.25 animals. The improved pasture produced 341.5 pounds of beef while the untreated pasture produced only 248.7 pounds. This shows an increase of almost a hundred pounds of beef due to fertilization. An increase that large should be enough to more than pay for the fertilizer and the labor to put it on. With results such as these the farm income can be expected to increase as a result of such treatments. Table IV gives a comparison between the fertilized and the unfertilized pasture.

TABLE IV. RETURNS FROM FERTILIZED AND UNFERTILIZED PASTURES (30)
(Ark. Experiment Station 1930 - 33)

	Fertilized	Not Fertilized
Number of acres	3.3	3.3
Number of grazing days	417	316
Average carrying capacity per acre (animal units)	2.25	1.73
Pounds of beef produced per acre	341.5	248.7

From the data presented there seems to be a tendency for livestock farms, especially dairy farms, which have the largest percentage of farm land in pasture to be more profitable than those having a less percentage in pasture. Improved pasture seems to be more profitable than unimproved pasture.

Pasture and Soil Conservation

Never before has the populace of the United States been more conscious of the ravages of soil erosion than at the present. The efforts and expenditures being made to control erosion can certainly be justified when the statistics on erosion are studied. This data shows (5) that at least 126,000,000,000 pounds of plant food elements are lost each year in the United States by erosion from pasture and crop land. The value of this enormous tonnage in nitrogen, phosphoric acid, and potash alone amounts to $2,000,000,000 annually. The vastness of this staggering loss is almost impossible to conceive. However, the figures do indicate that the problem of soil erosion and its control is one of the major problems facing the country today.

The problem of soil erosion can be discussed and estimated from the standpoint of the nation as a whole but the actual job of controlling it comes back to the farmer on his individual farm. It is the purpose of this discussion to show the value of pasture in soil conservation.

General observation as well as experimental data show erosion and surface runoff to be less on soil with a good vegetative cover than it is on cultivated land. Good pasture sod seems to be especially effective in controlling runoff and erosion.

A 14 year experiment at the Missouri Experiment Station (22) on a 3.68 per cent slope of Shelby loam soil shows bluegrass to be very effective in controlling runoff and erosion.

A plot in continuous bluegrass lost only .3 tons of soil per acre per year as compared to 19.7 tons for continuous corn. Only 12 per cent of the rainfall ran off the bluegrass plot while 29 per cent ran off the corn plot. Table V shows the erosion and runoff from soil receiving different treatments at the Missouri Experiment Station, Columbia, 1918-1932. A study of the material in Table V illustrates that the longer the land is covered by vegetation during the year the less the erosion and runoff. This seems to indicate that for best results in controlling runoff and erosion something should be growing on the land as much of the time as possible.

TABLE V. AVERAGE OF 14 YEARS MEASUREMENTS OF RUNOFF AND EROSION (22)
(Mo. Experiment Station, Columbia, 1918-32)

Cropping system or cultural treatment	Average annual erosion per acre in tons.	Percentage of total rainfall running off the land.
Bare, cultivated, no crop	41.0	30
Continuous corn	19.7	29
Continuous wheat	10.1	23
Rotation - corn, wheat, clover	2.7	14
Continuous bluegrass	0.3	12

Results at the Bethany Erosion Experiment Station, Bethany, Missouri, (22) are very similar to those obtained at the Columbia Station. Continuous bluegrass and alfalfa were more effective in controlling runoff and erosion than any other cropping system tried. Table VI shows the results of four years of erosion measurements under different crops and cropping

systems on an 8 per cent slope of Shelby loam soil.

TABLE VI. AVERAGE OF FOUR YEARS OF EROSION MEASUREMENTS UNDER DIFFERENT CROPPING SYSTEMS (22)
(Bethany Erosion Experiment Station, Bethany, Mo.)

Cropping system or cultural treatment	Percentage runoff	Tons soil eroded per acre annually
Bare soil kept cultuvated, no crop	28.5	105.1
Continuous corn, kept cultivated	28.2	67.2
Corn, wheat, clover rotation (Average three plots)	13.8	12.9
Continuous alfalfa (limed and phosphated)	4.5	0.28
Continuous bluegrass	7.9	0.33

These data indicate that a good turf will keep erosion and runoff at a minimum. However, it is to be expected that close grazing of pasture plants will cause an increase in erosion and runoff.

Weaver of the Nebraska Experiment Station (22) found that very close grazing increased erosion from 0 up to 5.08 tons of soil per acre. The percentage runoff increased from 2.5 per cent up to 15.1 as a result of very close grazing. Table VII shows the influence of excessive grazing on amount of erosion on grass lands.

The material presented on pasture and soil conservation reveals a few outstanding facts. Some of them are: (a) Erosion and runoff are less on good pasture than on cultivated land. (b) Because of the fact that pasture land does not erode so

TABLE VII. INFLUENCE OF EXCESSIVE GRAZING ON AMOUNT OF EROSION ON GRASS LANDS (22)
(Neb. Experiment Station, 15 months, 10% slope)

	Percentage runoff	Tons of soil eroded per acre
Native prairie, ungrazed	2.5	0
Mixed bluestem and bluegrass pasture, overgrazed	9.1	Trace
Mixed bluestem and bluegrass pasture, almost bare through close grazing	15.1	5.08

badly as cultivated land it seems that all land that cannot be used more profitably in other ways should be put in pasture. (c) Too close grazing of pastures will increase surface runoff and soil erosion. (d) Land having a good vegetative cover seems to conserve moisture better than land having poor vegetative cover.

CHAPTER II

PASTURE DEVELOPMENTS

Pasture Research

The nature of pasture, its growth, and its use makes accurate investigation both difficult and expensive. The problem of pasture investigation is not one for the agronomist only but the livestock man as well.

The problems of method of research and method or measuring results are limiting factors in pasture investigations. The ideal method would be to measure the results by means of livestock, which would give a practical answer to every problem tested. However, when the expense of land and livestock are considered available funds may limit the use of this method. Because of this fact other methods of pasture research have been developed.

In 1928 a survey of literature and of pasture projects under way (32) showed that there were thirteen different methods of pasture research being used in the eastern United States. Table VIII shows the methods, and their frequency, that have been or are being used by 12 states and the United States Department of Agriculture.

Schuster (32) after making the survey in 1928 of the various methods used in pasture investigations, came to the following conclusions: "There are many variable factors at work in pasture investigations, such as animals, soil, climate, grass population, etc. In order to reduce error of random sampling, replications are necessary. The author hesitates to make any recommendations as to the number of replications that should be made because of the costs involved in such an extensive project. A pro-

TABLE VIII. METHODS OF RESEARCH EMPLOYED BY 12 STATES AND BY THE U.S.D.A. IN PASTURE INVESTIGATION, 1928 (32)

Methods	No. of Places Employed
Profit	2
Hay weights	3
Clippings	6
Cattle weights	4
Sheep weights	1
Photographs	4
Surveys	3
Carrying capacity	7
Milk flow	3
Plant population	5
Chemical analysis	2
Palatability	2
Duration of grasses	2

> ject designed to obtain the basic results, i.e., animal weights, milk flow, or increased growth of meadow, should have four replication of plats with several control or check plots, and each plat should carry three animals. Other supplementary and explanatory data, such as duration of grasses, chemical analysis, etc., should be obtained under the conditions of the main project and at the same time."

Mr. Schuster's conclusions indicate that in order to obtain dependable data there must be considerable repetition. For best results there should be a number of plats run over a number of years. Repetition is necessary in order to smooth out possible errors, to level out seasonal variations, variations in climate, rainfall, and such factors. If livestock is used

to measure results, it is necessary to use several animals and conduct the experiment over several years in order to smooth out the individual differences in the animals; some may be better feeders or producers than others. As many measures as possible should be applied to each plat in order to make the results obtained more conclusive.

A questionnaire sent out by the National Fertilizer Association (44), in 1937, to the agronomists in charge of pasture research of the various states in the humid regions of the United States, showed over 300 separate and distinct pasture experiments under way. This survey covered 35 states. The fact that the majority of these experiments have been started since 1930 is evidence of the greatly increased interest in grassland improvement and of the growing realization of the importance of grass in preventing soil erosion.

Following is a list of some of the problems under investigation which will indicate the broad scope of the pasture research program under way in the United States at the present time. Some of the problems are:

"The adaptability of various legumes and their ability to withstand grazing.

Relationship between physical and chemical characteristics of the soil and the response of pastures to fertilization.

Factors that influence the longivity of white clover.

The forms of nitrogen occurring in variously fertilized grasses.

The effects of subsoil on the response of pasture species to fertilization.

The influence of various fertilizers on the duration of grasses and clovers.

Comparison of frequent clipping with one clipping per season as to influence on herbage.

New crops for supplementary pasture.

The development of improved varieties and strains of pasture plants.

The value of late fall as compared to early spring applications of different carriers of nitrogen on earliness and yield.

The effect of frequency of application of fertilizers upon botanical and chemical composition of herbage.

The varieties and strains of grasses most desirable for use in erosion control.

A study of methods of measuring yields of pastures.

The optimum soil reaction for growth of grasses and legumes on different soil types.

The influence of fertilizers and of grazing practices on the root reserves of grasses.

The value of a wide variety of grasses for pasture purposes.

Soil factors that are primarily responsible for the poor types of vegetation and undesirable grasses found in many pastures.

The effectiveness of surface application of fertilizer as compared to placement at different depths in the soil."

The Hohenheim Pasture System

A shortage of grain in Germany during the World War caused an outstanding pasture system to be developed in that country. The system was developed at Hohenheim, near Stuttgart, Germany, in 1916 (42). It was designed to produce milk without feeding concentrates. A luxuriant growth of grass rich in protein was provided, thereby making it possible for the animals, at least during the summer months, to obtain from the pasture all the feed necessary.

The Hohenheim system is best adapted to dairy cows. The following features distinguish it from the usual methods of grazing: (a) The pasture is divided into from 4 to 8 paddocks about the same size. (b) Heavy applications of fertilizers, especially nitrogen, are given the pasture. (c) The herd is divided into 2 groups - producers and nonproducers, or into 3 groups - high, low, and nonproducers. (d) Grazing is rotated, each group following another, the most productive animals get the best of the grazing.

The herbage is grazed when it is young and tender and high in protein content. If there are not enough animals to keep the grasses and legumes grazed sufficiently close during the flush growth of early summer, one or two paddocks may be mowed for hay.

The number of days that each group remains on pasture depends on the growth of the grass. It may vary from 2 to 4 days, sometimes more. The faster the growth the shorter the time each group stays on a pasture. When the last group has

been removed from the pasture it is a common practice to scatter the droppings with a shovel or harrow.

The original Hohenheim plan called for four applications of nitrogen during the year; one-half to go on in February and the remainder in May, June, and July. Ammonium sulphate or nitrate of soda was used for the February application but urea appeared to be more effective during the summer months. Phosphate and potash were applied in addition to nitrogen in the late fall, and lime was added once in 6 years. At the beginning the annual application of fertilizer was equivalent to 500 pounds of sulphate of ammonia, 260 pounds of superphosphate, and 200 pounds of 40 per cent potash salts. Potash and phosphate applications were later reduced but the nitrogen applications remained the same.

Due to the well distributed rainfall and the cool summers this system is particularly adapted to Germany, the Netherlands, and the British Isles. However, it is not well adapted to the United States because of the low temperatures and low rainfall during the summer months. The success of this system depends upon the efficient use of nitrogen fertilizer which means there must be plenty of moisture. Parts of this system may prove successful in this country, but it is doubtful if the original system can be used profitably.

Pasture Developments in Great Britain

Johnstone-Wallace (17) has very clearly described the pasture developments in Great Britain. His description is as follows: "In Great Britain, a country famous for its pastures and for its livestock, pasture research has received considerable attention for many years. The earliest successful work was commenced by the late Sir William Somerville at the Cockle Park Experiment Station at the University of Durham, and it has been continued by his successors, Sir Thomas Middleton, the late Professor D. A. Gilchrist and Professor J. A. Handley. The experiments established in 1897 demonstrated conclusively the importance of phosphorus in pasture fertilization. Sir William Somerville in reporting some of these results there, said:

'It is on the stimulus imparted to the leguminous plants that the beneficial effect of...phosphates depends. If these plants are naturally present...it is little short of marvelous how they respond to phosphatic dressings... Nearly all leguminous pasture plants are good...but best of all is wild white clover.'

During the first 21 years of the experiment a plot treated with phosphorus in the form of basic slag applied in amounts equivalent to about 1500 pounds of 16 per cent superphosphate every six years, resulted in a live weight increase of sheep amounting to 2427 pounds per acre during the period, compared with 602 pounds on the untreated plot.

The late Professor D. A. Gilchrist was the first to recognize the importance of wild white clover in pasture improvement. He was able to demonstrate that the white clover which occurred in old pastures and spread so rapidly when fertilized with phosphorus was different from the common white Dutch clover obtained from seedmen. Plants produced from white Dutch clover seed lived one or two years only, whereas the plants produced from seed of wild white clover harvested from old pastures, behaved as a true perennial and persisted permanently if properly fertilized and grazed."

CHAPTER III

FACTORS AFFECTING PASTURE PRODUCTIVITY

Soil

It is to be expected that the natural fertility, drainage and type of soil will effect the productivity of pastures just the same as other crops. In other words, the better the soil the better the pasture, providing there has been proper establishment of the right pasture plants and good pasture management.

Pasture trials run in Vermont (21) show clearly that the varying fertility levels of the soil is a major factor in grass production. Seventeen records of different pastures were kept showing the green weight and dry matter produced per acre. Out of the group of seventeen records the lowest yield for any pasture was 848 pounds of green weight and 320 pounds of dry matter. The highest production for any pasture was 20,336 pounds and 4,031 pounds of green weight and dry matter respectively. The average for the seventeen records was 7,807 pounds of green weight and 2,093 pounds of dry matter. Thus is shown the great variation in the productivity of the different soils. These results show that the soil plays a very important part in determining the productivity of the pasture.

Moisture

Pasture plants like all other plants are greatly influenced by soil moisture. The amount and distribution of rainfall determines to a great extent the productiveness of the pasture.

J. P. LaMaster of Clemson College, South Carolina in writing concerning the effects of various fertilizer treatments (18) on the yield of permanent pasture sod, said "The rate of growth during any period was largely determined by the amount of rainfall." This case shows clearly that, although a fertilizer treatment is given the pasture, the production will still depend, to a great extent, upon the amount and distribution of rainfall.

Shutt and Hamilton (43), in studying the effect of successive applications of nitrogen fertilizer to permanent pasture, found that rainfall was the limiting factor during any period of growth and that the protein and dry matter content were largely dependent upon the soil moisture as well as the success or failure of the system of fertilization. Table IX shows the effect that the amount of rainfall had upon the yield of dry matter and protein. It will be noticed that the yield of dry matter during the period of heavy rainfall was 759 pounds per acre as compared to 138 pounds during the period of low rainfall. The period of high rainfall shows an increase of 621 pounds of dry matter over the low rainfall period. The yields in protein compare favorably with those of dry matter. The protein yield for the high rainfall period was 141 pounds per acre as compared with 23.3 pounds for the low rainfall period. These data seem to indicate that the amount and distribution of rainfall as well as the plant food nutrients play an important part in pasture productivity.

TABLE IX. INFLUENCE OF RAINFALL ON PASTURE YIELDS (43)
(Central Experimental Farm, Ottowa, Ontario, Canada
(1933)

Rainfall Inches	Days of growth	Period of growth	Yields per acre	
			Dry matter pounds	Protein pounds
1.17	13	May 18 to June 1	759	141.0
0.53	16	June 1 to June 16	138	23.3

Temperature

Effect of moisture on Temperature?

A study of some of the better pasture regions seems to indicate that a part of the heavy production is due to temperature. The county of Leicester in England (12), which is one of the more famous pasture regions in that country, has a rather narrow range in temperature. The temperature ranges from an average minimum of around 40 degrees Fahrenheit and a maximum of around 60 degrees. Johnstone-Wallace (12) says in comparing Herkimer County, New York, which has an average maximum and minimum temperature of around 70 and 20 degrees respectively, with Leicester county that, "It is evident that the higher summer temperature in June, July, and August in Herkimer County provides the major disadvantage which it suffers in comparison with Leicester for the production of pasture." This indicates that a desirable pasture temperature is not one of extremely high or low temperature but one of a mild nature with a reasonably narrow range. If this condition is not true in New York, which compares favorably (12) with any other state as regards the suitability of summer temperature for the growth

of pasture, a condition less favorable for pasture production is to be expected in other parts of the United States.

If the temperature is not best for the growth of pasture it may be possible, by the use of certain pasture plants, to influence it in such a way that it will be more favorable. Of course it is impossible to influence the temperature of the air but experiments have been conducted (12) which show conclusively that the temperature of the soil can be influenced. Following is an account of the effect on soil temperature obtained by using wild white clover in New York (12):

> "The close sward produced by the growth of wild white clover shields the soil from the sun and results in a lower soil temperature during periods of hot weather. In experiments at Cornell University during the summer of 1933, the maximum soil temperature between July 3 and October 12, at a depth of one inch, averaged 8 degrees Fahrenheit lower on a plat of wild white clover and grass than on the adjoining plat of grass alone. The greatest difference occurred in August, when the soil temperature on the plat of grass alone reached 100 degrees and the temperature on the plat of grass and clover was 15 degrees lower. Such differences in temperature are probably sufficient to enable active growth to continue on the wild-white-clover plat when the temperature is too high for growth on the plat consisting of grass alone. Soil temperature probably accounts to a large extent for the continued productivity of good or improved pastures at times when poor, unimproved pastures have ceased growth and appear to be burnt up."

This experiment seems to indicate that, if the temperature of pasture soils is to be kept as low as possible during the summer months, there must be a close sward of pasture plants which will shade the soil. Concluding that this is true, then, in order to provide a more desirable pasture temperature in the United States there must be proper establishment of the proper pasture plants for any given locality.

Season

The carrying capacity of pasture, as a rule, is closely correlated with the season. That is, during spring and early summer more livestock can be grazed per acre than during late summer and fall. An experiment run at the Virginia Agricultural Experiment Station (49) shows that most pasture plants in Virginia show a tendency toward a high yield from early spring to June 1 and for the yield to decrease thereafter, and the lowest yield to be obtained from August 15 to late fall. Table X shows the yield of various pasture plants during different periods.

TABLE X. TOTAL YIELDS OF PASTURE PLANTS DURING 1922-24, HARVESTED AS PASTURAGE AT DIFFERENT PERIODS (49) (Va. Agricultural Experiment Station)

Kind of Plant	Pounds of air-dried material per acre			
	From early spring to June 1	From June 2 to June 30	From July 1 to Aug. 14	From Aug. 15 to late fall
Ky. bluegrass	1,200	660	680	510
Canada bluegrass	620	510	670	1,180
Orchard grass	3,970	2,080	2,160	1,180
Orchard grass and redtop	2,035	1,120	650	580
Orchard grass, redtop alsike clover	2,900	1,320	880	530
Ky. bluegrass and white clover	1,140	940	780	740
Ky. bluegrass, timothy, redtop, and red clover	2,845	1,190	1,035	620

Due to the fact that pastures do not produce as much during the summer and fall months there will have to be adjustments made in the grazing from one period to the other. The experiments cited seem to indicate that the greatest number of livestock should be grazed per acre during the early part of the season with a gradual decrease in number as the season progresses.

Pasture Flora

The ideal pasture is one that produces an abundance of pasturage throughout the season and not one that produces heavily for a few weeks and then dies out. Of course the greatest total production possible is desirable; but a pasture that produces well throughout the season, although the total production may be less than some pastures which produce only for a short period, is still even more desirable. The first step to take in producing such pasture is the selection of pasture plants. The selection of pasture plants brings about the question of a mixture or a single variety.

Johnstone-Wallace (16) found in experimenting with wild white clover and a number of different grasses that a combination of white clover and grass outyielded the grass grown alone in every case. Although the results given in this experiment are for only one year the data indicates what might be expected over a longer period. Table XI shows the results of the experiment with grasses grown alone and in combination with wild white clover.

TABLE XI. YIELDS OF GRASS GROWN ALONE AND IN COMBINATION WITH WILD WHITE CLOVER (16)
(Cornell University, 1933)

Grass	Yield of grass grown alone. Dry matter per acre. Pounds	Yield of grass and wild white clover grown together. Dry matter per acre. Pounds
Kentucky bluegrass	1,676	3,642
Canada bluegrass	2,154	3,841
Rhode Island bent	2,065	3,709
Red top	1,890	3,558
Commercial timothy	2,853	3,812
Aberstwyth pasture timothy No. S 50	1,828	4,084
Orchard grass	2,513	3,825
Perennial ryegrass	1,678	3,360

Vinall and Hein (46) at Beltsville, Maryland, obtained about the same results as Johnstone-Wallace in yields from a single variety and a pasture mixture. The pasture mixture outyielded in every case the single variety except bluegrass, Reed Canary grass, and alfalfa. The difference in yields, however, was very small in any case. The pasture mixture more than made up for the shortage in total production by yielding consistently throughout the season. The mixtures used in both trials by Vinall and Hein, and Johnstone-Wallace contained legumes. The addition of the legume to the grass seems to account for the added production.

The results from these experiments indicate that a mixture of pasture plants is more desirable than a single variety for permanent pasture. Some of the advantages of using a mixture are: (a) the total yield will compare favorably with yields of single varieties and in most cases will outyield the single variety, (b) the yields tend to be more consistent throughout the season than do single varieties, and (c) by using a legume in the mixture the benefit from the nitrogen gathered will be received which, in part, along with the actual yield of the legume, accounts for the advantages that a mixture has over a single variety.

Fertilizer and Lime

The factors influencing pasture productivity presented so far have been those of soil, climate, season and plants. The possibility of increasing the productivity by modifying some of these factors is of importance; especially when the natural conditions are not best for pasture production.

The increased productivity of any pasture due to fertilization depends, to a great extent, upon the condition of the soil before treatment. That is, if certain elements are expecially deficient in the soil, the increase in productivity will be greater as a result of application of the needed elements to this particular soil than it would be to a soil with sufficient plant food elements present. Therefore, it seems the success of a system of fertilization depends upon whether or not the elements needed by the plants, which are deficient in the soil, are supplied. Pasture soils, generally need fer-

tilizer treatment because of the fact that the pasture land, especially in the South, is land that has formerly been in crops or is poor, steep, or of an erosive nature. However, this is not always the case and pastures are quite often found on fertile land. Following is a discussion of the effects of lime, phosphate, potash, and nitrogen on the productivity of pastures.

Experiments conducted at various places in the United States seem to indicate that available phosphorus is the most widely needed element for pasture production. The addition of lime to phosphate fertilizers, as a rule, greatly increases the yield over the increase made by phosphate alone. There are very few cases where the addition of potash has been profitable. Nitrogen fertilizers seem to pay only when a new pasture is being established on a soil very low in nitrogen or when the pasture plants are largely grasses.

A five year experiment, 1913 to 1917 at the Virginia Agricultural Experiment Station (15) shows that superphosphate applied at the rate of 300 pounds per acre in 1913, 1915 and 1916 gave an increase of 87% over the untreated area.

Barnes in Ohio (6) found by cooperative experiments on farms in four counties in 1924 that the application of 2 tons of limestone and 400 pounds of superphosphate per acre increased the total vegetation from three to five times and the crude protein five to seven times.

The Mass. Station reports an experiment (13) showing that potash was the limiting factor in particular locality. Lime and superphosphate applied alone or together had little effect

while the addition of potash showed good results. However, the addition of lime and phosphate increased the productivity of plots receiving potash.

Experiments in England (8) show sulfate of ammonia and nitrate of soda to be not only useless but positively harmful. In an experiment at Cockle Park over a period of fifteen years the plat which received superphosphate produced 1,340 pounds more mutton than an untreated plat while the plat which received sulfate of ammonia in addition to superphosphate produced only 1,125 pounds more. This shows an actual decrease as a result of using the nitrate fertilizer on the soil treated with superphosphate. However, experiments in Pennsylvania (8) show that nitrogen fertilizers gave an increase in pasture hay of around 1,000 pounds. This increase was pasture hay, however, and not pasture. A trial was not run to determine what results a phosphate fertilizer would give. These results do show that the productivity may be increased with nitrates but due to additional expense it may be too costly to be very profitable. There may be, however, a place for nitrate fertilizers in an intensive pasture system providing the plants used are suited to nitrate fertilization and the plants are kept grazed closely. For more practical farm conditions, however, the best solution of the nitrogen problem seems to be an adequate population of legumes in the pasture mixture rather than nitrogen fertilization. If more manure is produced on the farm than is needed for other crops it may well be used on the pasture.

The Montana Station (4) reports results that show barnyard manure to be very valuable on irrigated pasture. Over a period of seven years pasture top-dressed with twelve loads of manure per acre each year had a carrying capacity of 2.2 cows per acre for 138 days each season. A similar pasture not top-dressed with manure carried only 1.4 cows per acre for six years with 135 days each season.

A study of some of the literature (4, 6, 8, 13, 15, 33, 45) on pasture fertilization, most of which has been cited in this discussion, brings out a few fundamental principles regarding pasture fertilization. Some of these are: (a) Usually the productivity of pastures can be profitably increased by the use of lime and phosphates and in many cases by using potash and manure, depending upon the condition of the soil. (b) If white clover grows in the pasture nitrate fertilizers and manure can probably be used more profitably on other parts of the farm rather than on the pasture. (c) Phosphorus is the most widely needed element for pasture production and as a rule will increase pasture productivity. The lack of the growth of clovers, providing an attempt has been made to establish them, is an indication that phosphates are needed. (d) Except in the limestone sections where the soil has plenty of lime it will usually be profitable to lime pasture land. Legumes do not grow well when the soil is too acid. (e) A combination of lime and phosphate seems to give better results than either used alone. (f) Potash is not generally needed on pastures, however,

it may pay to use it along with nitrogen, phosphates, and lime in establishing or renewing a pasture on a very poor soil. Potash is generally deficient in muck, peat, and sandy soils. (g) Fertilization may cause a change in botanical composition of the pasture. Nitrates tend to cause clovers to run out and grasses and weeds to increase. Phosphates, potash, and lime tend to cause an increase in clovers and other legumes.

Grazing

The grazing management of a pasture often determines the success of the pasture. The production may very often be reduced greatly because of too close grazing. The other extreme is often also true in that the pasturage is allowed to grow so rank that it is unpalitable and livestock do not eat it readily. The feeding value also decreases as the plants approach maturity.

The problem in grazing management is to get the most value out of the pasture. The total value is not measured in total pounds produced only, but in feeding value as well. The carrying capacity is a pretty good indication of a pastures worth. As the problem of carrying capacity is considered the question of rotation grazing immediately arises. Is it more profitable to divide the pasture into two or more pastures and rotate grazing or to graze one pasture continually?

A pasture field at the Nevada Agricultural Experiment Station (1) was divided into two equal sections. One of these parts was divided into three equal paddocks. Sheep were grazed

on these pastures, an equal number being grazed on the two original divisions. The grazing was rotated on the one that had been divided into three paddocks while the other was grazed continually. Enough sheep were used to keep the grass down and to make good use of it, but not enough to check it severely. The rotated pasture showed a 40% to 50% greater carrying capacity than the continuously grazed paddock. These results were calculated in grazing days from May 1 to October 1. Although the results given here are only for 1929-30 the experiment has been running for a number of years and this report corresponds fairly closely to results from previous years. This experiment shows a decided advantage in favor of the rotation pasture, but it will be noticed that the grazing was carefully regulated and at no time was the pasture grazed close enough to be damaged. If this had not been the case there would probably have been little difference in the two systems of grazing.

Combs (7) has the following to say about rotation grazing:

> "Where possible to do so, the practice of rotation grazing is an advantage. This would consist of grazing two or more pastures at regular intervals, giving a period of rest to one or more of the pastures at a time, and allowing the crops to develop to a proper stage. Such a system, however, requires close attention to the number of animal units used in order that the areas may be utilized to the best advantage. The carrying capacity of pasture handled in this manner can be materially increased. Rotation grazing, however, is not justified unless close attention can be given to the area being used."

Terracing

Although there is very little erosion on pastures having

a good turf, there are still benefits to be derived from terracing or contouring pasture land. Due to the fact that there is usually a period of light or no rainfall during the summer, pastures suffer because of a lack of moisture. Pasture land properly terraced or contoured will receive much benefit from the moisture stored up in the soil which ordinarily runs off when not terraced or contoured.

One of the major objections to terracing pasture land is the inconvenience of mowing. However, if the terraces or contour ridges are spaced far enough apart mowing may not be greatly hindered. Mowing can be kept at a minimum, however, if proper grazing practices are followed.

Terraces or contour ridges are especially beneficial in preventing the seed formed by such annuals as lespedeza and hop clover from being washed off. The seed collect in the channels rather than being washed off the pasture.

Experimental data are not available to show definite results from terracing or contouring pasture land. However, there has been some work done along this line at the McNeil Experiment Station, McNeil, Mississippi (11). Following is an account of the methods used and the results obtained from the experiment: "The rainfall for this region is heavier than for any other extensive area in the United States. At the McNeil Experiment Station over a period of 27 years the average annual rainfall was 63 inches with three inches for November the least for any month of the year. In spite of this heavy and well distributed rainfall hill pastures frequently become dry in late summer and fall.

Terraces on cultivated land are seriously in the way of using improved machinery but since this not an

objection on pasture land the idea was conceived of using closely spaced level terraces on hill pasture as a means of preventing runoff and conserving moisture. In 1929, a small area of carpet grass pasture with 20 percent grade was selected and level contours run out with a terracing instrument. These lines were plowed out with a two-row tractor middle buster making a continuous series of closed end, level terraces, 40 inches apart. The area was seeded broadcast with lespedeza and the carpet grass turf soon replaced itself. This method of terracing was effective in preventing all runoff for the season except for excessive rains which overflowed the terraces. The area was kept under observation and it was very noticeable during late summer that the growth of the pasture plants was more vigorous and of better color than on the adjacent area. It was also noticed that cattle preferred to graze on the terraced area.

In 1930 an additional area was terraced using other tools and different spacings between terraces. It was found that the most satisfactory method of terrace construction with the tools available was to make a one round back-furrow with a double gang tractor plow, leave a strip to be cut with the tractor disc and then make another back-furrow. This left the crest of the terraces 12 feet apart.

The results were so promising in 1930 that in 1931 sixty acres of very rough land with steep slopes was level terraced with a spacing of 12 feet. Following the first heavy rain, some hand work was necessary to repair breaks in low places but after these were repaired all of the rainfall for the season of 1931 was held without runoff with exception of two excessive rains which filled and overflowed the terraces.

The pasture was seeded in March to carpet grass and lespedeza and in June was carrying one animal unit to each two acres and was still carrying this amount November 11. The erosion for the first year consisted almost entirely in the shift of soil from the crest of the terraces to the trough and because of the close spacing this was not serious. With a complete sod the second year this shifting should be almost entirely stopped and the soil placement final.

No detailed comparative figures for terraced and natural slope pastures have yet been obtained but it is obvious that more forage is being produced per acre on the terraced pastures. It is also obvious that the cattle have preferred the growth of the pasture plants on the terraces to that on an unterraced corner of about five

acres. Catch basins were put in on a 10 percent slope of carpet grass sod to determine the amount of runoff with a 10-foot and 20-foot spacing. Seven rains sufficient to produce runoff from these plots, averaged 1.41 inches each and gave a runoff of 24.9 percent from the 20-foot plot and 6.5 percent from the 10-foot plot. This indicates that the length of the slope or distance between terraces is an important factor in the rate of absorption of rainfall."

CHAPTER IV

THE FEEDING VALUE OF PASTURAGE

It has long been known that fresh green pasturage grown on fertile soil is almost a perfect ration for livestock. However, from time to time there have been cases where livestock have suffered from nutritional ailments due to the inadequacy of some of the vital elements in the pasturage being grazed. Due to the fact that all pasturage does not seem to have the same feeding value a study of the factors affecting the feeding value of pasturage has been made. Following is a discussion of some of the major factors affecting the feeding value of pasturage.

The Effect of Soil Fertility and Fertilizer Treatments on Composition of Pasture Plants

There are several outstanding examples of diseases and conditions of livestock in the United States (34) which have been attributed to deficiencies in the soils which in turn have caused deficiencies in the pasturage. In Texas a condition known as loin disease developed as a result of phosphorous deficiency in the soil. The condition was readily cured by feeding a mixture of bone meal and salt to make up for the deficiency. In a certain section in California the breeding efficiency of sheep was so low that only a 10% crop could be had. The crop readily increased from 10% up to 90% by spreading phosphate fertilizer on the pasture.

Although, in several instances, nutritional complications have resulted from grazing animals on pasture there are millions of examples where excellent results have been obtained. Therefore, it seems logical to conclude that the conditions and soils have a great deal to do with the composition of the pasturage produced. Table XII shows a comparison of the mineral content of various pasture grasses grown under varying soil and climatic conditions without applications of fertilizer (47). From these

TABLE XII. COMPOSITION OF PASTURE GRASSES UNDER VARYING SOIL AND CLIMATIC CONDITIONS (47)

Mineral Element	Percentage of indicated mineral in the dry matter of various grasses grown in the states named.			
	Bluegrass in Ky.	Bluegrass in Md.	Carpet G. in S. C.	Carpet G. in Fla.
Calcium	0.470	0.491	0.318	0.972
Iron	0.032	-----	0.034	-----
Magnesium	0.197	-----	0.207	0.531
Manganese	0.008	-----	0.048	-----
Nitrogen	3.83	2.452	1.170	2.00
Phosphorus	0.952	0.379	0.147	0.272
Potassium	2.585	-----	0.839	1.428
Silicon	3.02	-----	0.313	-----
Sodium	0.242	-----	0.536	-----
Sulphur	0.656	-----	0.170	-----

analyses it may be seen that the soil does have a decided effect on the composition of pasturage, especially on phosphorus which seems to be one of the most important elements as far as de-

ficiencies in composition and livestock feeding are concerned. There is also noticed a large difference in the nitrogen content of the grasses shown.

Experiments have been conducted (47) which show conclusively that the constituents in the dry matter of pasturage can be changed by the application of fertilizers. Table XIII shows the percentage of certain herbage constituents (47) in the dry matter of Kentucky bluegrass on plats receiving annual

TABLE XIII. PERCENTAGE OF HERBAGE CONSTITUENTS IN BLUEGRASS PLATS RECEIVING AND NOT RECEIVING FERTILIZER TREATMENTS (47)
(Beltsville, Md. 1930-33)

Herbage Constituents	Average percentage of constituents in herbage from plats.					
	Nitrate of Soda		Superphosphate		Muriate of Potash	
	Fert.	Not Fert.	Fert.	Not Fert.	Fert.	Not Fert.
Dry Matter	18.28	18.27	17.11	18.81	17.50	19.02
Ash	12.15	11.66	12.32	11.54	12.60	11.26
Ether extract	03.34	03.35	03.30	03.37	03.36	03.33
Crude fiber	15.67	15.74	15.51	15.81	15.75	15.59
"True" Protein	21.00	21.01	21.03	21.02	21.18	20.85
Non-protein nitrogen	06.29	06.59	06.73	06.17	06.33	06.58
Nitrogen free extract	41.63	41.67	41.11	42.13	40.82	42.42
Calcium	01.26	01.41	01.41	01.26	01.33	01.34
Phosphorus	00.50	0.49	0.55	0.45	0.50	0.49

applications of nitrate of soda, superphosphate and muriate of potash as compared with herbage from plats which did not receive these fertilizers. The experiment was conducted at Beltsville, Md. 1930-33.

The composition of pasturage as discussed so far has included only the influence of soils and fertilizers. A treatment of this subject would not be complete without a discussion of the effect of lime and the combination of lime and fertilizer. Godden at the Rowett Research Institute in Scotland (16) has shown that lime alone has some effect on the chemical composition of dry matter of pasture herbage, but a combination of lime and superphosphate has an even greater effect. Table XIV shows the change in the percentage of protein, phosphoric acid and calcium oxide due to the application of lime, superphosphate and a combination of the two. The increase in these constituents

TABLE XIV. CHANGES IN CHEMICAL COMPOSITION OF DRY MATTER OF PASTURE HERBAGE WHEN LIME, SUPERPHOSPHATE AND A COMBINATION OF THE TWO ARE USED (16) (Rowette Research Institute, Scotland)

Treatment	Protein %	P_2O_5 %	CaO %
Untreated	9.15	0.29	0.59
Superphosphate	9.31	0.71	0.94
Lime	9.63	0.30	0.77
Superphosphate and Lime	10.72	0.73	0.98

may be explained in two ways, first, a part of the increase - is no doubt due to the fertilizer and lime applied, and second,

it may be due to the change in the botanical composition. The change in botanical composition is due to the application of lime and fertilizer which make for better growing conditions for some of the more desirable pasture plants such as the clovers which naturally have a higher protein and mineral content than some of the grasses.

The Effect of Legumes on the Feeding Value of Grasses

The Farmer in producing pasturage naturally wants to grow those plants which will give him the highest yield but at the same time he wants a feed of the highest feeding value which is practical to grow. Therefore, the question arises as to what plants or combination of plants will give him the best pasturage.

An investigation made at Cornell University (16) shows that wild white clover grown in combination with several different grasses caused an increase of protein and calcium in every case over the protein and calcium content of the grasses grown alone. The phosphorus content, however, decreased or only equalled that of the grass grown alone. Table XV shows a comparison of the content of several grasses grown alone and in combination with wild white clover.

The Ohio Experiment Station reports (48) results very similar to those at Cornell. Timothy grown in combination with alfalfa had an average protein content of 7.2% over a period of three years while timothy grown alone had a protein content of only 4.8%. The alfalfa and timothy mixture had a protein content of 10.4% while the alfalfa grown alone had

TABLE XV. THE CHEMICAL COMPOSITION OF GRASSES GROWN ALONE AND IN COMBINATION WITH WILD WHITE CLOVER (16)
(Cornell University, 1933)

Grass	Composition of grass grown alone			Composition of grass and wild white clover grown together		
	Protein %	P_2O_5 %	CaO %	Protein %	P_2O_5 %	CaO %
Ky. bluegrass	23.4	1.35	0.32	30.7	1.19	0.52
Canada bluegrass	27.1	1.48	1.19	31.2	1.33	1.39
Rhode Island bent	25.3	1.21	1.36	32.1	1.27	1.36
Red top	23.6	1.30	1.10	31.5	1.25	1.36
Commercial timothy	24.0	1.38	0.79	30.1	1.19	0.96
Aberstwyth pasture timothy No. S50	24.5	1.26	0.56	31.6	1.20	0.94
Orchard grass	23.5	1.54	0.78	29.3	1.30	0.88
Perennial ryegrass	22.8	1.36	0.78	30.2	1.19	1.08

15.2% protein. These results show that a grass and a legume mixture will have a lower protein content than a pure stand of a legume. However, the protein content of the mixture will be higher than the content of the grass grown alone. It is known that a pasture mixture needs a grass in it to provide a turf and grazing during the summer months, therefore, it would not be logical and practical to have a pure legume permanent pasture. As has just been shown, grasses grown alone are low in protein. From the data presented the best pasture seems to be, from a practical and feeding value standpoint, not one of grass alone but one with both grasses and legumes.

The Effect of Innoculation on Protein Content of Legumes

The livestock man is interested in increasing the feeding value of his pasturage only to the extent that it will be profitalbe to him. For this reason the innoculation of legumes is being considered.

Fred, Whiting and Hastings (10) of the Wisconsin Experiment Station report results from experiments with alfalfa and soy beans that show conclusively that innoculation of legumes does increase the feeding value. Alfalfa grown on unlimed soil gave a yield of 46.2 pounds of nitrogen per acre or 2.69% when uninnoculated. Alfalfa grown under the same conditions but innoculated gave a yield of 86.7 pounds of nitrogen per acre or 3.02%. Thus an increase of 40.5 pounds of nitrogen per acre was given as the result of innoculation. This increase in nitrogen is not only important from a feeding standpoint but a fertilizer standpoint as well. Another experiment was run in 1925 on a different soil which showed some very interesting results. The nitrogen content of the tops on the uninnoculated soil was 1.90% while the tops on the innoculated soil was 2.55%. Thus is shown a decided difference in the amount of nitrogen available for livestock consumption in the innoculated and uninnoculated alfalfa.

The examples cited would seem to indicate that the protein content of any legume being grown on uninnoculated soil could readily be raised by innoculation. This possibility should expecially be considered when new pastures are being established.

The extra nitrogen gained by fixation by the organisms will aid the pasture in several different ways, namely - increase the yield due to the added nitrogen, increase the nitrogen content of the legume, and aid in increasing the nitrogen content of the grasses by providing nitrogen for the legumes which in turn increase the nitrogen content of the grasses through plant association.

Influence of Maturity of Pasture Plants on Feeding Value

The problem of just when to start grazing and how close to graze is one of importance. The ideal grazing management is to graze the plants so the greatest amount of feeding value can be obtained over the longest period of time.

Morrison has brought together (31) and summarized all available data on the subject of changes in composition of forage plants due to maturity. Table XVI gives a summary of this material.

A study of the material in Table XVI reveals several outstanding facts. The digestible protein tends to decrease as the plant approaches maturity. Therefore, the young plants are more valuable in digestible nutrients. The total digestible nutrients decreased in every case, except one, as maturity approached. Soy beans showed an increase toward maturity because of seed formation. It is also noticed that the younger plants were higher in mineral content. From the analyses presented it is evident that from the analysis standpoint the feeding value is greater in the younger plants than in those approaching maturity.

TABLE XVI. AVERAGE COMPOSITION OF FORAGE PLANTS AT DIFFERENT STAGES OF MATURITY (31)

Stage of development	Digestible protein	Total Digestible nutrients	Average total composition					
			Protein	Fat	Fiber	N. free extract	Mineral matter	No. of analyses
	%	%	%	%	%	%	%	%
Alfalfa								
Before bloom	14.2	53.2	19.0	2.7	22.3	36.6	9.8	12
1/10 to ½ bloom	11.0	50.1	14.9	1.7	30.1	35.0	8.9	29
3/4 to full bloom	9.9	49.7	14.0	2.0	30.3	35.8	8.3	21
Past bloom	8.6	44.9	12.8	2.1	31.9	36.1	7.5	10
Red Clover								
Before bloom	12.0	56.4	18.7	3.6	18.3	41.8	7.2	2
In bloom	7.8	53.4	12.6	3.6	26.2	39.6	6.2	45
Past full bloom	7.3	51.7	12.3	3.6	28.1.	36.8	7.4	9
Soy Beans								
In bloom or before	13.1	51.0	17.4	3.4	21.4	39.3	10.0	8
Seed developing	11.2	50.0	14.9	2.4	28.2	38.0	7.4	22
Seed well developed	11.9	53.0	15.8	5.1	27.2	36.6	6.1	16
Seed nearly ripe	11.8	56.0	15.7	6.8	24.8	39.3	4.1	2
Annual Lespedeza								
Before bloom	10.7.	55.5	14.2	2.6	20.8	45.2	6.2	3
In bloom	10.1	53.1	13.4	1.8	25.8	42.8	5.2	6
After bloom	8.9	51.1	12.5	1.6	31.3	39.1	4.5	6

Fagan (16) made a study of orchard grass which shows results very similar to the material just presented on legumes. Table XVII gives the composition of orchard grass cut at 1, 2 and 3 months. It will be noticed that the percentage of

TABLE XVII. THE INFLUENCE OF MATURITY ON CHEMICAL COMPOSITION OF ORCHARD GRASS (16)

Age when cut	Protein %	Fibre %	P_2O_5 %	CaO %
1 month	12.3	21.3	0.92	0.91
2 months	11.8	23.0	0.86	0.94
3 months	9.1	32.4	0.82	0.99

protein decreased with maturity and fibre increased. Phosphorus and lime showed little change, but with a slight tendency for phosphorus to decrease and calcium to increase.

Woodman, Evans and Norman in England (31) studied the digestibility of alfalfa cut at different stages of maturity. They found that the digestibility like the percentage of important nutrients decreased as the plant approached maturity. This discovery seems to indicate more conclusively that as the forage plant approaches maturity the feeding value decreases. These facts are very important from the pasture standpoint. It would seem that in order to obtain the full benefit from pasturage the grazing will have to be carefully regulated. For best results, this means, graze the plants while they are young and continue close grazing throughout the year in order to get the full benefit from the young, tender rich plants. However, the grazing will have to be closely regulated so as

not to kill or injure the plants and to allow sufficient growth in the fall to protect the soil during the winter months if it is a permanent pasture.

The Quality of Meat Produced on Pasture

In the past there has been quite a bit of complaint to the effect that grass fattened beef is dark in color, unattractive on the block, and difficult to sell. Recent investigations are proving that this condition, as a rule, is not necessarily true.

A two year experiment conducted at the Kansas Agricultural Experiment Station (20) with three and four year old Herford steers seems to indicate that there is not much difference in the color of beef produced on pasture alone and that produced on pasture with corn and cottonseed cake as supplement. However, during the summer of 1926, which was a very dry summer, the color of the carcasses of the cattle produced on grass alone did show a wider variation in color than those fed a supplement. The carcasses of the cattle grazed in 1927, which was a better pasture year than 1926, were, as a whole, more uniform and brighter than those grazed in 1926.

Semple (40), of the Bureau of Animal Industry, makes the following statement concerning the quality of meat from livestock fattened on pasture based upon experiments run at the Louisiana, Virginia and West Virginia Agricultural Experiment Stations. - "Beef from two to three year old cattle fattened on good pasture alone was very similar in palitability to beef from cattle fed grain while on grass. The greatest differences were in aroma, flavor of fat, and

> in the richness and quality of juice, the beef from the grain-fed animals being superior, but the differences were small. It appears that the lack of finish or gain due to poor or insufficient pasture is often the cause of the low quality that is sometimes attributed to the use of grass. The meat of suckling lambs produced on good pasture has been found as satisfactory from the standpoint of both fatness and palitability as that from suckling lambs which received a supplement of grain on pasture."

The opinion of the authorities cited in the material just presented seems to be that the quality and abundance of pasturage grazed controls the quality of meat produced on it. Therefore, it is to be concluded, that if good pasture is provided meat of good quality can be produced on pasture alone.

Analyses of Pasture Plants

Professor F. B. Morrison of Cornell University has probably brought together the most complete analysis of feeding stuffs of any writer on animal nutrition. By using these analyses it is possible to feed livestock a balanced ration and yet make use of the greatest amount of feed produced on the farm by feeding only enough supplement to balance the ration. This information is especially valuable when feeding livestock on pasture. By using the analysis of pasture plants it is possible to get full benefit from the pasture and then supply only those nutrients lacking in the pasturage.

Table XVIII shows (28) the percent of total dry matter, digestible protein, total digestible nutrients and the nutritive ratio of some of the more important pasture plants in the United States.

TABLE XVIII. ANALYSES OF PASTURE PLANTS (28)

Feeding stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio
	Per ct.	Per ct.	Per ct.	1:
Alfalfa, green, all analyses	25.4	3.4	14.7	3.3
Bermuda grass	34.2	2.8	25.0	7.9
Bluegrass, Canada	33.2	1.3	19.5	14.0
Bluegrass, Ky., all analyses	31.8	2.4	18.6	6.8
Brome grasses, misc.	36.3	3.0	20.8	5.9
Clover, alsike	22.2	2.4	13.2	4.5
Clover, bur	20,8	3.7	12.8	2.5
Clover, crimson	17.4	2.3	11.3	3.9
Clover, hop	25.7	2.9	18.6	5.4
Clover, red, all analyses	25.1	2.6	14.9	4.7
Clover, sweet	22.0	3.0	14.0	3.7
Clover, white	16.2	2.5	9.8	2.9
Clover and mixed grasses	27.3	1.9	17.1	8.0
Cowpeas	16.3	2.3	10.9	3.7
Crab grass	30.9	1.5	16.6	10.1
Fescue, meadow	30.5	1.8	17.8	8.9
Grasses, mixed, immature	29.7	3.6	20.2	4.6
Johnson grass	29.1	1.1	16.5	14.0
Kudzu vine	30.6	4.2	19.4	3.6
Lespedeza, annual	36.6	5.0	20.9	3.2
Millet, foxtail varieties	29.6	1.9	19.1	9.1
Oat fodder	25.4	2.3	15.4	5.7

(continued)

TABLE XVIII. ANALYSES OF PASTURE PLANTS (28) (Continued)

Feeding Stuff	Total dry matter	Dig. protein	Total dig. nutrients	Nutritive ratio
	Per ct.	Per ct.	Per ct	1:
Orchard grass, all analyses	29.1	1.7	16.0	8.4
Pasture grasses and clovers, from closely grazed, and fertile pastures	28.7	4.4	20.6	3.7
Pasture grasses and clovers, mixed, from fertile pasture, southern states	24.4	2.6	16.1	5.2
Pasture grasses, mixed, from poor to fair pasture, before heading out	30.2	3.3	19.6	4.9
Rape	16.4	2.6	13.0	4.0
Rescue grass	30.6	1.8	17.6	8.8
Red top	39.3	1.9	23.1	11.2
Reed canary grass	37.0	1.7	21.4	11.6
Rhode Island bent grass	32.7	1.4	18.7	12.4
Rye fodder, all analyses	22.3	2.3	16.2	6.0
Rye grass, Italian	27.1	1.5	15.7	9.5
Rye grass, perennial	26.6	1.4	15.5	10.1
Soy beans, all analyses	24.4	3.2	15.1	3.7
Sudan grass, all analyses	25.7	1.4	17.7	11.6
Sweet vernal grass	31.2	1.2	18.4	14.3
Timothy, pasture stage	22.8	3.7	16.0	3.3
Trefoil, yellow or black medic	22.7	3.3	13.2	3.0
Vetch common	20.4	2.7	12.2	3.5
Vetch, hairy	18.2	3.5	12.3	2.5

(continued)

TABLE XVIII. ANALYSES OF PASTURE PLANTS (28) (Continued)

Feeding Stuff	Total dry matter	Dig. protein	Total dig. nutri-ents	Nutri-tive ratio
	Per ct.	Per ct.	Per ct.	1:
Wheat fodder, all analyses	26.0	2.6	15.2	4.8
Wire grass, western	38.9	1.8	22.6	11.6

PART II

A PASTURE PROGRAM FOR TENNESSEE

CHAPTER I

THE PASTURE SITUATION IN TENNESSEE

According to the United States Census of Agriculture for 1935, Tennessee ranks high in the South East as a pasture State.

Tennessee has 5,643,998 acres of land in pasture out of a total of 19,085,837 acres in farms. This is 29.5 % of the total farm land in pasture. This percentage is fairly high compared to some of the other surrounding States. The States surrounding Tennessee are ranked as follows according to the percentage of farm land in pasture, starting with the highest: Kentucky, Mississippi, Tennessee, Arkansas, Alabama, Georgia, and North Carolina. Table XIX shows the rank and percentage of farm land in pasture of the States listed above.

TABLE XIX. RANK AND PERCENTAGE OF FARM LAND IN PASTURE IN TENNESSEE AND SURROUNDING STATES (U. S. Census of Agriculture, 1935)

Rank	State	Percentage of farm land in pasture
1.	Kentucky	41.1
2.	Mississippi	33.2
3.	Tennessee	29.5
4.	Arkansas	27.5
5.	Alabama	25.6
6.	Georgia	24.5
7.	North Carolina	15.1

Tennessee not only ranks fairly high in regards to the percentage of farm land in pasture, but in percentage of farm land in plowable pasture as well. The State ranks higher in this respect than it does in percentage of farm land in pasture. Kentucky is first with 27.4 per cent of farm land in plowable pasture and Tennessee is second with 15 per cent. The next State in line is Mississippi with only 9.6 per cent with Arkansas, Alabama, North Carolina, and Georgia following with 8.4, 7.1, 4.7, and 3.7 per cent respectively.

Thus we see that as far as acres are concerned, Tennessee ranks fairly high in the South East as a pasture State. However, one in travelling over the State readily notices a great variation in pastures. Some are well improved and highly productive while others might well be classed as plots of land rather than pastures. The variation is not only from one section of the State to the other but from farm to farm in the same section and locality. Good pastures may be found in every part of the State and at the same time poor pastures may be found.

From casual observations on travelling over the State there seems to be a great need for pasture improvement in Tennessee. Observations also show that pastures may be improved, due to the fact that in practically every locality some few farmers will have well kept, highly productive pastures.

Thus, one may say, in speaking of the pasture situation in Tennessee, that, although Tennessee ranks high in acres as a pasture State, there is a great need for pasture improve-

ment throughout the State.

Due to the fact that a great amount of the pasture land is plowable, certain pasture improvement methods may be carried out, whereas, they could not be if the land were not plowable.

The census of agriculture for 1935 shows 1,285,743 acres of idle land in the State. The fact is readily noticeable on travelling through the State. Although much of this land is poor and eroded and probably would not produce a cultivated crop profitably it might well be turned into pasture. The mere act of fencing such land and putting livestock on it will not make it a pasture; however, such is often the practice. By proper management and practices such as cultural and mechanical treatment, green manures, barnyard manure, mineral fertilizers, lime, seeding of proper plants and controlled grazing, it is expected that most of this idle land can be developed into profitable pastures within a few years.

As a summary of the pasture situation in Tennessee the following statement may be made: There is a great need for (a) improving the pastures already established, (b) establishing and improving pastures on land now idle, and (c) establishing pastures on land which is now in cultivation but should be in pasture.

CHAPTER II

PLANTS AND MIXTURES FOR TENNESSEE PASTURES

Tennessee pastures may be described as four kinds, they are: permanent pastures, rotation pastures, temporary pastures, and all other pastures which may be called simply other pastures.

Permanent pastures - which remain year after year on the same land.

Rotation pastures - which are part of a regular crop rotation, as, for example, lespedeza in a corn, wheat, lespedeza rotation.

Temporary pastures - used to supplement the other pastures during periods of drought or low production. These pastures usually occupy the land one season, and include such as grain crops or their aftermath and quick growing annuals like Sudan grass.

Other pastures - may include woodland, range land, or other pasture not coming under one of the above heads. Woodland pasture, in general, is not desirable due to its low production and the injury caused the timber by grazing animals. Range lands may be desirable where large acreages are available and no better pastures are to be had.

The choice of pasture plants for any farm depends upon the prevailing conditions on that particular farm. Such factors as type and fertility of the soil, drainage, prevailing weather conditions, and use for which the pasture is intended must be considered. Due to these facts it is impossible to make

recommendations which will fit every farm in the state. However, it is possible to name the plants which are generally adapted to the state and to describe the conditions to which these plants are best suited. By using this list of plants and the description of the conditions to which they are best suited, one may, to a certain extent, select pasture plants suitable for a particular farm or field.

Pasture Plants for Tennessee

Following is a list of plants which may be used for pasture in Tennessee:

Non Legumes

Barley

Bermuda grass (Cynodon dactylon)

Johnson grass (Andropogon halepensis)

Kentucky bluegrass (Poa pratensis)

Millet (Setaria italica)

Oats (Avena sativa)

Orchard grass (Dactylis glomerata)

Redtop (Agrostis alba)

Rescue grass (Bromus unioloides)

Rye (Secale cereale)

Ryegrasses (Lolium perenne, Italicum)

Sudan grass (Andropogon sorghum sudanesis)

Tall oat grass

Timothy (Phleum pratense)

Wheat Triticum sativum)

Legumes

Alfalfa (Medicago sativa)

Alsike clover (Trifolium hybridum)

Bur clover (Medicago arabica)

Cowpeas (Vigna catiang)

Crimson clover (Trifolium incarnatum)

Hop clover (Trifolium procumbens)

Lespedeza:

Korean (Lespedeza stipulacea)

Kobe (Lespedeza striata)

Tenn. 76 (Lespedeza striata)

Sericea (Lespedeza sericea)

Rape (Brossica napus)

Red clover (Trifolium pratense)

Soybeans (Soja max)

Sweet clover (Melitotus alba)

Vetch (Vicia villosa)

White clover (Trifolium repens)

In order to select plants best suited to a particular farm it is desirable to know the climatic and soil requirements of the desirable plants. By knowing this information it is possible to select plants suited to the soil. Following is a list of forage crops adapted to Tennessee conditions showing their adaptation to various soil and climatic conditions:

high fertility levels.

Drouth resistent

Lespedeza no

Sweet clover

Alfalfa

Sudan grass

Johnson grass

Tolerant to shade

Orchard grass

White clover

Hot weather required

Sudan grass

Bermuda grass

Soybeans

Cowpeas

Lespedeza

Johnson grass

Cool weather required

Kentucky bluegrass

Timothy

Winter vetch

Red clover

Alsike clover

Crimson clover

white cl

Rich soil required

Kentucky bluegrass

Timothy

Perennial ryegrass

Alfalfa

Red clover

Alsike clover

White clover

Tolerant to poor soil

Orchard grass no

Tall oat grass no

Redtop

Lespedeza

Sweet clover

Tolerant to sandy soil

Italian ryegrass

Tall oat grass

Redtop

Bermuda grass

Lespedeza

Alfalfa

Winter vetch

Cowpeas

Requiring lime	Tolerant to wet soil
Alfalfa	Timothy
Red clover	Redtop
Sweet clover	Alsike clover
White clover	Lespedeza (if seeded every year)

Use of pasture plants - Following is a list of pasture plants showing their usual use in permanent, rotation, or temporary pastures:

Permanent pasture plants

Bermuda	Johnson grass
Kentucky bluegrass	Lespedeza:
Orchard grass	Korean
Redtop	Kobe
Rescue grass	Tennessee 76
Rye grasses	Red clover
Timothy	Sweet clover
Alfalfa	White clover
Alsike clover	
Bur clover	
Hop clover	

Rotation and temporary pasture plants

For winter grazing:	For summer grazing:
Barley	Alfalfa
Oats	Millet
Rescue grass	Orchard grass
Rye	Sudan grass

(Continued)

(Continued)

Rye grasses
Wheat
Crimson clover
Rape
Vetch
Cowpeas
Lespedeza
Redtop
Red clover
Soybeans
Sweet clover
Timothy
Tall oat grass

Pasture Mixtures for Tennessee

Following is a number of suggested pasture mixtures which may be used to fit different conditions:

For rich, well-drained soils

Timothy	6
Kentucky bluegrass	7
Red clover	3
White clover	2
Total	18 lbs.

Orchard grass	6
Kentucky bluegrass	4
Redtop	3
Red clover	2
Alfalfa	2
White clover	2
Alsike clover	2
Hop clover	2
Total	20 lbs.

Orchard grass	6
Bermuda grass	(sod)
Lespedeza (common)	5
Kentucky bluegrass	4
Red clover	2
Alsike clover	2
White clover	2
Hop clover	2
Total	23 lbs.

For fertile but poorly drained soils

Timothy	6	Timothy	4
Redtop	8	Redtop	6
Alsike clover	3	Alsike clover	3
Total	17 lbs.	White clover	3
		Total	16 lbs.

For poor but well-drained soils

Orchard grass	6	Orchard grass	5
Redtop	4	Bermuda grass	(sod)
Alsike clover	2	Redtop	4
Lespedeza (common)	6	Lespedeza	6
Total	18 lbs.	White clover	2
		Hop clover	2
		Total	19 lbs.

For sandy soils

Bermuda grass	(sod)	Lespedeza (common)	10
Lespedeza (common)	6	Redtop	8
Redtop	6	Italian ryegrass	5
Italian ryegrass	6	Total	23 lbs.
Alfalfa	3		
Total	21 lbs.		

For soils varying in topography and fertility

Orchard grass	4	Orchard grass	4
Redtop	3	Redtop	3
Kentucky bluegrass	3	Kentucky bluegrass	3

(Continued)

For soils varying in topography and fertility (Continued)

White clover	2	Alsike clover	2
Lespedeza (common)	5	White clover	2
Hop clover	2	Lespedeza (common)	5
Bermuda	(sod)	Total	19 lbs.
Total	19 lbs.		

For shaded areas

Orchard grass	12
White clover	4
Total	16 lbs.

CHAPTER III

PASTURE MANAGEMENT FOR TENNESSEE

A good pasture management program aims at four things, namely: (a) to provide the longest grazing period possible, (b) to produce and maintain the highest production practical, (c) to produce the highest quality of forage possible, and (d) to make the best use of the forage produced.

Tennessee Pasture Calendar

Due to the fact that feed produced by pastures is more economical than harvested crops it is desirable to extend the grazing period as long as possible. It is a well known fact that permanent pastures, as a rule, produce grazing in the early season with a heavy drop-off during the hotter months and do not come back in production until fall when the fall rains come. Also there is very little grazing provided during the winter unless some growth is left on the pasture for winter use.

It is the purpose of this discussion to set up a number of all-year pasture programs, generally built around the permanent pasture, which may be applicable to Tennessee conditions. The season of grazing expected from the various pasture plants is also given.

All-Year Pasture Program Used at the West Tennessee Experiment Station. - Hazelwood, at the West Tennessee Experiment Station (14), Jackson, has very successfully produced all-year pasturage by using the following combination: Crimson clover for

late fall, winter, and early spring grazing. Permanent pasture supplemented with Sudan grass the remainder of the year. The permanent pasture consisted of a mixture of Bermuda grass, orchard grass, bluegrass, hop clover, lespedeza, and white clover.

All-Year Pasture Program Used at the Middle Tennessee Experiment Station. - Neel, of the Middle Tennessee Experiment Station (29), has the following to say about the all-year pasture combination used at that station: "The all-year pasture we are using here consists of a pasture of Bermuda with white and hop clovers, bluegrass, white and hop clover combination, a rye pasture sown to Korean lespedeza and one sown to Kobe lespedeza. This combination of pastures furnish pasture almost all of the year."

All-Year Pasture Program Used in Missouri. - An all-year pasture system has been developed in Missouri (9) which is very similar to the one used by Neel at the Middle Tennessee Experiment Station, Columbia. The Missouri system contains bluegrass, Korean lespedeza, and early fall grain crops - mainly barley. The bluegrass is grazed from April until late June or early July. The bluegrass is grazed again from the first or middle of December until the middle of March. Korean lespedeza is grazed from late June or early July until late September or early October. Winter barley is grazed from late September or early October until the first or middle of December. The barley is grazed again from late March or

early May. The system just outlined is for a fairly fertile soil. For soils of medium to low fertility the following combination is suggested; redtop or orchard grass, lespedeza and rye. Redtop or orchard grass and rye take the place of bluegrass and barley in the system above. On soils of good fertility the quality of the winter grazing may be greatly increased by seeding from 12 to 15 pounds of crimson clover with 5 to 6 pecks of barley or rye per acre. Crimson clover is not as dependable when sown alone as when sown in combination with a small grain.

An All-Annual All-Year Pasture Program Used in North Carolina. - The Pasture systems presented thus far have been built around permanent pastures. A system has been developed in North Carolina (39) which is composed entirely of annual plants. It is believed that if varieties of plants adapted to local conditions are selected that this system may be used quite successfully in Tennessee. The plants, dates of seeding, and periods of grazing are as follows: "Rye, sown in September and grazed from November 15 to March 15; crimson clover and hairy vetch, sown August 15 to September 1, and grazed from March 1 to May 15; Sudan grass, sown April 1 and grazed from May 15 to November 15; and Soybeans sown March 15 and grazed from June 1 to November 15. Several progressively later sowings of soybeans, or soybeans and Sudan grass in alternate rows, usually furnish pasturage needed during the season indicated, thus leaving the pure Sudan grass for night grazing or to be cut for hay as circumstances demand."

Grazing seasons of pasture plants. - Table XX shows the seasons of grazing that may be expected from some of the more important pasture plants in Tennessee.

TABLE XX. GRAZING SEASONS OF PASTURE PLANTS (38)

Name of Plant	Season for Grazing
Permanent pasture plants:	
Bermuda grass	Late spring to early fall
Johnson grass	Spring to fall
Kentucky bluegrass	Spring to late fall (unless some growth is saved for winter)
Orchard grass	Early, spring to fall
Rye grasses	Fall, winter, spring
Redtop	Early spring to late fall
Rescue grass	Fall to spring
Timothy	Early spring to late fall
Alfalfa	Spring to early fall
Alsike clover	Early spring and fall
Red clover	Early spring to fall
White clover	Early spring and fall
Hop clover	Spring
Bur clover	Fall to spring
Lespedeza	Early summer to fall
Supplementary pasture plants:	
Barley	Fall and spring
Cowpeas	Late summer and fall
Crimson clover	Fall to spring

(Continued)

TABLE XX. GRAZING SEASONS OF PASTURE PLANTS (38) (Continued)

Name of Plant	Season for Grazing
Italian ryegrass	Early fall to midsummer
Oats	Fall, winter and spring
Rape	Early summer, late fall and winter
Soybeans	Midsummer to fall
Sudan grass	Early summer until frost
Sweet clover	Very early spring to late fall
Vetch	Fall, winter and spring
Wheat and rye	Fall and spring

Pasture Establishment

It takes nature a long time to establish a pasture. This undirected and unaided establishment of improved pastures requires many years for its full development and thus results in a great waste of potential resources. The low production of the average pasture in Tennessee is due, to a large extent, to the lack of effort on the part of the farmers to establish desirable pasture plants.

Seed-bed preparation and seeding. - "Most of the plants recommended for permanent pastures (36) have small seeds, and the young seedlings are weak. It is necessary, therefore, to prepare a good, firm seed-bed and to cover the seed lightly. A general practice is to seed the grasses, and legumes in small grain, which is considered a nurse crop. In the defense of this practice it is claimed that the wheat, oats, rye, or barley take the place of weeds and are less harmful to the pasture plants than are weeds, and in addition there is a crop of grain or hay which pays for the labor expended. Numerous experiments have shown that pasture mixtures, if sown in the fall or early spring without a nurse crop, will be highly productive the first year, and if grazed properly will provide a larger net

return than the grain crop. The land to be seeded should be plowed long enough before seeding time so that it will become settled and firm. A light discing will put the soil in condition for seeding, which is usually accomplished by broadcasting. If a cultipacker is available, running this over the land after seeding is the best method of covering the seed. If there is no cultipacker available, then an ordinary spike-tooth or drag harrow with the teeth sloping slightly backward should be used. Where the seed is such as will flow through a drill the seeding and covering may be accomplished in one operation, and usually a better, more uniform stand results if the seed is drilled than if it is broadcast."

Seeding dates. - It is important that plants be seeded at their proper time in order to get the best results. Table XXI shows the seeding dates of the more important pasture and forage plants in Tennessee. These dates are not absolutely stationary but may be adjusted to a certain extent to fit a particular situation. Dates, especially for the supplementary pasture plants, may be adjusted so that the grazing will be furnished when it is most needed.

TABLE XXI. DATES OF SEEDING PASTURE PLANTS IN TENNESSEE (27)

Name of Plant	Date of Seeding
Legumes:	
Alfalfa	August 20 - September 10
	March 1 - 20
Alsike clover	August 15 - September 1
	March 1 - 15 or earlier
Bur clover	August 1 - 30
Cowpeas	March 20 - June 20
Crimson clover	July 20 - September 1
Hop clover	

(Continued)

TABLE XXI. DATES OF SEEDING PASTURE PLANTS IN TENNESSEE (27)
(Continued)

Name of Plant	Date of Seeding
Lespedeza:	
Kobe	March 1 - 30
Korean	March 1 - 30
Tenn. 76	March 1 - 30
Serecia	March 15 - July 1
	January, February
Rape	March 1 - 20
	September 1 - 20
Red clover	August 1 - September 10
	March 1 - 15
Soybeans	April 15 - May 20
Sweet clover	March 1 - 30
	August 15 - 30
Vetch	August 1 - September 15
White clover	August 1 - 30 - March 1 - 15
Non Legumes:	
Barley	September 20 - October 7
Bermuda grass	March 15 - May 15
Johnson grass	
Kentucky bluegrass	February 1 - March 15
Millet	April 20 - July 15
Oats	March 1 - 15
	September 15 - October 1
Orchard grass	March 1 - 15
	August 20 - September 20

(Continued)

TABLE XXI. DATES OF SEEDING PASTURE PLANTS IN TENNESSEE (27)
(Continued)

Name of Plant	Date of Seeding
Redtop	March 1 - 15
	August 1 - 30
Rescue grass	September 1 - 20
Rye	October 1 - 20
Rye grasses	September 1 - 20
Sudan grass	May 1 - 30
Tall oat grass	September 1 - 30
Timothy	March 1 - 15
	August 1 - October 15
Wheat	October 10 - 20

Methods of establishing pastures. - Neel of the Middle Tennessee Experiment Station (29) has developed several methods of establishing permant pasture. The methods are as follows:

(a) "Prepare land for alfalfa, liming and using fertilizer and manure if available. Then seed 20 pounds alfalfa, 1 to 2 pounds bluegrass, and ½ pound hop clover to the acre. Use as meadow till grass takes alfalfa. Late August or early September seeding preferable. (b) Seed mixture of 10 pounds (yarrow free or practically yarrow free) redtop, 2 pounds bluegrass, 1 pound white clover, 2 pounds common lespedeza and ½ pound hop clover to the acre. Late August or early September seeding preferable for all but lespedeza. Spring seeding should be made in February. (c) On thinner land in February or early March sow 15 to 20 pounds per acre of common lespedeza and with this seed 2 pounds bluegrass and ½ pound white clover per acre. Another method is to seed lespedeza alone and in October run disc about straight in lespedeza and use harrow unless growth on land prevents and seed bluegrass, white clover, and hop clover. After lespedeza has enrighted the land, larger amounts of bluegrass may be sown. (d) Bermuda. - A good method with

Bermuda is to establish bluegrass, white clover, hop clover, and common lespedeza on the land first and then set out Bermuda roots at intervals of 6 feet. If land is good enough this will give a fair all-year pasture."

The following method (19) may be used to establish permanent pasture on poor soils. Sow 5 to 10 pounds of lespedeza per acre in March. In September or October disc the lespedeza and sow rye, be sure enough lespedeza seed have matured to reseed the land. Use 200 pounds of phosphate per acre where needed. After one or two years of lespedeza prepare the land in August. Apply 200 to 300 pounds of acid phosphate and 800 to 4,000 pounds of limestone per acre in September and sow rye with permanent grasses and clovers. The following is a suggestion: 1 bushel rye, 8 pounds orchard grass, 2 pounds redtop and bluegrass mixed, 2 pounds alsike and white clover mixed, 2 pounds alfalfa (inoculated). Add 6 pounds sweet clover (inoculated) and lespedeza mixed in the spring.

Temporary pastures may be established by preparing a good seed-bed and sowing the seed broadcast, or with a grain drill if possible, at the time desired.

Pasture Fertilization and Liming

Due to the fact that the fertility level varies from farm to farm as well as from one section to another in the state it is impossible to make fertilizer and lime recommendations which will fit every particular situation. To make accurate recommendations one should know the history of the soil, the analysis, the pH value, and the plants that are to be grown upon it.

Need of plant food elements in soils of various parts of the state. - With the exception of the western two thirds of West Tennessee and the Central Basin (outside of the red lands of Rutherford County, and parts of adjoining counties) the soils of the entire state show a decided need for phosphorus (24). The very sandy soils of Fentress County show a great need for potash. Practically all of the soils in the state need nitrogen.

Need of lime for various types of Tennessee soils (25)

"The soils of East Tennessee are chiefly of limestone origin. Even the shale, or slate which produces the so-called slaty soils, contains an appreciable quantity of lime. East Tennessee soils, however, regardless of origin, analyze poor in lime, practically no carbonate, the form found in the limestone rock, being present. In general the brown or chocolate-colored soils need lime less than either the gray or the yellowish-colored soils. In fact, it may be assumed for practically all uplands long in cultivation and much depleted in fertility, or "worn out", that liming will prove highly beneficial.

The soils of the Cumberland Plateau are especially poor in lime, so that liming is profitable from the outset on the newly cleared land. It should be considered one of the first essentials to the successful farming of this promising section.

The soils of the Highland Rim are, generally speaking, in need of liming. Even on the best of the brown, or mulatto-colored, soils such as are found in Franklin County, it has been amply demonstrated that liming is required in order to produce alfalfa successfully. The gray lands of the Barrens type are naturally very poor in lime.

The soils of the Central Basin are less apt to require liming than are those of any other large area in the state. However, numerous trials have convinced the writer that liming will prove profitable on the majority of the uplands in the Basin.

The soils of West Tennessee, though not of limestone origin, except along the eastern border, are about as well supplied with lime as are the average soils in other portions of the state. In certain places, such

as the rich alluvial lands of Lake County and the rich lowlands of Obion County, alfalfa is grown successfully without the aid of liming. If, however, the soils at the Jackson Station be taken as representative of West Tennessee, liming is fundamentally important."

Fertilizer recommendations. - Mooers of the Tennessee Experiment Station (24) makes the following fertilizer recommendations for meadows and pastures in Tennessee:

Group I.
(a) The poor types of dolomite soils such as the gravelly ridges and hills of East Tennessee.
(b) The poor shale or slate soils of East Tennessee.
(c) The Cumberland Plateau soils.
(d) The "Barrens", both gravelly and "flatwoods" of the Highland Rim or Middle Tennessee and of the western border of West Tennessee.
300 pounds per acre of a 5-10-5

Group II.
(a) "Yellow" land of western two-thirds of West Tennessee.
100 pounds per acre of a 15-0-0

Group III.
(a) "Red" land of West Tennessee.
(b) "Yellow" land of eastern third of West Tennessee.
250 pounds per acre of a 6-10-6

Group IV.
(a) "White" land of West Tennessee.
300 pounds per acre of a 5-10-10

Group V.
(a) Red soils of Rutherford County.
(b) "Mulatto" soils of the Highland Rim and of East Tennessee.
(c) Better class of dolomite soils (Valley type).
(d) The deeper and more fertile types of shale soils of East Tennessee.
300 pounds per acre of a 6-10-6

Liming recommendations. - Mooers (12) in writing on liming for Tennessee soils has the following to say about rate of liming: "Three series of experiments with ground limestone applied at four different rates, namely, 2, 4, 6, and 8 tons per acre, were conducted on ¼ to 1 acre plots in three different localities on the

Highland Rim and also in two different counties of the Central Basin. In each series the crop grown was Alfalfa, and in every case the same amounts of manure and fertilizer were used for each rate of liming. Although in four out of five trials, lime proved necessary to the profitable production of alfalfa, 2 tons of ground limestone per acre proved ample, the yields of hay being practically the same for each of the different rates."

Summary and recommendations for the fertilization and liming of pastures in Tennessee. - It must be remembered that any pasture fertilization and liming program has, from the farmers standpoint, two purposes, namely, to increase the yield of the pasture, and to increase his income. Profit must not be sacrificed in order to produce a good pasture. Therefore, it will be necessary to fertilize the pasture in the most economical way possible.

The use of nitrogen on pastures is of doubtful economy except under very intense pasture management and in establishing new pasture, nitrogen aids greatly in getting the plants started, barnyard manure as well as commercial nitrogen will do well in such a situation. After the pasture has been established it will be, as a rule, more profitable to induce legumes such as white clover to grow in the pasture by making conditions favorable by using lime and phosphorus.

Potash may prove profitable on lands which have been cropped heavily for a long period of time or on soils naturally low in potash. With these two exceptions, potash, as a rule, will not prove profitable on Tennessee pastures.

Phosphorus and lime are especially needed on most Tennessee pastures. These two elements not only increase the

yields but improve the feeding value of the pasturage as well. Better results are usually obtained when phosphorus and lime both are applied than when either is used alone. With few exceptions, all of the pasture soils in Tennessee will show response to phosphorus and lime.

An application of manure will greatly improve most pastures. However, the controlling factor in its use will be the need for it on other crops.

Fertilizer and lime for new pastures on land which has been cropped heavily:

(a) Fertilizer - use complete fertilizer as recommended by the Experiment Station. Amount of phosphorus may be increased.

(b) Lime - 2,000 pounds per acre, except on soils which will grow red clover.

(c) Fertilizer and lime for established pastures:

(a) Phosphorus - 800 pounds of 16% phosphate per acre, or equivalent, except on soils not responding to phosphorus. Apply about every four years.

(b) Potash - use only on soils low in potash. 100 pounds of muriate of potash about every four years.

(c) Nitrogen - not generally recommended. Supply by using legumes. Barnyard manure may be used if available.

(d) Lime - 2,000 pounds per acre every four to eight years. Sufficient to permit the growth of red clover.

Grazing Management

Grazing newly seeded pastures. - Newly seeded pastures must be grazed rather carefully. The seedlings are young and tender and are not firmly rooted and due to this fact the grazing animals pull them up. Grazing should be light and very carefully regulated the first year.

Grazing established pastures. - The system of grazing used determines the best grazing management practice. If intensive grazing is being practiced it will probably be profitable to divide the pasture into two or more fields and rotate the grazing. That is, graze one pasture for a while and then shift the animals to another pasture, grazing it while the first pasture is recovering. If a very large acreage of pasture is available for each grazing animal, the added expense of fencing and furnishing water for rotation grazing probably would not be justified. For best returns and more uniform grazing it is advisable to use two or more kinds of livestock. It is well known that some animals prefer the leaves, others will eat the stems and the coarser plants, while some will eat the growth of sprouts and shrubs.

Grazing supplementary or rotation pastures. - The aim of any grazing management program is to get the most grazing from the pasture without reducing its productiveness. The grazing of supplementary pastures is naturally determined by the permanent or rotation pasture. Supplementary pastures should be so arranged that they will be in their maximum production when most needed. In that way full benefit may be had from

both permanent or rotation and temporary pasture. Following is an example of a grazing management program built around a bluegrass pasture. Use bluegrass from April to July, Korean lespedeza from July to October, Winter barley from October to December, Bluegrass from December to March and Winter barley again from March to April.

When to start grazing. - It is known that young grass is a more desirable feed than grass approaching maturity. Therefore it seems logical that young grass should be grazed. However, the pasture must have a chance to make a good early growth of about three inches before grazing is started or it may suffer later.

When to stop grazing. - Grazing should be stopped in time to allow about three inches of growth to accumulate before winter. This growth will aid the production of the pasture the next year and will protect the soil from erosion during the winter. If pasturage is to be saved for winter grazing the cattle should be removed in late June or July.

Clipping

There are two reasons for clipping pastures, namely: to control weeds, briars, bushes, etc., and to promote a more uniform growth which means the animals will graze more uniformly and will thus receive a larger amount of high grade forage.

To control weeds, briars, bushes, etc. - A well planned clipping program may completely control such growth. Such

plants as bitter weeds and dog fennels which are propigated by seeds may be completely eradicated if they are not allowed to go to seed. Experience has proved that it is best to clip the plants about three or four inches above the ground in the early summer and close to the ground in later summer. A higher percentage of eradication results if this method is followed. If the land is too rough to put a mower on, the clipping may be done by hand. Close grazing also tends to weaken and destroy undesirable plants. It is usually desirable to let the livestock graze the pastures close at least once a season for this reason.

To promote a more uniform growth. - Pastures should be clipped fairly close at least once a year. The clipping should be done just after the peak period of growth. Clipping at this time will remove the high rank growth that has accumulated and become tough and unpalitable and will encourage uniform grazing and growth throughout the pasture. Clipping to control weeds and promote uniform growth should be done at the same time.

Renovating Old Pastures

Pastures become unproductive because of a lack of desirable pasture plants. There may be several reasons for pastures running down. The pasture may be grazed too close for a long period of time, a practice which tends to kill out pasture plants. The soil may be so lacking in plant food elements that it cannot support a productive growth. Also, poor drainage, the presence of undesirable plants such as weeds and brush may cause pastures to become unproductive.

Renewing pastures which have large bare places and a large weed population. - Probably the best solution to the problem of improving such pastures is cultivation, liming when needed, fertilization with mineral and nitrogeneous fertilizers (barnyard manure if available), opening up all drainage ditches if needed, and reseeding with desirable pasture plants. It may also be deisrable to terrace or run contour furrows or ridges at this time.

If the fertility of the pasture is very low, good results cannot be expected from cultivation and seeding alone. Neither can cultivation alone be expected to give good results. If the fertility level of the pasture is raised and desirable pasture plants established a productive pasture with a minimum population of weeds may be expected if proper grazing management is practiced. If the organic matter in the soil is low and manure is not available it may be necessary to turn under a green manure crop. This treatment requires more time but the benefit to the pasture will be great.

If the pasture is rough and rocky and cultural treatment cannot be given, probably the best solution is to remove all brush, sprouts, etc. which are undesirable and top dress with fertilizing material and lime and reseed with desirable plants.

Renewing pastures partially unproductive. - Pastures which are only partially unproductive may not need much cultural treatment. All brush and undesirable plants should be removed. The bare or galled places should be spread with manure or have livestock fed on them. Top dress with mineral

fertilizers, and nitrogeneous material if available, lime, and reseed with desirable plants. The fertilizing material, lime and seed should be disked or harrowed in. If the pasture has a fair sod on it disking probably should not be done.

The amount of fertilizer and lime to use in any case will depend upon the particular situation. General recommendation have been made under the heading - Fertilizing Pastures.

Size of Pastures

There is no definite rule for determining the desirable size of pastures in general. The size must be determined for every particular situation. Factors which determine the desirable pasture size are: the amount of pasturage available, the kind of pasturage available, the productivity of the pasture, and the number of animals units to be grazed.

It must be borne in mind that the young tender grass is the most desirable for grazing. Therefore, enough animals should be on a pasture to keep it fairly close, although not enough to graze the pasture close enough to injure it. If a number of pastures are provided and enough livestock are grazed to eat the grass a little faster than it grows on any one pasture it may be possible to get full benefit from the young, nutritive plants by rotation grazing. If some of the pasturage is not needed for grazing it may be cut for hay.

In general, supplementary pastures should be smaller than permanent. Supplementary pastures are, as a rule, more productive and do not last as long. For these reasons the animals being pastured should be on an acreage small enough

that they can graze it fairly close. In this way the entire acreage pastured is consumed and not trampled and picked over. By using such a system, any part of the supplementary pasturage not needed for grazing can be cut for hay. Temporary fence may be used to divide the field into smaller areas.

Water and Shade

It is very necessary that livestock have plenty of water and shade, especially during the summer. If natural shade, such as trees, is not present it may be necessary to construct shed for the purpose. These need not be expensive, such materials as brush, poles, and straw may be used. Shade should not be located along streams or lanes but should be scattered over the pasture in order to conserve the droppings. Droppings falling in lanes and streams are wasted.

There should be a plentiful supply of clean water at all times. If ponds are used the water should be piped to a trough at a lower level if possible and animals not be allowed to wade in the pond. If streams are used one should be sure the water is not polluted. In general, springs and wells are usually the safest source of water. The water supply should be as convenient to the animals as possible so they will not have to walk long distances to it.

Level Terraces for Pasture

Level terraces or contour ridges benefit pastures in three ways, namely, in checking erosion, conserving moisture, and preventing the seeds formed by such annuals as lespedeza

and alsike clover from being washed off the land.

The main objection to contour ridges in pastures is the inconvenience they cause in mowing. Mowing can be kept at a minimum, however, if close grazing is practiced. This inconvenience need not be great if care is taken in spacing the terraces. They should be far enough apart to allow a mower to run freely between them.

Terracing may be done at the time the seed-bed is prepared for establishing the pasture or it may be done after the pasture has been established. Both times have certain advantages. If the soil is rather impervious to water it may not be wise to terrace at the time of seed-bed preparation. The terraces may cause concentration of water if a heavy rain comes and if the terrace should break over a ditch may be washed out. While if it were terraced after the sod had been established such would not be the case. If the soil is of a porous nature it will probably be best to terrace at the time of seed-bed preparation.

The following directions are given for level terracing in seed-bed preparation of pastures by the United States Department of Agriculture (37). "To terrace a pasture, one should first establish level contour lines with a terracing instrument. A satisfactory method of terrace construction consists of making a one round back furrow with a double gang plow, leaving on a steep slope such as a 20 - percent slope strips to be cut the width of a disk. This would leave the crest of the terraces about 10 feet apart. On gentler slopes more space may be left between the terraces. Such plowing of terraces, disking, and rolling in preparation for seeding can be done at the rate of 1 acre in 2 or 3 hours and costs but little more

than the ordinary methods of seed-bed preparation. Following the first heavy rain, some hand work is necessary to repair breaks in the low places. After that only the very heavy rains are likely to overflow the terraces."

In terracing pastures already established the general direction as to laying out the terraces and back furrowing are the same as used in terracing when preparing the seed-bed.

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