Correcting Soil Deficiencies For More and Better Forage From Permanent Pastures

ARNOLD W. KLEMME AND WM. A. ALBRECHT

At left, no soil treatment, the herbage was not eaten.

At right, well-fertilized pasture was grazed short.

Pastures differ with the herbages they grow and with the different levels of nutrition offered by the soils.

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Arnold W. Klemme and Wm. A. Albrecht

INTRODUCTION

The grazing animals have been supplying food and fiber for the support of man ever since time left any records. The increasing population with its more new mouths to feed is focusing attention on the production of the essential protein foods, namely, meat and milk. An increased supply of these foods can be obtained by the use of more forage crops grown on soils not suitable for regular tillage and intensive crop production.

More consideration is now being given to the grazing animals because they (a) manufacture and directly deliver these most essential and costly of our foods, and (b) are consumers of the grasses needed for soil cover against erosion.

The soil is the starting point in the creation of plant and animal life by means of air, water and sunshine. But it is only when the soil contains all the essentials of creation that the pasture grasses are highly nutritious feed for cattle, sheep and horses. No other feed is produced, processed and marketed more economically. None is more apt to keep these farm animals in vigorous health, growing and gaining rapidly, reproducing regularly, and producing meat and milk abundantly.

Nutritious pasture forage can also be used to supplement the ration of hogs and poultry. Here, too, it aids in maintaining good animal health. Only fertile soils will deliver to the plant all the nutrients needed in its growth processes, in its youthful regrowth when grazed, and in its synthesis of proteins, vitamins, enzymes, and other life-giving essentials for a high level of animal nutrition.

Forage crops, whether grasses or legumes, must provide the animals with the collection of proper compounds out of which they create their own more complex ones. Fortunately, with chemical soil tests, plant tissue tests in correlation therewith, and these supplemented through the bioassays of the crop products by test animals, we are now in much better position to choose for most any soil those soil treatments required to make it balanced nourishment for plants and thereby good animal nutrition. Accordingly then, as the soils are given the limestone and other fertilizer treatments which bring them up to the higher fertility levels serving to grow better forages for better animal nutrition and reproduction, rather than for only greater tonnage yields of vegetable bulk, those acreages become a firmer foundation for agriculture.

Not only will such land areas be restored to delivery of good feed quality, but also, they will be deepened in their surface soils. They will become more stable in their granular structure. They will not hammer into slush so readily under rainfall. They will be less erosive. And they will repay their treatment costs many fold by the increasing returns from this kind of agricultural restoration.

Soil treatments for permanent pastures mean more than just quick profits of a temporary expediency in an emergency. They are a major step toward a more permanent agriculture—through better food possibilities and greater security for the farm families—balanced on the soil's enlarged and continuing productive capacity by which alone these can be created and guaranteed. Soil restoration in its fertility for the improvement of permanent pastures is an important phase of balanced farming by which the farm families of Missouri are building a more lasting foundation for a more permanent agriculture.

PASTURES REPRESENT LARGE AREAS OF MISSOURI

Because of its rolling topography, nearly as much of the land in Missouri is used extensively for permanent pastures and livestock production as is cultivated intensively for grain crops. Missouri farmers are aware of the increasing erosion hazards connected with tilling the soil for grain crops on this rolling land. As a consequence, they have much of it under continuous grass cover for pasture. The census of agriculture in 1950 shows that in Missouri there are slightly over 11.1 million acres used as permanent pasture in contrast to 12.2 million acres used for crop production.

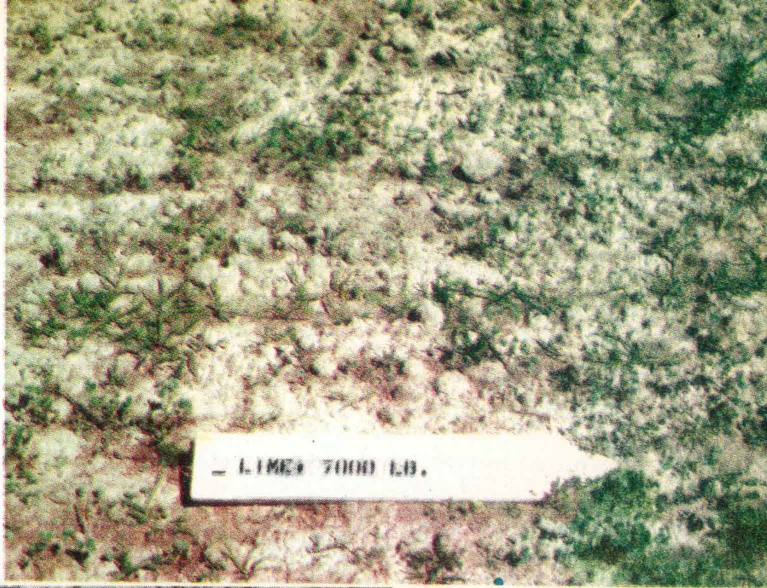
DEFICIENT SOIL FERTILITY BRINGS DOMINATION BY WEEDS AND WILD GRASSES IN PASTURES

Because of their depleted soil fertility, many of the pastures grow vegetation such as poverty grass (*Aristida dichotoma*), broom sedge (*Andropogon virginicus*), ragweed (*Ambrosia*), red sorrel (*Rumex Acetosella*), and other wild grasses and weeds which are too low in nutritive values to be relished by livestock. As the result, there is a low livestock carrying capacity and much over-grazing of the limited choice forage in the flora.

Studies of the chemical composition of these wild grasses, weeds, and other vegetation, volunteering on poor soil in contrast to grasses and legumes grown on soils where mineral deficiencies had been corrected, showed the following significant differences. Broom sedge yielded nearly two tons per acre of air-dry materials. But, in spite of that much yield as bulk, it contained only 0.107 per cent of calcium, or a total of only 2.14 pounds per ton. It contained only 0.109 per cent of phosphorus, or a total

Fertility of the soil, more than pedigree of the seed, gets the newly seeded forage, like this alfalfa, off to an early start.

While legumes must have lime to provide the calcium so necessary in their creation of the proteins, lime alone was not enough to get a good stand of alfalfa here.



Phosphate, as a supplement to the calcium in lime showed its value for this alfalfa by getting the crop going soon after seeding.

When lime, phosphate and potassium were put on the soil, the alfalfa stand was still better. Perhaps some boron and other trace elements would also have been helpful on this soil—as other trials have shown.

of but 2.18 pounds per ton. Poverty grass, also a poor land plant, yielded about three-fourths of a ton per acre and contained only 0.152 per cent calcium, which is a total of but 3.04 pounds per ton. Its phosphorus concentration was only 0.095 per cent or but 1.9 pounds per ton. In total protein content, these two plant species contained concentrations of only 4.43 per cent and 3.48 per cent or totals of 88.6 and 69.62 pounds per ton, respectively.

On the other hand, a nutritious pasture mixture of clover and grass grown and harvested at the same stage of maturity, i.e. the bloom stage, grown on a soil where mineral nutrient deficiencies had been corrected, produced nearly three tons of air-dry material per acre. It contained 9.06 per cent protein or a total of 181 pounds per ton. This mixed forage contained 1.3 per cent of calcium and 0.198 per cent phosphorus. These figures correspond to 26.00 pounds of calcium and 3.98 pounds of phosphorus per ton, respectively. The chemical compositions of this mixture and of some weeds are given in greater details in Table 1.

TABLE 1--The Yields and Their Contents as Protein and Nutrient Elements of Weeds and Wild Grasses Grown on Infertile Soil as Compared with Those of Pasture Grasses and Clovers Grown on Soils Where Fertility Deficiencies Were Corrected.

NAME	YIELD	ASH	CALCIUM		MAGNESIUM		PHOSPHORUS		POTASSIUM		PROTEIN	
	lb./A.	% (dry wt.)	%	lb./A.	%	lb./A.	%	lb./A.	%	lb./A.	%	lb./A.
Golden Rod (Solidago)	3500	6.02	0.875	30.62	0.165	5.76	0.155	5.43	1.20	41.93	4.24	148.4
Crab Grass (Digitaria)	2000	11.39	0.360	7.20	0.227	4.54	0.279	5.58	1.52	30.42	4.41	88.2
Ragweed (Ambrosia)	2357	7.88	1.750	41.25	0.445	10.49	0.178	4.19	1.74	41.08	6.33	149.2
Red Sorrel (Rumex acetosella),	1100	4.15	0.960	10.56	0.285	3.14	0.190	2.09	2.60	26.95	7.36	34.7
Wild Barley (Hordeum nodosum)	2536	9.08	0.250	0.39	0.190	4.81	0.246	6.24	1.10	27.64	5.49	139.2
Broom Sedge (Andropogon virginicus)	3852	4.68	0.107	3.58	0.105	3.86	0.109	3.50	0.36	13.67	4.43	170.66
Tickle Grass (Aristida)	1550	8.69	0.152	2.52	0.015	0.23	0.090	1.20	0.43	6.68	3.48	53.94
Clover-Grass Mixture (Timothy-Red Top)	5960	8.04	1.32	78.08	0.321	19.13	0.198	[illegible]1.80	1.48	88.27	9.10	542.36

Specimens collected in the bloom stage
Chemical analysis made by Sampson Lewis Wilhite

Even plants commonly considered as nutritious feed show chemical compositions varying widely with the soil. Little bluestem in the Western Gulf Region dropped as low as 1.5 per cent protein, 0.03 per cent phosphorus, 0.07 per cent calcium and 0.10 per cent potassium on one soil while on another soil the corresponding figures were 16.0, 0.31, 1.58 and 2.17 per cent respectively. These higher values were ten times the lower ones in the cases of protein and phosphorus, 20 times for the calcium and 21 times for the potassium.

In order to provide adequate calcium and phosphorus for young, growing steers of 300 to 400 pounds weight, the ration should contain at least 0.4 per cent of calcium and 0.33 per cent of phosphorus according to the authorities on animal nutrition (1). Fattening steers of 1000 pounds weight require rations with 0.17 per cent calcium and 0.18 per cent phosphorus. Dairy cows, giving liberal quantities of milk, should have rations which contain at least 0.25 to 0.30 per cent calcium and a like amount of phosphorus (2). According to the chemical studies cited above, such forages growing on fertility-depleted pastures, fall far below these minimum levels for good animal nutrition.

Many farmers have observed that livestock chooses the forage from areas in the pasture which have received full soil treatments and refuses the forage from the untreated areas. As a result of animals making this selection it is a common practice where full soil treatments have been made on relatively pure stands of red top and other grasses in established grass waterways for terrace outlets, to fence these outlets out of untreated permanent pastures. Unless this is done livestock graze these treated areas so closely as to severely damage the sod.

Such chemical composition studies of grasses and weeds that volunteer on the soils developed under higher rainfall, as has been common in Missouri and much of the humid area of the United States, along with the choices of animals, are telling us that those soils may be capable of making plant bulk, but not necessarily of providing much nutritional value in it. If then, these soils are now to be animal feeders by way of the grasses, the fertility in the soil must be raised above that supporting this volunteer growth, which animals disregard. The higher fertility foundation within the soil must be provided, first, to feed the forages well, and second, to feed well the animals consuming them.

ASSEMBLY LINES IN THE SOIL KEEP FERTILITY FLOWING IN NUTRITIOUS PASTURES

Pastures will be productive and more permanent only when both the primary and the secondary fertility lines in the soil are delivering the essentials for nutrition of plants and animals. As a primary support of life, via the soil, there is the breakdown of the mineral and rock fragments, to set free, and to convert into soluble forms, the essential inorganic elements they contain. Mineral particles of silt size are very slowly broken down by contact with the acid roots and with the clay made acid as a result of the root respiration and the root's removal of the clay's stock of fertility through exchange of acid for it. This is the primary assembly line.

(1) Mitchell, H. H. and F. J. McClure, *Mineral Nutrition of Farm Animals*—National Research Council—Bulletin 99, pp. 135.

(2) Meigs, Edward B., *The Feeding of Dairy Cows for Intensive Milk Production in Practice,* Food and Life, Yearbook of Agriculture—1939, pp. 585-586.

It is bringing fertility to the plant roots. But unfortunately, it is doing so at a rate too slow for economic production on many highly weathered and intensively used soils.

As a secondary assembly line of agricultural creation, there is the decay of the organic matter. This represents the repeated use of the elements after they have already served in a cycle of growth and death of a preceding generation of plants. This process of decay is rapid in its effects. It is timed to agree in its rate of fertility release more nearly with the needs for it by the growing plants it serves. In early spring, when plant growth is slow, decay is also slow. But in the late spring and summer, the warmer season speeds organic matter decay and its delivery of fertility as elements, and possibly also as compounds, when growth of the crops and their needs for the fertility are also mounting higher.

That compounds of decay may be taken up as such rather than as elements, is an aspect of this secondary assembly line of production deserving consideration. There may also be compounds from the animals as remnants of their digestion that may be taken up by the plant roots. They may be serving in plant nutrition because of this high degree of complexity they represent as a stage in their being elaborated into still more complex compounds. In these respects the plants' nutrition may be helped through the by-products of the nutrition of the animals above them and of the microbes below them in the pyramid of the different life forms.

So, while fertilizers may be the equivalent of much mineral fertility added to the soil's stock in total, good pasture soils must also be built up in organic matter while they are being built up in the inorganic fertility, in order to give extended seasonal provision of fertility. Pasture soils, initially rich in organic matter and kept so by that added through extensive root additions as a result of fertilizer use, can be permanent only when both the primary assembly line of providing inorganic essentials and the secondary assembly line of providing organic necessities are both going at full capacity. Going to grasses is no escape from the necessity of providing a steady flow of plenty of fertility from the soil to the crops.

SOIL TREATMENTS ARE THE STARTING POINT IN THE RESTORATION AND MAINTENANCE OF BETTER PASTURES

Field experiments and demonstrations show that the starting point in the creation of a permanent pasture on most Missouri soils is the treatment of the soil with adequate supplies of all the plant nutrients necessary to correct the deficiencies of them. Such soil treatments, coupled with mechanical renovation, reseeding and good practices in pasture management, make possible the (a) establishment and maintenance of the nutritious pasture grasses and legumes, (b) replacement of the non-nutritious weeds and wild grasses by encouraging thicker and more vigorous growth of the nutritious forages which are richer in minerals and protein, (c) two- to three-fold increases in the forage yields, the livestock carrying capacity, and the milk and meat, and (d) retardation of the run-off of rain water permitting enough of it to infiltrate into the soil, so that soil erosion becomes insignificant. As a result, pasture improvement, aside from being highly profitable in providing nutritious feed for livestock at low cost, is also the most effective and economical way of reducing erosion, of attaining economical soil conservation, and of bringing about better land use.

Lengthen the Grazing Season at Both Ends.—Permanent pastures consist of the perennial grasses, or those that do not go from seed to seed in one year with the death of the plant after seed making. Perennials can usually become more or less dormant when drastic seasonal conditions demand, and then grow again under return of those more favorable. Too often water shortage and winter weather have been considered the only drastic circumstances restricting the grass growth. Fertility shortage is responsible much more often than water shortage for grass failing (a) to start growth early in the spring, (b) to carry its growth well into the summer, (c) to begin growth in late summer after dormancy and (d) to extend its growth late into the autumn. Fertilizers can help to lengthen the grazing season by bringing grass on earlier in the spring and by keeping it growing later in the fall.

Early spring growth follows a good growth extended into the late fall of the preceding year, because of ample fertility going into the grasses at that late season. In the fall when the sunlight is becoming less intense and the days shorter, this extra fertility builds up the root reserves, particularly the protein. This is ready then for elaboration into plant tops in the succeeding early spring well before the extension of new roots would provide more nourishment from the cold soil. Extra fertility, going into the plant in the autumn, is not only keeping the plant active and green late into that season, but is also shifting the plant's activity from one of making more tops by exhausting the root reserves to one of making more root reserves to guarantee the early start next season. Only plenty of fertility in the soil to last for more than the plant's growth in the spring, can lengthen the grazing season at both ends to say nothing of escaping much of what is too commonly called "effects of the drought" when, in truth, it is summer starvation. The fertility supply must be coming into the plant throughout all the growing season if we are to lengthen the season of grasses as good pasture.

Hasten Recovery After Grazing; Crowd out Vegetation of Low Nutritive Value.—Pastures are permanent only when the growth of grass, grazed or cut back, recovers by making new growth promptly. Growth of young grass results from multiplication of the cells more than just enlargement of those already formed. Reproduction of cells calls for an increase in the total protein. This results only when ample fertility of the soil brings about the conversion of the carbohydrates—elaborated from air and water by sunshine—into that complex compound. With only the limited fertility stored in the small seed, the seedlings of grass cannot live through grazing as successive cuttings back. They will not recover quickly unless the grass roots are finding plenty of well-balanced fertility. This includes nitrogen, phosphorus, potassium and other essential elements in the soil. Recovery by grass in the form of its new growth soon after the grazing by livestock is possible only when protein, the carrier of life and center of the life processes, is created by the help of ample fertility in good balance from the soil for complete plant nutrition. The quick recovery after grazing of the nutritious forage helps to prevent the establishment of the non-palatable low nutritive vegetation such as broom sedge (*Andropogon virginicus*), poverty grass (*Aristida*) and similar vegetation refused by livestock.

Increase Mineral and Protein Contents of Forage.—Field trials supplemented by laboratory studies show that soil treatments not only produced larger yields of forage, but also increased its mineral and protein contents. For example, in a study of the yield and chemical composition of pasture forage grown on Lindley loam, the tonnage yield of forage with soil treatments was increased about 132 per cent over that from the untreated soil. The untreated soil gave a yield of 2,516 pounds of air-dry forage per acre with a crude protein concentration of 7.8 per cent. The yield of the treated plots was 5,960 pounds per acre with a protein concentration of 9.1 per cent. The yield of total protein on the untreated plots was 196.5 pounds per acre whereas on the treated plots it was 540 pounds per acre. The forage was one-sixth richer in its concentration of protein. The yield of protein per acre from the treated plots was increased 275 per cent over the untreated plots. One treated acre, so far as production of crude protein was concerned, was equal to nearly 2.75 untreated

Good legumes still are top feeds for growing animals. Lime alone, in the test plantings pictured here, failed to get a good stand of clover. But lime and manure gave the results shown in the last picture on this page.

Left half of picture shows results from lime only. Right half shows results of lime and manure.

This seeding was on a plot treated with lime only.

Close view of clover on plot treated with both lime and manure.

Manure adds nitrogen and potassium liberally. It also may add some organic compounds that give benefits not yet fully understood.—Photos by H. L. Garrard, American Potash Institute, and Penn State College.

acres. In total forage produced, one treated acre was equal to 2.36 untreated acres. These data are reported more completely in Table 2.

The soil treatments made it possible for legumes to grow in the grass mixture and to provide some nitrogen for the grasses. The more rapid growth of the more nutritious grasses and legumes helped to crowd out the vegetation of low nutritional quality. Consequently, the forage grown was rich in both mineral elements and protein.

TABLE 2--Yield and Chemical Composition of Pasture Forage as Influenced by Soil Treatments--Lindley Loam. 1945-1946

Soil Treatments N	P_2O_5	K_2O	Air Dry Forage Lbs./A.	Calcium %	Calcium Lbs./T.	Calcium Lbs./A.	Phosphorus %	Phosphorus Lbs./T.	Phosphorus Lbs./A.	Protein %	Protein Lbs./T.	Protein Lbs./A.
0	0	0	2,516	0.746	14.9	18.7	0.124	2.48	3.1	7.8	156.0	196.5
0	100	100	5,960	1.310	26.2	78.1	0.198	3.97	11.8	9.1	182.0	540.0
Increase from Soil Treatments			3,444	0.564	11.4	59.3	0.074	1.48	8.7	1.3	26.0	343.5

In viewing the concentrations of nutrient elements (and protein) in a forage as certain percentage of the dry matter, and the effects of the higher fertility of the soil in pushing these concentrations higher, it is well to note the significance of the latter as an effect on the quality of the forage as feed. An animal does not digest the nutrient elements out of the feed completely. If then there still remains in the feces after animal digestion a concentration of one per cent of an element in those residues, then a concentration of two per cent in a forage at the outset gave the animal but one pound of the nutrient element on digesting one hundred pounds of the forage. But if the soil treatment pushes the concentration up to three per cent, then the quality in terms of that element is increased one hundred per cent, since now two pounds rather than one pound are digested out of each hundred pounds of the forage. What appeared originally as but 50 per cent increase in the concentration as a result of the treatment of the soil becomes an increase of one hundred per cent in the quality of the forage as nutrition.

Increases Yields of Forage, Milk and Meat Per Acre.—The response that can be expected in the form of increased forage yields from the application of the necessary plant nutrients to provide a balanced supply of these in the soil is indicated by field results, for example, on the river hill soils in Boone County in Central Missouri and on the residual soils in St. Francois County in Southeast Missouri. According to the soil tests, these soils were all low in organic matter and phosphate. They were medium to high in potassium and slight to medium in acidity. During 1945 and 1946 on the river hill soils, the average annual acre yield of air-dry forage from the untreated plots was 3,925 pounds. Where three tons of limestone per acre alone were used, the yield was 5,251 pounds or 1,326 pounds more per acre than that from the untreated plots. When the limestone was applied along with 100 pounds of phosphoric acid (P_2O_5), the equivalent of 500 pounds of 0-20-0, and both cut into the soil before seeding, the yield of air-dry forage was 8,277 pounds or 4,352 pounds more than that from the untreated plots.

During 1947 to 1949 inclusive, in a similar study on the residual soils of St. Francois County, the average annual acre yield of air-dry forage was only 1,712 pounds where no treatments were used. Where initial acre applications of 72 pounds of nitrogen (N), 100 pounds of phosphoric acid (P_2O_5) and 100 pounds of potash (K_2O) were applied, the average annual acre yield of air-dry forage was 3,354 pounds or nearly double that from the untreated plots. These plant nutrients were applied in the form of 833 pounds of 3-12-12 and 146 pounds of ammonium nitrate per acre. These data are given in Tables 3 and 4.

TABLE 3--Increased Yields by Pasture Grasses from Fertilizers on the River Hill Soils, Boone County, 1945-1946.

Initial Soil Treatments* Rates Per Acre			Yields Air-Dry Forage Lbs. Per Acre	Annual Increases From Soil Treatments Lbs. Per Acre
N	P_2O_5	K_2O		
0	0	0	3,925	-
0	0	0-Lime-3 tons	5,251	1,326
0	100	0-Lime-3 tons	8,277	4,352

Field tests were conducted under the supervision of T. A. Ewing, former Boone County Agent.

* Fertilizer materials for field tests were supplied by the Middle West Soil Improvement Committee, Chicago, Illinois, and Spencer Chemical Company, Kansas City, Missouri. This cooperation is gladly acknowledged.

While applications of 100 pounds per acre of phosphate (P_2O_5) and potash (K_2O) respectively gave highly significant increases in yields of forage and protein per acre, later studies indicate that on soils strongly deficient in these elements that double to triple these initial applications gives more lasting benefits and lengthens the time interval necessary for repeated applications.

The increase of milk and meat, the protein- and mineral-rich foods, from pastures as the result of correcting soil fertility deficiencies, of mechanical renovation and of reseeding them is shown by the results obtained from both experiments and farmer experience. During the pasture season of 1951, six farms with improved pastures given full soil treatments produced an average of 2.9 to as high as 6 tons of milk per acre. Pastures on untreated soil produced less than one ton of milk per acre.

Likewise, farmers with beef cattle grazing on their improved permanent pastures obtained gains of 300 to over 500 pounds of beef per acre whereas unimproved pastures gave from one-third to one-half of this amount.

TABLE 4--Increased Yields by Pasture Grasses from Complete Fertilizers on the Residual Soils--St. Francois County--1947 to 1949 Inclusive. Average of Three Different Locations.

Initial Soil Treatments* Pounds Plant Nutrients Per Acre			Yield Air-Dry Forage Lbs. Per Acre	Annual Increase From Soil Treatments Lbs. Per Acre
N	P_2O_5	K_2O		
0	0	0	1,712	-
72	100	100	3,350	1,642

Field tests were conducted under the supervision of Willard Rumburg, St. Francois County Agent.

* Fertilizer materials for field tests were supplied by the Middle West Soil Improvement Committee, Chicago, Illinois, and Spencer Chemical Company, Kansas City, Missouri. This cooperation is gladly acknowledged.

A BALANCED SUPPLY OF PLANT NUTRIENTS IS REQUIRED

The soil must provide an adequate supply of plant nutrients through the entire growing season to grow an abundant supply of nutritious forage for grazing. The soil must be fertile and that fertility must be active. Deficient fertility for the roots, going deeper as the surface soil dries, is commonly mistaken for "summer drought". The plant nutrients usually deficient in Missouri pasture soils are the same as those deficient in soils under corn or under any other crop. They are nitrogen, calcium, phosphorus, and frequently potassium and magnesium, to say nothing of others not so commonly catalogued.

Nitrogen is the chief constituent of plant proteins, which are reassembled from that source by animals into the more complete and more highly prized animal proteins. Without an ample fertility supply in the soil, a forage of high concentration of complete protein cannot be produced. Calcium, phosphorus, and sulphur are essentials coming from the soil for the plant's synthesis of proteins. Sulphur is a part of every living cell and a part of the complete protein molecule. So is phosphorus, which with calcium, makes up the skeletal framework of animals. Potassium is known as the "sugar maker" and functions as a catalyst in the plant's production and transformation of carbohydrates. Calcium, while not in the protein molecule, is always associated with protein creation by plants. Sufficient trace elements like copper, zinc, boron, manganese, molybdenum and others must be present in the soil in available forms to serve in the growth processes in plants. They and others like iodine, cobalt, sodium and chlorine must also be in the plants in quantities and forms sufficient to provide for the nutritional and health requirements of the animals consuming them. Pasture plants must be grown, not just to be plants, but to serve this purpose of delivering to the animals the feed quantities and qualities they require.

Calcium and magnesium help to "mobilize" phosphorus, nitrogen and sulphur into the plant. Thus, the effects from phosphorus are related to the supply of calcium in the soil. Then, in turn, the results from the applications of calcium depend upon the soil's available supply of magnesium which is the chief constituent of chlorophyll. Other interrelationships exist.

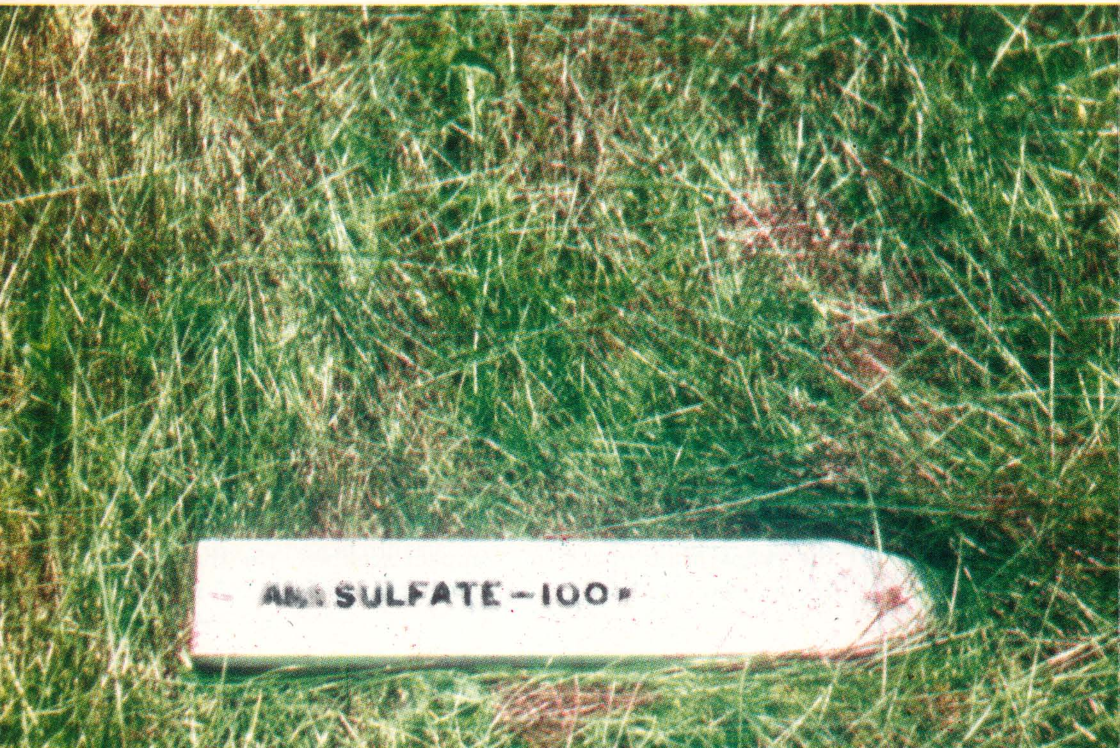
Other elements may indicate their shortages in the soil's supply through visible plant irregularities. These shortages are registered more pronouncedly as shortages in the plant's production of the proteins. In that connection, the whole list of trace elements seems to be of significance. Legumes, considered for their nitrogen-fixing services in making more protein, demonstrated for us recently their needs for boron and other trace elements. The shortages in the soil of what is required to make quality in feed, more than quantity, is emphasizing the mechanics of putting back into the soil, as well as taking out of it, the means of agricultural creation. In general, it can be said that in order to grow an abundant supply of nutritious pasture forage, all plant nutrient elements must be available in the soil in a balanced relationship to each other. Chemical soil tests will serve in determining the kinds and amounts of these removed most grossly that must be applied in order to bring about this balanced relationship.

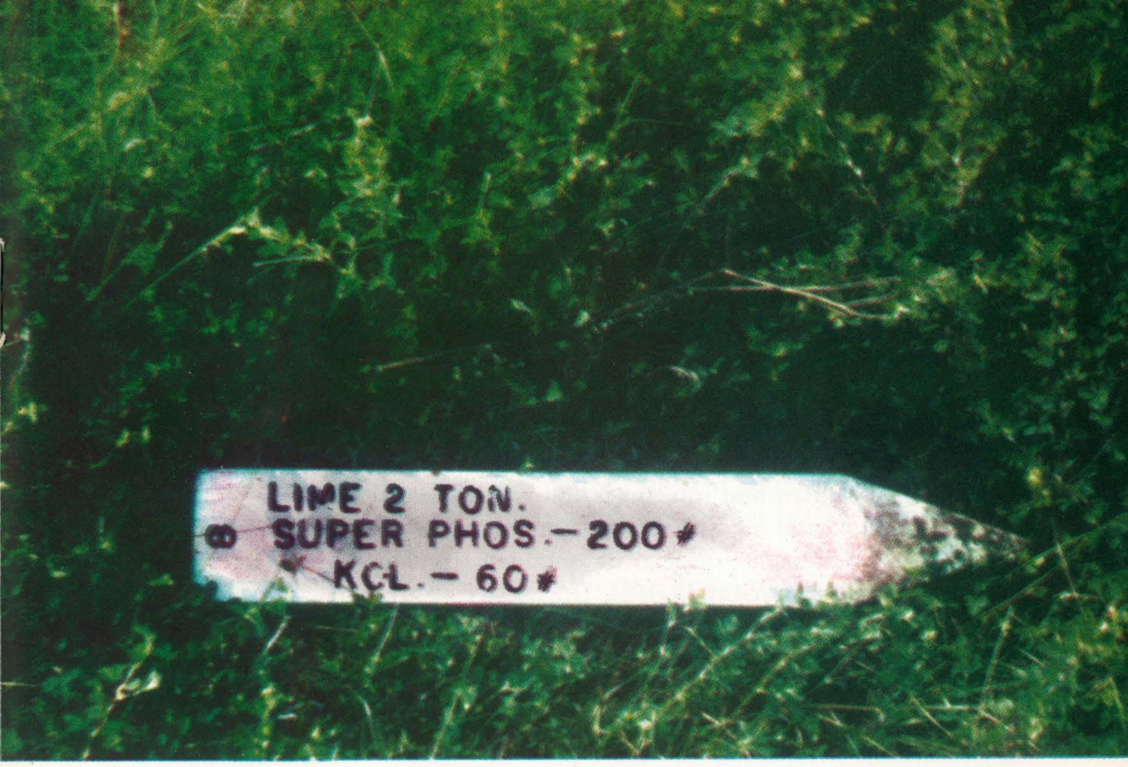
PROCEDURES FOR CORRECTING FERTILITY DEFICIENCIES OF PASTURE SOILS

The suggested steps in correcting the fertility deficiencies of pasture soils are (1) the making of the chemical tests, (2) the application of the fertilizers in accord with needs indicated by the soil tests, (3) the plowing of the mineral fertilizers under or the discing or working of them well into the soil, (4) the preparation of a firm, compact seedbed, (5) the use of starter fertilizer at seeding, and (6) the application of chemical nitrogen as needed.

An area of Putnam silt loam was seeded in 1937 with timothy, lespedeza and bluegrass, and kept as permanent grass. The part shown above has had no soil treatment since seeding in 1937. Growth in 1951 contained: bluegrass 42%, lespedeza 35%, weeds 23%.

The part below was given only nitrogen regularly since seeding. The growth in 1951 contained: bluegrass 92%, lespedeza 4%, weeds 4%.





The part of the area shown above was treated regularly with limestone and superphosphate since seeding. The growth in 1951 contained: bluegrass 23%, lespedeza 73%, and weeds 2%.

The part below received nitrogen, phosphorus in superphosphate, calcium in limestone, and potassium regularly since seeding. Growth in 1951 contained: bluegrass 87%, lespedeza 12%, and weeds 1%.

Chemical Soil Tests are Guides to Kinds and Amounts of Plant Nutrients Needed.—Soil tests usually include determinations of (a) the organic matter—from which the nitrogen release in the soil can be estimated; (b) the acid soluble phosphorus; (c) the exchangeable potassium; (d) the exchangeable magnesium; (e) the exchangeable calcium; (f) the pH; and (g) the total hydrogen. From the tests for exchangeable magnesium, calcium, potassium and hydrogen the total base exchange capacity can be ascertained.

The first requisite for a high degree of accuracy of these soil tests and of their subsequent interpretation is the careful sampling of the soil. Instructions for taking soil samples and for gathering other information pertaining to the soil tests can be obtained from the county agricultural agent or the Department of Soils, University of Missouri.

TABLE 5--Lime Requirement in Pounds Per Acre for Clovers or Alfalfa for Various pH Ranges, Degrees of Soil Acidity and Exchangeable Calcium

pH Range	4.5 to 4.9	5.0 to 5.4	5.5 to 5.9	6.0 to 6.4	6.5 to 6.9	7.0
Soil Acidity	Very Strong	Strong	Medium	Slight	Very Slight	Neutral
Exch. Calcium						
Very Low	10,000	8,000	6,000	4,000	*None	*None
Low	9,000	7,000	5,000	3,000	*None	*None
Medium	8,000	6,000	4,000	2,000	*None	*None
High	7,000	5,000	3,000	1,000	None	None
Very High	6,000	4,000	2,000	500	None	None

* Calcium can be supplied in other mineral plant foods such as phosphate.

Limestone Supplies the Soil with Calcium and Magnesium.—The amounts of limestone containing the calcium needed to establish clovers or alfalfa in pasture mixtures for various pH ranges, degrees of acidity and exchangeable calcium in the soil are given in Table 5. For example, a soil with a "very strong" acidity, which would be represented by a pH of 4.5 to 4.9 and a test reading of "low" in exchangeable calcium, would require an application of 9,000 pounds of limestone per acre. On the other hand, a soil which is of a "very slight" acidity; i.e., with a pH of 6.0 to 6.4, and "low" in exchangeable calcium which has not had an application of limestone in the past several years would require about 3,000 pounds of limestone per acre. If it has had limestone equal to the 3,000 pounds per acre, in the past two or three years, as indicated, it would not require an additional application.

The ratio of magnesium to calcium should be about 1 pound of magnesium to a range of 10 to 15 pounds of calcium. Should the soil be low also in magnesium as well as in calcium, then a dolomitic limestone should be used. If dolomitic limestone is not available and the soil is high in exchangeable calcium and very slightly acid or neutral in reaction (pH 6.5 to 7.0) which shows that additional limestone is not needed, then a fertilizer containing magnesium salts should be used. Such fertilizers as sulphate of potash-magnesia, which contains about 18 per cent magnesium oxide and about 21 per cent potash, can be used to supply both magnesium and potassium where the latter is also needed.

Initial Application of Fertilizers Often Needed at Heavy Rates.—By studies in the field of the correlation between the response of crops and the levels of phosphorus and potassium in the soil, as indicated by soil tests, it has been found that 200 pounds of acid soluble phosphate (86 pounds of phosphorus) and 200 pounds of exchangeable potash (160 pounds of potassium) in the surface seven inches of soil are the minima in favorable growing seasons that will keep these nutrients from limiting the plant growth. If shortages of these plant nutrients are to be removed as limiting factors to plant growth in unfavorable growing seasons, then the phosphate level should be brought up to 200 to 300 pounds or higher while the potash levels should be 300 pounds or more as shown by soil tests.

If pastures are to be more permanent and to be maintained over a number of years, then it is highly desirable to correct the deficiencies of the major plant nutrients at the time of the initial application. On most soils, this requires a rather heavy first application and at considerable expense. Benefits from a heavy initial treatment of mineral fertilizers to rebuild an old pasture into a more nearly permanent one should last for eight to ten years or longer. It is for such lengths of time that heavy rates of application are required.

Phosphorus and Potassium Needed as Heavy Initial Applications.—Where a soil is "very low" in phosphate, and "very low" in exchangeable potash according to the soil test, these deficiencies can be corrected by an application of 1200 to 1500 pounds of rock phosphate and 250 to 450 pounds of muriate of potash with effects lasting possibly for a period of ten years or longer. Another alternative would be to apply 330 to 440 pounds of an 0-45-0 fertilizer plus the muriate of potash mentioned above. Superphosphate (0-20-0) at the rate of 750 to 1000 pounds per acre, plus the muriate of potash, could also be used. Still another equivalent treatment would apply about 750 to 1000 pounds of 0-20-20 ferilizer per acre. Suggested amounts to give such lasting effects are shown in Tables 6 and 7. These tables also indicate the amount of phosphate and potash for initial applications for other fertility levels indicated by soil test readings. The lower rates of mineral plant food applied in the processed phosphatic materials would necessitate more frequently repeated applications than the larger amounts of phosphate applied as rock phosphate or other phosphatic materials.

Split Applications of Processed Fertilizers.—While it is more economical to make an initial heavy application of mineral plant nutrients to correct the nutrient deficiencies for ten years or longer, there may be cases where this cannot be done. If so-called "split" applications of processed fertilizers can be made, this soil treatment consists of making generous applications every three to four years. The first applications should be sufficient to remove phosphorus and potassium as factors limiting the growth of the more exacting plants, such as the clovers, in the pasture mixtures. Where the phosphorus is "very low" the soil will usually require an application of at least 150 pounds of phosphate (P_2O_5). This is equivalent to about 750 pounds of 0-20-0 fertilizer or 330 pounds of 0-45-0. Where potassium is "very low" an application of 125 pounds per acre

TABLE 6--Suggested Amounts of Phosphate (Pounds Per Acre) to Apply as an Initial Application for Different Phosphate Levels as Measured by Soil Tests.

Soil Test Readings and Pounds Per Acre	Pounds of Phosphate (P_2O_5) to Apply Per Acre	Suggested Rate Per Acre of Various Phosphate Carriers
Very Low (30 or Less)	150 to 200 or 360 to 450	750 to 1,000 pounds of 0-20-0, or the equivalent or 1,200 to 1,500 pounds of rock phosphate
Low (31 to 80)	120 to 170 or 270 to 360	600 to 850 pounds of 0-20-0 or the equivalent or 900 to 1,200 pounds of rock phosphate
Medium (81 to 140)	60 to 120 or 150 to 270	300 to 600 pounds of 0-20-0 or the equivalent or 500 to 900 pounds of rock phosphate
High (141 to 191)	20 to 70	100 to 350 pounds of 0-20-0 or the equivalent
Very High (192 or more)	With new seedings starter applications of complete fertilizers are suggested.	

The phosphate (P_2O_5) in starter fertilizers is included in the above applications of processed phosphate. When rock phosphate is used, starter fertilizers should be used in addition.

of potash (K_2O) equivalent to 250 pounds of muriate of potash should be used.

With a soil test showing "low" phosphorus and "low" potassium, an application of 600 pounds of 0-20-20, or the equivalent in other grades, would supply these plant nutrient requirements for several years. On soils where their tests are "medium" for these essentials, the rate for split applications should be about half of that applied for "low" readings. Like with the heavy initial applications, the best results will be obtained when the fertilizer is plowed under or worked into the soil with a disc or field cultivator. In either case, a starter of some complete fertilizer should be applied in addition at seeding.

These split applications will likely need to be repeated every three to four years. The repeated applications can be made without serious injury to the sod with a disc drill in the fall after good soaking rains or in the spring soon after the frost comes out of the soil and when it is soft but in fit condition to work. It is advisable to place the mineral plant nutrients down four to six inches into the soil, since this is the soil area that is not subject to so much intermittent drying and, thereby, root exclusion.

TABLE 7--Suggested Amounts of Potash (Pounds Per Acre) to Apply as an Initial Application for Different Exchangeable Potash Levels as Measured by Soil Tests.

Soil Test Readings and Pounds Per Acre of Exchangeable Potash in the Soil	Pounds of Potash (K_2O) to Apply Per Acre*	Suggested Rates Per Acre of Various Potash Carriers
Very Low (75 or Less)	125 to 225	250 to 450 pounds of Muriate of Potash or the equivalent.
Low (76 to 150)	125 to 150	250 to 300 pounds of Muriate of Potash of the equivalent.
Medium (151 to 220)	50 to 125	100 to 200 pounds of Muriate of Potash or the equivalent.
High (221 to 280)	25 to 50	50 to 100 pounds of Muriate of Potash or the equivalent.
Very High (281 and more)	With new seedings starter applications of complete fertilizers are suggested.	

* Of the above amounts not over 30 to 40 pounds of potash (K_2O) should be used in starter fertilizers.

When the grasses "run out" and the pasture is "taken over" by weeds, this is nature's way of "covering the naked"—it's no longer a matter of producing feed.
Here, in the final year of the rotation (1951), is shown what a difference is made by the soil. With no treatment, the crop was broom sedge 44% lespedeza 50%, timothy 4% and tickle grass 2%.

Treated with 3 tons of manure on the corn, wheat and first-year grass, the invasion by broom sedge was less severe. The crop consisted of: (a) broom sedge 15%, (b) tickle grass 80%, (c) lespedeza 2%, and (d) timothy 3%.

Where complete soil treatments were given according to soil test, three cuttings, instead of one, were made for hay, and this fine green crop, which was plowed under in December to close the rotation, consisted of timothy 99%.

Here the soil was not only clothed but also well fed—conditioned for high production of nutritious crops the following year.

Seasons and Conditions for Applications of Mineral Fertilizer.— Limestone, rock phosphate, superphosphate or mixed mineral fertilizers intended to build back the plant nutrient reserves can be applied at any time when machinery can be driven over the pastures. When the pastures are scheduled to be reseeded to grasses in the late summer or early fall, then the late spring and early summer are excellent times for these mineral fertilizer applications. When reseeding is to be made in the spring, then these applications can be made in late fall or early winter. In either case, the fertilizers should be applied before the preparation of the seedbed is started, so they can be placed well into the soil.

Mineral Fertilizers Should Be Plowed Under or Worked Into the Soil. —Phosphates or mixed fertilizers can be applied with the least manual labor from trucks with special spreader attachments, much in the same manner as limestone is applied. Where this service is not available or soil conditions make this method impossible, fertilizer distributors or drills can be used.

Phosphate, and to a lesser extent, potash and limestone are rather immobile within the soil and do not move readily through it. Instead they remain near where they are placed. Therefore, it is necessary that they be put well down into the soil so that they will be in the zone of the more numerous feeder roots of the pasture plants and also where the moisture supply is most constant. It is only when they are in this location that their mineral particles can react most readily with the soil and become available to the plant.

They can be placed well into the soil by plowing them under after they are applied on the surface or by working them into the soil with a disc or field cultivator. Further preparation of the seedbed will help to get them down into the soil. While the best crop response will usually be obtained from placing the mineral fertilizers well into the soil, beneficial results will still be obtained by applying them on the surface, under conditions where they cannot be plowed or mixed with the soil, as in the case on steep, rocky slopes.

Starter Fertilizers Give New Seedings Quick Start.—In addition to the heavy initial application or split applications of mineral plant nutrients to correct the deficiencies in the soil, it is usually advisable to apply a starter fertilizer with the new seeding. The readily available plant nutrients near the feeder roots of the young seedlings hasten growth and enable them to (a) establish themselves more quickly; (b) withstand winter freezing and summer droughts better; and (c) compete with other growing vegetation. Starter fertilizers can be applied with a fertilizer drill or distributor at the time of seeding. Usually a complete fertilizer containing nitrogen, phosphate and potash is preferable, such as a 12-12-12, 10-10-10, 8-8-8, 10-20-10, 8-24-8, 4-24-12, 4-16-16, 5-10-10, 3-12-12, 10-20-

0, 16-20-0 or 11-48-0. The grades, without potash, are suggested where the soil is very high in this mineral nutrient.

CHEMICAL NITROGEN A NEW BOON FOR PROTEIN-RICH FORAGES

Use of Chemical Nitrogen to Supplement Legumes.—With chemical nitrogen fixation now a widespread industry as a sequel of its importance in war explosives, this form of nitrogen has become widely available as fertilizer and at prices encouraging its extensive use. When it is the key element for the plant's service in converting carbohydrates into proteins, and when plant responses by greener color and rapid growth are so readily recognized; it is not surprising that commercial nitrogen fertilizers are being used so widely on arable lands as supplements to what the limited amounts of barnyard manures, and legumes plowed under as green manures, have been able to provide. More commercial nitrogen will naturally be expected to go on the pastures. This will occur especially when the other elements of fertility in the soil are adequate.

Many pasture soils which are to be seeded to permanent pastures are very deficient in organic matter. As the result, they fail to release sufficient nitrogen to enable the new seedings of grass and legumes to make sufficient top and root growth to withstand the low temperatures of winter or the drought of summer. Likewise, on established grass pastures there may not be sufficient growth of legumes to supply adequate nitrogen for rapid regrowth and recovery of the grass after it is grazed. Without the addition of nitrogen the results are usually not satisfactory. This nitrogen deficiency can be corrected through the use of chemical nitrogen. The amounts to use will depend on the organic matter in the soil. This can be determined by soil tests.

Responses from Chemical Nitrogen.—The responses in terms of increased pasture forage from the use of chemical nitrogen were measured in six tests during 1947 on the light-colored upland soils in Northeast, Central and Southeast Missouri. These soils contained about 200 pounds of exchangeable potassium per acre. The phosphorus deficiency was corrected. The yields were obtained from plots (a) without treatment; (b) where 100 pounds of P_2O_5 were used (equivalent to 500 pounds of 0-20-0); and (c) where the latter treatment plus 40 pounds of nitrogen were applied as 125 pounds of ammonium nitrate at seeding or as top dressing after growth had started. The average yields of the untreated and treated plots on several different soil types in 1947 are given in Table 8.

The average annual yield of air-dry forage in these five trials on four different soil types without treatment was 2293 pounds. Where 100 pounds of P_2O_5 (500 pounds of 0-20-0) were applied the yield was 3374 pounds, and where 40 pounds of nitrogen (125 pounds ammonium nitrate)

TABLE 8--Yields of Air-Dry Forage (Pounds Per Acre) for Nitrogen Applications

		Soil Treatments Per Acre	
Soil Type	No Treatment	100 lbs. P_2O_5	100 lbs. P_2O_5 plus 40 lbs. nitrogen
Lindley	2,680	3,360	4,890
Lindley	1,987	3,620	3,885
Union	2,536	3,080	3,886
Tilsit	2,250	3,000	5,000
Hagerstown	1,817	3,000	4,500
Average	2,293	3,374	4,624

were used in addition the average yield was 4624 pounds. This was more than the double of that where no treatment was used. These data show that chemical nitrogen is highly essential for satisfactory yields of pasture forages on soils shown by soil tests to be low to medium in organic matter. Previous experiments and observations have shown that nitrogen applied alone, where either phosphorus or potassium is deficient, may increase the yield of forage, but the mineral content of the forage is usually lowered.

Forms of Chemical Nitrogen Available.—There are a number of forms of chemical nitrogen that can be used. Among those available and most commonly used are the solid or salt forms such as ammonium nitrate, which contains about 33 per cent nitrogen, and ammonium sulphate with 20.5 per cent nitrogen. New nitrogen materials on the market are urea, also a solid material with about 42 per cent nitrogen; ammonia solutions containing 32 per cent nitrogen; and anhydrous ammonia containing 82 per cent nitrogen. Similar response can be expected per unit of nitrogen from any of the above forms.

Amount of Chemical Nitrogen for New Seedings.—On soils high in organic matter, adequate nitrogen can usually be supplied in starter fertilizer, where these containing as much as 8 per cent or more nitrogen are used at rates of 300 to 400 pounds per acre. For example, 400 pounds per acre of an 8-8-8 or 300 pounds of 10-10-10 or 10-20-0 would apply 32 and 30 pounds of nitrogen per acre respectively which, in general, is sufficient nitrogen as a starter on such soils.

On soils found by test to be medium to low in organic matter, or where large amounts of weeds, wild grasses, straw or other non-leguminous materials are plowed under or cut into the soil, sufficient nitrogen cannot be applied in starter fertilizer, thus necessitating the use of chemical nitrogen materials. Where this condition exists, 20 to 30 pounds of nitrogen per ton of this non-leguminous material will balance it as a better microbial diet. This added nitrogen will serve to hasten its decay and the release of the plant nutrients it contains. When new seedings are to be made on soils low in the more stable organic matter and where there are little organic residues to incorporate, 50 to 100 pounds of chemical nitrogen per acre are suggested.

Chemical Nitrogen on Established Pastures.—On established pastures where there is little clover or alfalfa and where the mineral plant nutrients are already adequate or their deficiencies have been corrected, an application of 50 to 100 pounds of nitrogen per acre can be expected to give a substantial increase in the growth of grass, and livestock carrying capacity. If the grass is allowed to produce seed, the nitrogen frequently doubles this yield. Where legumes dominate, an application of chemical nitrogen will hasten the growth of grass, making it possible for it to gain a foothold in the mixture.

On the other hand, where grass dominates over the legumes, chemical nitrogen applications will tend to hasten the growth of the more shallow-rooted grass, and further crowd out the more deeply-rooted legumes from the mixture. So whether to apply chemical nitrogen depends upon the proportion of legumes to grasses and the grazing management practices that can be used.

Time of Applying Chemical Nitrogen.—Chemical nitrogen can be applied to new seedings before or during the preparation of the seedbed. If solid forms of nitrogen, such as ammonium nitrate and sulphate of ammonia, or solutions of ammonia containing 32 per cent nitrogen are used they can be applied on the surface and plowed under. They may also be applied as a top dressing after the new seedings have made several inches of growth. The material should be applied when the vegetation is dry in order to prevent scorching or burning.

On established grass sod, the forms of chemical nitrogen can be applied as a top dressing in August, September or October of the Autumn; or in January, February or early March of the Spring. The early fall applications have the advantage of providing increased growth and forage yet in that season as well as providing for the plant's storage in its roots. This reserve, in turn, will give it an earlier start next spring. Early spring applications will usually give earlier growth and carrying capacity.

On new seedings anhydrous ammonia can be applied while plowing or during seedbed preparation. On established sod it can be applied at the same time as listed above for solid materials. It should be placed 5 to 6 inches into the soil. Consequently the condition of the soil will govern the time of application of this material on established grass pastures.

Methods of Application.—The regular fertilizer grain drill or the fertilizer distributor can be used to apply the solid forms of nitrogen. For the 32 per cent ammonia solutions the regular weed spraying equipment with aluminum fittings can be used. Special equipment including a tank and an applicator is required to place anhydrous ammonia in the soil at depths of 5 to 6 inches so that it will be in contact with moist soil.

Cautions to Take in Using Chemical Nitrogen.—Since some of these solid salt forms of chemical nitrogen are highly corrosive for iron and other metals, care must be taken to clean thoroughly and oil the equipment after applying them.

Chemical nitrogen can be expected to give the most satisfactory results when used on soils where the mineral plant nutrients such as phosphorus, potassium, calcium, magnesium and others used in minute amounts are present in adequate supply. Chemical nitrogen applied on soils deficient in one or more of the mineral plant nutrients may result in the production of forage of lower nutritional value for livestock. Thus, to obtain the most satisfactory results with chemical nitrogen all the essential minerals should be present in the soil in adequate amounts.

PREPARATION OF SEEDBED AND MAKING NEW PASTURE SEEDINGS

In the preparation of a seedbed for new pasture seedings it is essential that (a) any gullies existing in the field should be filled; (b) the wild and unpalatable vegetation such as weeds, wild grasses and small brush be uprooted and covered; (c) the basic mineral plant nutrients should be placed well into the soil; (d) a smooth, compact, moist seedbed with sufficient loose soil to cover the new seedings should be made; and (e) the field should be left smooth enough so that it can be clipped with a mower. On badly eroded fields, terraces are usually needed to divert the water out of the gullies. Plowing will usually uproot the unpalatable vegetation and place the basic fertilizers deeper into the lower soil areas. While a heavy disc may be used plowing is preferred.

Where fall seedings are to be made, plowing or discing can be done in late spring or early summer after the major soil treatments have been applied. For spring seeding, these operations can be performed in the late fall or early winter preceding. Frequent cultivations with a disc harrow and finally a roller after late spring or summer will provide a firm, compact seedbed with sufficient moisture to germinate the fall seeding. Similar operations in the spring will do likewise with late fall and winter plowing for spring seedings.

Pasture Mixtures Can Be Seeded in Either Late Summer or Spring.—Pasture seedings can be made in either the late summer or early spring. In general, fall seedings should be made in late summer from August 15 to October 1 in South Missouri, and by September 20 in North Missouri. Ladino clover should not be seeded any later in the fall than the above dates. If it can not be seeded by then it should not be seeded until spring. Usually best results are obtained by making spring seedings as early as the seedbed can be made—preferably March and the first half of April.

When the protein-producing legumes are considered "hard to grow", it simply means they are not being given the fertility necessary to make what they need for their growth.

The legume shown here was partly taken by weeds and grasses. It was treated with a calcium limestone and the major fertility elements.

Here the same treatment was used, except that a magnesium limestone instead of a calcium limestone was applied. Here, also, the legume is mixed with other plants.

This nice clean crop—free from admixtures of other plants — was p r o d u c e d where the "minor" or "trace" elements were used as soil treatments. They serve in protein production.

Method of Seeding.—Pasture seedings may be made alone or with a half- to full-seeding of a companion crop of small grain when full soil treatments have been made. Where the pasture mixture is sown with a full small grain seeding the cost of soil treatments and pasture seedings can frequently be partially to fully recovered from the small grain crop. Pasture seeding without a companion crop will more likely survive drouth and other hazards and provide forage more quickly than when sown with a companion crop.

The most satisfactory stands of new seedings are obtained when (a) the seedings are made on a firm compact seedbed with sufficient moisture to germinate the seed, and (b) the seed is uniformly distributed and placed in the soil from one-fourth to one-half inch in depth. Seedings can be made with grain drills with grass seed attachments, or with special seeders which distribute and cover the seed uniformly by means of corrugated rollers in front and behind. The seed may be broadcast and then covered by means of a cultipacker, a corrugated roller, a harrow or a drag.

Grass and Legume Mixtures for Permanent Pastures.—After soil treatments and a firm compact seedbed have been made, a legume-grass mixture should be seeded. Suitable mixtures for permanent pastures for the various Missouri soils (1) are as follows for kinds of plants and pounds of seed per acre.

On deep, fertile well-drained soils:

1. Brome grass 10, and ladino clover 1 pound per acre.
2. Brome grass 5, timothy 3, and ladino clover 1 pound per acre.
3. Brome grass 10, alfalfa 6, and ladino clover ½ pound per acre.
4. Brome grass 10, red clover 5, and ladino clover ½ pound per acre.

On soils from moderate to poorly drained where fertility deficiencies have been fully corrected:

5. Orchard grass 10-15 and ladino clover ½ pound per acre.
6. Orchard grass 10-15, red clover 5, and ladino ½ pound per acre.
7. Tall fescue 10, alsike 3, and ladino clover ½ pound per acre.

On shallow soils where fertility deficiencies have been only partially corrected:

8. Orchard grass 10 and annual lespedeza 15 pounds per acre.
9. Tall fescue 10 and annual lespedeza 15 pounds per acre.
10. Red top 5 and annual lespedeza 15 pounds per acre.

On soils subject to flooding where fertility is naturally at a high level or where fertility deficiencies have been corrected:

11. Reed canarygrass 6-8, timothy 3, and alsike 3 pounds per acre.

(1) Brown, E. Marion, *Good Pastures Pay,* Agri. Experiment Station Bulletin 547, Page 5, University of Missouri, 1951.

Use and Maintenance of Permanent Pastures.—A thick heavy grass sod or sward capable of making a rapid recovery after it is eaten can be maintained by:

(1) Practicing rotation grazing of pastures.
(2) Avoiding over-grazing of pastures.
(3) Clipping of pastures in both spring and fall to keep an even growth of grass and legumes and also to keep weeds under control.
(4) Managing so as to provide adequate cover during the hot summer months. This helps to keep the direct rays of the sun away from the soil. It keeps the soil temperature lower around the roots and reduces injury to them by the summer heat.

Where soil fertility deficiencies have been corrected there will usually be excessive growth in late spring which frequently can be removed for grass silage or hay in time to allow it to make sufficient growth to provide 6 inches or more cover during the hot summer months. Grasses not consumed during the regular grazing season can be used during the winter.

Further information on seeding pasture mixtures, and management can be obtained from the county agricultural agent, or by writing to the University of Missouri, College of Agriculture, Columbia, Missouri.

SUMMARY

The soil is the starting point in the creation of plant and animal life by means of air,, water and sunshine. But it is only when the soil contains all of the essentials of creation that the pasture grasses grow rapidly and are highly nutritious feed for animals.

Pasture forage which is actively growing ranks at the top of the list of nutritious feeds for cattle, sheep and horses and can be used as a supplemental part of the rations for hogs and poultry. No other feed is produced and marketed more economically. None is better able to keep animals in a vigorous state of health, reproducing regularly, growing with rapid gains and producing meat and milk abundantly.

In Missouri, approximately eleven million acres are used for permanent pasture. Because of depleted soil fertility, much of this pasture acreage is heavily infested with vegetation that can make bulk on soils supplying very little fertility, consequently it is of low nutritive value. Such growth is widely illustrated by broom sedge *(Andropogon virginicus)*, poverty grass (*Aristida dichotoma*), ragweeds (*Ambrosia*), and other "unpalatable" grasses and weeds.

Studies of the pattern of the different crops suited to different soils and of plant species in general as they dominate on (or take over naturally) soils of different levels of fertility show that the less fertile soils produce vegetation cover but such growth has less of proteins and less of the correspondingly valuable nutritional essentials.

Studies of the chemical composition of vegetation grown on fertility depleted soil, such as broom sedge, show that it may contain as little as 0.107 per cent calcium, 0.109 per cent phosphorus, and 4.2 per cent protein. Poverty grass, another poor land plant may contain only 0.152 per cent calcium and 0.09 per cent phosphorus.

Nutritionists advise that young growing steers of 300 to 400 pounds weight should have rations containing at least 0.4 per cent calcium and 0.33 per cent phosphorus. Dairy cows giving liberal quantities of milk should have rations that contain 0.25 to 0.30 per cent calcium and a like amount of phosphorus. The vegetation mentioned above as unpalatable, as weeds or as Bluestem falls below these minimum levels. Nutritious pasture mixtures of clover and grasses, at the same stage of maturity, grown on similar soil where mineral deficiencies had been corrected, contained 1.3 per cent calcium and 0.198 per cent phosphorus.

The flow of soil fertility for creating the abundant growth of nutritious pastures depends in the first place on the constant liberation of mineral plant nutrients from the rock fragments of silt size. This is accomplished by contact with the plant roots and with the clay made acid by root respiration on which clay the fertility is stocked until it is removed by the plant root through acid exchange. This may well be considered as the primary assembly line of agricultural production. Fertilizers are means of promoting more flow of fertility along this line.

The flow of fertility depends, in the second place, on the decay of organic matter, which is the secondary assembly line. Many pasture soils are geologically old, deficient in organic matter, and thus are unable to release sufficient fertility beyond that taken by microbial competitors struggling to survive on the protein-poor, mineral-poor organic matter grown on the soil. Consequently, there is insufficient flow of fertility on either the primary or secondary assembly line for the abundant growth of nutritious grasses and legumes. The reinforcing of these assembly lines through soil treatments, offers more fertility flow in both the inorganic and organic activities in the soil and removes soil fertility as the limiting factor to plant growth.

Field experiments show that with soil treatments of limestone and other fertilizers on fertility-depleted soils to provide a balanced nutrient supply, along with renovation, reseeding to grass legume mixtures, and good management practices, it is possible to replace the weeds and grasses of low nutritive value with nutritious forages. By so doing, the grasses recover more quickly after grazing, the grazing season is lengthened, the livestock carrying capacity is doubled or tripled and the runoff of rain water is retarded making soil erosion insignificant. Where adequate soil treatments were made for the soil, one acre produced as much forage as 2.4 acres in untreated pasture. In protein production, one acre of treated pasture was equal to 2.75 untreated acres. Acre yields of milk and meat as beef have been doubled or tripled over those of untreated pastures.

The suggested procedures for correcting fertility deficiencies of pasture soils are: (1) make chemical soil tests, (2) apply mineral fertilizers in accord with these tests, (3) plow the mineral fertilizers under or disc and work them well into the soil, (4) use starter fertilizers at seeding, and (5) apply chemical nitrogen as needed to supplement that supplied by legumes.

Limestone should be applied to meet the needs of pasture plants for calcium and magnesium. Excessive liming may reduce the availability of other plant nutrients.

Phosphate or phosphate and potash may be used in heavy initial application in order to remove them as limiting factors for plant growth for 8 to 10 years. When such heavy initial applications cannot be made and the soil is not completely exhausted of fertility, then split applications of processed fertilizers can be used. This method consists of making generous applications every 2 to 4 years. When necessary to repeat applications of fertilizer on established pasture, this can be done without injury to the sod, by using a disc drill in the fall after good soaking rains or in the early spring after the frost comes out of the soil.

Because of the relative immobility of limestone, phosphate and potash, they should be placed well down into the soil. This can be accomplished by applying them on the surface any time machinery can be driven over the fields. Later they should be plowed under or worked into the soil with a field cultivator or heavy disc. A starter application of a complete fertilizer at seeding time is suggested.

Chemical nitrogen can be used advantageously on new pasture seedings to give them a quick start. It can also be used to supplement the nitrogen supplied by legumes. This treatment gives earlier spring and later fall pasture and increased livestock carrying capacity and/or greater seed production.

After the mineral soil treatments have been applied and placed well into the soil, a firm compact seedbed should be prepared by discing, harrowing and rolling. A grass legume mixture is suggested. This may be sown in either late summer in August and September or in the late winter or early spring in February or March, when there is sufficient moisture to germinate the seed. New seeding should be covered to shallow depth.

In order to maintain a thick vigorously growing pasture, weeds should be kept under control and close grazing should be avoided during the summer months. Excess forage over what is needed for pasture can be used for grass silage or hay.