FEED EFFICIENCY IN TERMS OF BIOLOGICAL ASSAYS OF SOIL TREATMENTS

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THE relationship between the distribution of livestock and fertility of soils is well defined. Throughout the United States the livestock population is largest in areas of high soil fertility. As the soil productivity declines in humid regions, the problems of keeping livestock thrifty and profitable have increased. Losses from bacterial and virus diseases are not as great as in past decades. However, despite extensive breed improvement, increased knowledge of production, and better equipment, nutritional diseases have not diminished, nor has the percentage of young that are saved kept pace with improved livestock practices. More problems are constantly presenting themselves. It is not unreasonable to believe that the feed crops on depleted soils may not be as nutritious as when soils were more productive and that some of the present animal production problems may be traced to the low quality of feeds now being used.

CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF FORAGES INFLUENCED BY SOIL TYPE AND SOIL TREATMENT

Reports from most of the experiment stations in the eastern half of the United States show that the use of commercial fertilizers for the addition to the soil of deficient elements (9)[3] may increase, may decrease, or may have little effect on the concentration within the plant tissue of the added elements. These variations are often explained, for fields with mixed herbage or in pastures, on the basis of the changes in kind of plant that may be brought into dominance by the treatment. Nevertheless, these soil treatments may bring about variation in content of protein, minerals, or fiber within a single plant species. The extent of variation in chemical composition is influenced by any particular nutrient excess in the soil, and by the greater or lesser demands by the plant on nutrient elements coming from the soil.

It has been shown that plants produced on soils having a deficiency of one or more nutrients are of lower biological value to animals than are those where these elements are not lacking (1, 3, 4). Digestion trials have shown that the feed efficiencies and utilization of minerals vary widely for forages produced on different soils (10, 11). These digestion differences cannot be correlated exactly with analyses of the feeds as commonly determined. Crampton and Maynard (5) have pointed to the relationship between the lignin content of feeds and their utilization by animals.

Data showing the effect of soil treatments on the vitamin content of crops are none too consistent. It is probable that methods and technics in making analyses are not yet sufficiently standardized for reproducible results in the hands of different analysts. However, many of the data (6, 7) indicate that where crops are grown on soils containing a well balanced supply of plant nutrients or where conditions are optimum for plant growth, the vitamin content will be amply high.

If crops are of low nutrient value when grown on soils where certain elements are deficient, it is also probable that those forages containing unduly high percentages of these elements would be unbalanced, low in other elements, and of lower nutrient value than where all elements are present in more nearly balanced amounts. The excessive use of a single element fertilizer, or of unbalanced fertilizers on crops, may result in plants of as low biological value as those produced with a deficiency of the same element.

ANIMALS SHOW FEED EFFICIENCIES RELATED TO SOIL TREATMENT

FORAGES INFLUENCE RATE OF GAIN AND PHYSIOLOGY OF LAMBS

In a continuation of work reported previously (1), in which lespedeza hays from the same soil given different soil treatments were fed to feeder lambs, a wide variation in nutrient efficiency was obtained, as is shown in Table 1.

If the mean figure of the 3 years for the lespedeza is calculated, a ton of the hay receiving only phosphate with grain supplement is found to produce 128 pounds of animal gain, while a ton of hay from the soil receiving lime and phosphate would produce 164 pounds of gain, or an increased gain of nearly 44%.[4] The average yield of lespedeza hay for 3 years from the soil receiving phosphate was 2,120 pounds, while on the land where lime had been applied in addition

[1]Contribution from the Department of Soils, Missouri Agricultural Experiment Station, Columbia, Mo. Journal Series No. 874.
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[3]Figures in parenthesis refer to "Literature Cited", p. 330.
[4]Assuming all gains were made from hay as all animals received the same amount of grain.

TABLE 1.—*Lespedeza and soybean hays required to produce 1 pound of lamb gain when grown on Putnam silt loam soil receiving different soil treatments.**

Year	Hay	Soil treatment		
		None	Phosphate	Lime + phosphate
1939	Lespedeza	—	29.2	19.4
1940	Lespedeza	—	14.2	12.6
1941	Lespedeza	12.7†	9.7	7.6
1941	Soybean	9.7†	5.4	4.4

*Assuming all gain was made from hay, all animals received ¼ pound of shelled oats and ¼ pound of wheat bran daily. Each figure is average results from 7 to 12 lambs in each pen. Number varied in different years.
†No treatment; hay fed in 1941 only.

to the phosphate the yield was 2,770 pounds. This is a difference in crop yield of 26%. However, when the hay corresponding to 1 acre of the phosphated land was fed to sheep, it produced a gain of 136 pounds, while the hay from 1 acre of the limed and phosphated land produced 227 pounds of gain. This is a difference in returns per acre of 67%.

EFFICIENCY OF GRAIN UTILIZATION AFFECTED

Not only has the hay grown on the treated soil given greater animal gain than the difference in tonnage yields would indicate, but the quantity of grain consumed for each pound of gain was widely different.

The figures given in Table 2 show that even though animals are fed the same amount of grain from the same source, the quantity required to produce a unit of gain can be much influenced by the kind of forage which it supplements. As an average of the figures for lespedeza hay, 4.6 pounds of grain were consumed for each pound of animal gain for the animals fed hay from the soil receiving only phosphate. Those fed the hay from land receiving both lime and phosphate consumed only 3.34 pounds of grain for each pound of gain. Thus, the hay from the land receiving only phosphate required over a third more grain to produce the same amount of gain than did the hay from land receiving both lime and phosphorus. In terms of a practical farm viewpoint where it is assumed cheap forage is available and where grain is purchased, it would require 4,600 pounds of grain to produce a thousand pounds of lamb gain if the animals had free access to the phosphated hay, but only 3,340 pounds of grain if the animals had access to the hay grown on the soil treated with lime and phosphate.

TABLE 2.—*Grain supplement consumed per pound of gain by lambs fed lespedeza and soybean hays grown on differently treated soils.*

Year	Hay	Soil treatment		
		None	Phosphate	Lime and phosphate
1939	Lespedeza	—	6.8	4.5
1940	Lespedeza	—	3.5	3.0
1941	Lespedeza	4.3	3.5	2.5
1941	Soybean	4.2	2.3	1.7

ANIMAL APPEARANCE REFLECTS EFFECTS OF SOIL TREATMENT

The lambs were vigorous at all times in all of the trials using the lespedeza and soybean hays. The only noticeable difference in the animals was in the appearance of the wool and its yolk content. In every trial the lambs on the hay from limed and phosphated soil were much dirtier, more shaggy, and rougher in appearance. On parting the wool, a large amount of yolk gave it a deeper yellow color. In contrast, the animals fed either the hay with no treatment or with phosphate were clean and smooth in appearance, while the wool was much whiter and contained less yolk. The lambs shown in Fig. 1 are representatives of the groups fed in the four trials.

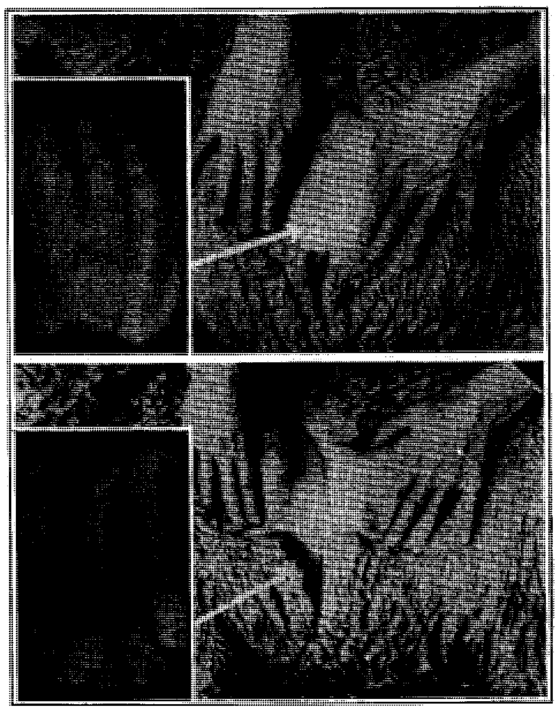

FIG. 1.—Differences in wool as related to the forage from different soil treatments. *Above,* little yolk, white fibers, and smooth top of sheep from lespedeza with phosphate applied to the soil. *Below,* much yolk, yellow fibers, and rough top of sheep from lespedeza with lime plus phosphate applied to the soil.

FIG. 2.—Scoured wools from sheep fed lespedeza hays from soils with different treatments. *Left*, phosphate as soil treatment. *Right*, lime plus phosphate as soil treatment. After scouring in 1% potassium hydroxide, the wool on the left could not be carded without its breaking down.

Analyses of the wool showed that the fleeces from the sheep receiving the limed hay contained 2% more fat than those receiving the phosphated hay. When the wools were scoured with a 1% solution of potassium hydroxide, that from the lambs receiving only phosphated hay was attacked and lost 34% of its weight, while the wools from the lambs receiving the limed and phosphated hay remained fluffy and lost only 24%. Fig. 2 shows the appearance of these two wools after scouring.

Evidently the wool from the lambs on the limed and phosphated hay had a different composition or had a thicker protective coating of fat and yolk which prevented it from heavy attack by the alkali. Regardless of the chemical or physical differences in the wools, it is significant that a simple treatment applied to the soil has not only been reflected in increased yield of forage, but when fed to sheep has brought about differences in rate of gain and altered the physiology of the animals sufficiently to be observed in the appearance and quality of the wool.

FEED EFFICIENCY REDUCED BY UNBALANCED SOIL TREATMENTS

In view of differences in the biological value of forages obtained in bioassays with sheep and the similar results obtained with rabbits (1), numerous bioassays have been made with rabbits of both forages and grains grown on various experimental fields of Missouri. The procedure followed was similar to that used by Crampton (3) where uniform young rabbits were fed in screen-floored pens with facilities for collecting urine and feces. The animals were given *ad libitum* of the feed under test, and a constant amount of grain or hay supplements when they would not grow satisfactorily on the feeds under test alone. All animals were given distilled water and common salt. By keeping records of feed given and refused, the amount consumed was obtained; the digestibility was obtained from analyses of the feeds, feces, and urine; and the comparative efficiency of the feed in producing animal gain was determined.

Many of the assays made to date have been of an exploratory nature. Results have varied, depending on the soil type, season, and other factors. Nevertheless, these feeding and digestion trials show that the use of a soil treatment can alter the value of the plant as animal feed. It is significant, and somewhat surprising, that some of the soil treatments which have given maximum increases in yield in the field, particularly when the soil treatments were not considered as balanced, have produced crops of lower biological value than those from soils having received no treatment. It is also evident that the correlation between standard feed or mineral analyses and digestibility, or some animal response, are not so specifically related that these analyses can be used to forecast the value of a particular feed.

NITROGEN IN EXCESS REDUCES FEED EFFICIENCY OF TIMOTHY

Pure stands of timothy[5] produced on a meadow fertilization experiment at Columbia, Mo., were fed to young rabbits for a period of 112 days. These animals were fed all the hay they would consume plus a constant daily feed of oats. The data in Table 3 give the analyses of these hays and the gains made by the animals.

All of these hays were of good quality. That receiving the sodium nitrate was much coarser and of a darker green color. The mineral analyses show that where nitrogen was applied, the percentages of phosphorus and calcium in the hay were lower than in the untreated hay. With the exception of the hay receiving nitrate of soda, the protein content in any of the hays receiving soil treatment was no higher than in the untreated. This would indicate that the increased growth compensated for the increased absorption of these nutrients.

The animals receiving the sodium nitrate hay ate a greater amount per day and produced a more rapid gain than those given the untreated hay (Fig. 3) or those receiving the ammonium sulfate treated hay. However, when the gains are expressed on a

[5]None of the hays fed contained over 5% of other species than timothy.

TABLE 3.—*Relation of chemical composition of timothy hay (1941 crop) to gains of rabbits.*

Soil treatment	Yield, lbs. per acre	Nitrogen		Ca, %	P, %	Grams gain in 112 days	Hay consumed per gram of gain*	Grain consumed per gram of gain
		Total, %	Water-soluble, %					
None	1,745	1.12	0.16	0.49	0.142	721	11.6	2.6
Ammonium sulfate, 100 lbs. per acre in March	2,894	1.06	0.12	0.34	0.124	553	12.7	3.3
Sodium nitrate, 100 lbs. per acre in March								
Sodium nitrate, 100 lbs. per acre in May	3,250	1.64	0.20	0.46	0.110	778	14.3	2.5
Complete†	2,524	0.98	0.10	0.41	0.217	1,039	7.6	1.8

*Assuming all gain was made from hay. The grain ration was constant for all years.
†Limestone at 2½ tons in 1937, 100 lbs. of ammonium sulfate annually, 200 lbs. superphosphate and 50 lbs. KCl per acre in alternate years. (Applied in 1941.)

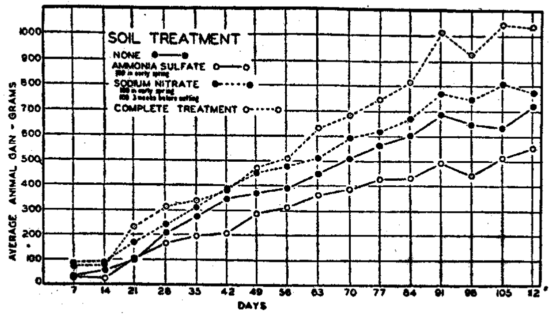

FIG. 3.—Rates of gain for rabbits fed timothy hays grown on Putnam silt loam given different soil treatments. Average of three animals fed each hay.

basis of gain per unit of hay consumed, the efficiency was lower than on any of the other hays. The higher biological assay of the complete treatment hay over the others shows its higher nutritive value, although this difference would not be expected from the appearance of the hay or from the chemical analyses.

It is probable that the use of nitrogen alone on this phosphorus and calcium deficient soil furthered an already unbalanced soil condition resulting in abnormal plant metabolism and a forage of low quality. As a practical farm consideration, it would be a gross error to interpret the value of treatments on this soil, measured by their influence on the yield of timothy as a corresponding measure of the animal gains they would produce.

DEFICIENCY OF POTASH PRODUCES FORAGE OF LOW NUTRIENT VALUE

Rabbits were fed soybean hay produced on Putnam silt loam where various soil treatments had been used. An extreme potash deficiency had developed where limestone had been applied for some time. There was no evidence of potash deficiency on the unlimed soil.

The hays with no treatment and with no lime contained considerably more grass than the limed hay. The hays were chopped and the animals given all they would eat plus a small daily supplement of shelled oats.

The data given in Table 4 and Fig. 4, show that, although these differently treated hays vary little in

TABLE 4.—*Relation of chemical composition of soybean hays to gains of rabbits.**

Soil treatment	Yield in lbs. per acre	N, %	P, %	Ca, %	Average gain in grams, 49 days
None	2,780	2.35	0.217	1.31	296
0–20–0, 150 lbs.	2,500	2.15	0.240	1.28	229
0–20–10, 150 lbs.	3,800	2.50	0.232	1.35	352
0–20–0, 150 lbs. plus† limestone	2,940	2.78	0.260	1.07	88
0–20–10, 150 lbs. plus limestone	3,800	2.92	0.262	1.28	363

*One year rotation of barley and soybeans. Fertilizers applied only to barley.
†Extreme potash deficiency.

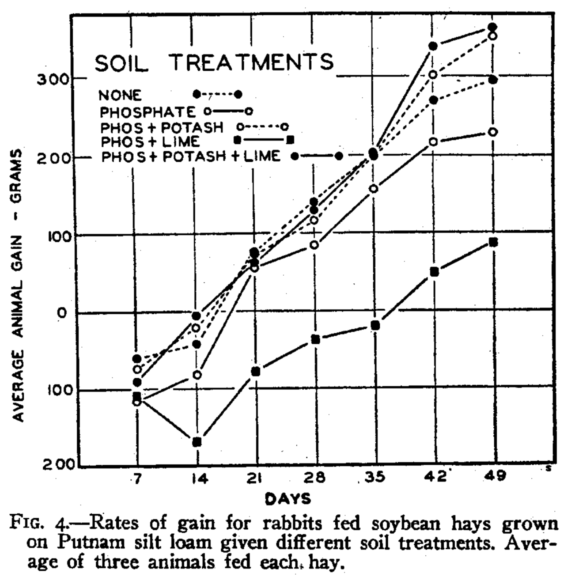

FIG. 4.—Rates of gain for rabbits fed soybean hays grown on Putnam silt loam given different soil treatments. Average of three animals fed each hay.

nitrogen, phosphorus, and calcium contents, the hay from the plot receiving lime and phosphate and showing extreme potash deficiency was inferior as feed. There was a marked difference in animal gain caused by this one hay as compared to all the others. The hays from plots which received phosphate and potash and lime, phosphate, and potash produced the most rapid and efficient gains. All of these differences cannot be attributed to the effect of potash alone on the soybean plants since the untreated hay and that which received only phosphate contained considerably more grass than did the others. It is significant, however, that even though the hay re ceiving lime and phosphate and showing the extrem potash deficiency was practically pure soybeans, it was definitely inferior to the other hay containing some less nutritious species. From a practical standpoint, yield would be a poor index of the monetary returns that would be obtained from soil treatments when the hay is marketed through animals.

These animal gains indicate that when the potash became a limiting element, the physiology of the soybean plants was altered. The low content of calcium in the potash-deficient beans, which was the lowest for all hays despite the fact the soil had been limed, might indicate the inability of the limed plants to take up certain nutrients. It is possible that the physiological processes within the plant were so altered by the deficiency of potassium that organic compounds essential in the growth and development of the young animals were not produced by the plant.[6] If they were, they were not digested, because the animals fed the hay from the soil receiving 0–20–10 made practically the same gain as those receiving the hay that received lime in addition. The latter might have been somewhat deficient in potassium (no fertilizer applied with soybeans) even though no plant deficiency symptoms were observed. If this was the case, then this deficiency would tend to reduce the hay quality but to a lesser degree than where the potash deficiency was evident. This would account for the small benefit from the limestone in contrast to the results with sheep on hays where no potash deficiency symptoms were observed. It is also probable that the calcium added to the soil by the fertilizer alone on the plot receiving only 0–20–10 was sufficient to supply the needs of the soybean (calcium content of this hay was highest of any fed) and these plants were growing on a more balanced supply of plant nutrients than where heavy applications of lime were made. If this is true, then it would appear that the application of calcium (or other elements) in excessive quantities without regard for the balance of other essential nutrients might produce crops of lower nutrient value than where no application of any kind was made.

[6]Unpublished data

BIOLOGICAL VALUE OF ALFALFA INFLUENCED BY SOIL TREATMENT

Alfalfa hay produced on Marshall silt loam, a soil of high fertility level, was fed to rabbits for two successive years. The hay yields were more than a ton and a half per acre on the untreated soil in 1940, the first year after seeding, and over 3 tons in 1941. There resulted a substantial yield response, nevertheless, to both lime and phosphorus. Analyses of the hays, whether from treated or untreated soil, show that these did not differ widely, except that the hay from the land receiving the heaviest application rate of phosphate had the highest concentration of phosphorus and of protein. This same hay also had the lowest calcium concentration, but there was little difference in percentage of calcium between any of the hays and the percentage figure for the no-treatment hay was almost as high as that of those hays receiving lime.

The first feeding trials with alfalfa were made in 1940. Nothing but hay, salt, and distilled water was fed to the animals at the outset of this first trial. Gains were so erratic that a supplement of corn was added to all pens. The hay from the untreated soil had the finest stems and the rabbits consumed it with the least waste. That from the plot with heavy phosphate was coarsest and much of it was refused. The gains were for only three animals on each hay in 1940 (Table 5) but serve, nevertheless, to point

TABLE 5.—*Gains by rabbits fed alfalfa hay produced under different soil treatments on Marshall silt loam.**

Soil treatments	1940 crops		1941 crops	
	Yield, lbs. per acre	Average gain, grams in 49 days†	Yield, lbs. per acre	Average gain, grams in 49 days‡
None	3,300	502	6,623	816
Limestone, 2 tons	4,170	692	8,470	608
Limestone, 2 tons 0–20–0, 400 lbs.§	4,220	636	7,820	619
Limestone, 2 tons 0–40–0, 500 lbs.**	6,290	571	9,120	732

*Alfalfa was seeded in the fall of 1939.
†Average of three animals.
‡Average of nine animals.
§Phosphate applied in alternate years.
**Phosphate (T.V.A.) applied only before seeding.

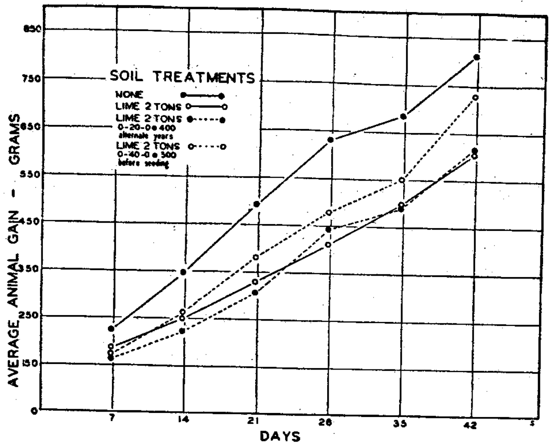

FIG. 5.—Rates of gain for rabbits fed alfalfa hays grown on Marshall silt loam given different soil treatments. Average of nine animals fed each hay.

to the low feeding value of the hay receiving the large amount of phosphate.

In the trial with the hay grown in 1941, a larger number of animals (nine on each treatment) was used. They were given a constant amount of corn with the hay. Animal gains were much more consistent, as shown in Fig. 5. The hay receiving heavy applications of phosphate produced better gains than did the hays with lighter applications of phosphorus. This is the reverse of the results obtained in 1940. However, in 1941 both of the hays receiving phosphate were inferior to that from untreated soil when considered in terms of the rate of animal gain. The hay from the untreated soil again had finer stems than the hays from land receiving phosphate.

It is possible that the plants in 1940 from land receiving 500 pounds of 40% phosphate had an abnormal metabolism because of the excess of available phosphorus in relation to other elements. This possibly produced a feed of lower biochemical value under the assay conditions followed than that from the plants receiving only 400 pounds of 20% phosphate. The hay grown on the land in 1941 where the lesser amount of phosphorus was put on 2 years preceding may not have obtained sufficient phosphorus for optimum nutrient value, while the hay grown in 1941 where the heavier amount of phosphorus was applied in the fall of 1939 was probably no longer suffering from an excessive amount of phosphorus which may have been fixed in the soil by 1941 and partially removed by the previous year's crop. Further, it seems possible that the addition of lime alone may have magnified the phosphorus, or other nutrient, shortage in the alfalfa and may have produced a feed of inferior quality as evidenced by the slower rate of rabbit gain for 1941. There is in these data an indication that soil treatments producing a maximum crop yield will not necessarily give highest feeding value if some essentials for crop growth are present in the treatment in excessive or deficient amounts.

BIOCHEMICAL VALUES OF GRAINS DIFFER

Soil treatments have much less effect on changing the mineral and protein content of grains than of forages (8). However, soil treatments have influenced the biochemical value of grains. Animals have shown a distinct preference for grains grown under balanced nutrient conditions. Feed efficiency, as measured by rabbit growth, has varied widely, depending on the soil treatment.

It has been difficult to obtain consistent differences through biological assays in grains produced on the same soil given different fertilizer treatments. The differences between grains are not as great as between forages and the experimental animal error is large in contrast to the possible differences between the grains. However, in some biological assays which are typical of a number that have been made, some of the soil treatments giving the highest bushel yields of grain have failed to give as satisfactory animal gains per unit of feed as have some of the soil treatments producing lower grain yields.

KAFIR QUALITY ALTERED BY SOIL TREATMENT

Kafir grain produced on Clarksville gravelly loam in the Missouri Ozarks was fed to rabbits. The data given in Table 6 are an average of two feeding trials of the grain produced in the same season. The figures for gain are the means for six animals. In each case the animals were given free access to the grain and were given a supplement of mature bluegrass hay of poor quality, salt and distilled water.

That the efficiency of the grain should be lower as there were increasing soil treatments and decidedly increasing yields per acre is quite the unexpected.

TABLE 6.—*Gains made by rabbits in 42 days on kafir grain produced in 1940 on Clarksville gravelly loam with different soil treatments.*

Soil treatment	Rabbit gain, grams	Grain yield, bu. per acre
None	789	11.5
Limestone, 2 tons 0–20–0, 150 lbs	741	20.0
Limestone, 2 tons 10–20–20, 150 lbs	654	28.0

The results of the second trial confirmed those of the first.

The soil where this kafir was grown is low in organic matter and will give for most crops increases in yield from nitrogen, phosphorus, and lime but not from potash until after being limed for some years. No minor element deficiency symptoms in plants have been observed.

The kafir used in this feeding trial followed a crop of sweet clover plowed under as a green manure. It is possible that the addition of the nitrogen in the fertilizer plus the amount added in the sweet clover may have supplied an excess of nitrogen in relation to other elements, resulting in changed composition of the grain that was reflected in poorer utilization from the land receiving the 10–20–20 fertilizer.

FEEDING EFFICIENCY OF CORN GRAIN ALTERED BY SOIL TREATMENTS

Four lots of corn produced on Putnam silt loam were fed to rabbits. The results obtained (Table 7), involving three animals on each grain, are typical of a number of trials with corn. They agree with the responses to the grain of kafir. In the first feeding it was difficult to keep the animals alive on the grain produced on the land where sweet clover had been turned under. The data are omitted. The grain was ground finely and kept before the animals at all times. In addition they were fed mature bluegrass hay.

The differences in nutritive value of these corn grains are evident. In these tests, as well as in other trials, difficulty was encountered in keeping the animals thrifty on grain produced on a soil high in nitrogen, especially when there were no additions of phosphorus or potash to the soil. From the poorer animal gains made on the grain following sweet clover, it appears that a level of active soil nitrogen too high in contrast to other elements, may produce grain of inferior feeding quality under the feeding plan followed. Grain produced under these high nitrogen conditions may be changed in its nutrient value sufficiently that it would need a different supplement for most efficient animal utilization.

TABLE 7.—*Gains made by rabbits in 84 days on corn from soils receiving different treatments.*

Soil treatment and cropping system	Rabbit gain, grams in 84 days	Yield, bu. per acre
3-year rotation corn, wheat, red clover; no treatment for 50 years	679	40.0
3-year rotation corn, wheat, red clover; manure, 6 tons per acre, 1888–28; since 1928, lime, 2 tons, 0–16–0, 200 lbs. on corn and wheat	655	58.5
Corn, wheat; manure, 8 tons on corn	836	40.0
Corn, wheat, sweet clover (under); 0–10–10, 400 lbs. on corn and wheat	640	65.8

ANIMAL PREFERENCE AND HARDNESS OF GRAIN INDICATE VARIABILITY OF GRAINS

A further suggestion of the difference in grain properties brought about by soil treatments is shown by animal preference trials and hardness tests. Corn was fed finely ground, cracked, and shelled under conditions giving the animals free choice. Usually, when the grains were fed whole or only cracked, the animals showed a preference for the softer corn. When they were finely ground, this difference in choice was largely eliminated and in some cases even reversed. The animal choice may differ if a protein supplement is given. In the preference trials with pigs, hardness seemed to be the primary factor in determining their choice. Soil treatments influenced the hardness of the corn grain as shown by a number of tests on corn grown under different soil fertility conditions. The results given in Table 8 are typical of the effect of different soil treatments on the relative hardness of the grain.

It is significant that manure increased the hardness of corn and that it was made still harder where sweet clover had been turned under. The addition of phosphorus and potash in all cases made the grain softer than it was on the comparison plot receiving no fertilizer. It appears that high fertility levels are conducive to the production of hard grain and that the grain is most resistant to breakage when grown on soil in which the nitrogen is particularly high in relation to the mineral elements. Regardless of animal choice or animal gain, it is not unreasonable to believe that corn grains of different hardness would contain different chemical compounds and that they

TABLE 8.—*Relative hardness of corn grains grown on soil receiving different treatments in a rotation of corn and wheat.*

Soil treatment	Relative hardness*
None	16.4
0–10–10, 400 lbs. on corn and wheat	15.8
Manure, 8 tons on corn	18.0
Manure, 8 tons on corn; 0–10–10, 400 lbs. on corn and wheat	17.0
Sweet clover under ahead of corn	20.0
Sweet clover under ahead of corn; 0–10–10, 400 lbs. on corn and wheat	15.5

*Determined by force required to push a 15° point, 2 mm in diameter, into the endosperm.

might have different biological values, or influences, on the animals consuming them.

In animal preference trials with oats, wheat, and forages, where hardness could not be a factor, there were distinct animal choices for grain produced under certain conditions. Usually the grains preferred were those produced on soils of balanced fertility treatments rather than on those where one nutrient element may have been excessively high or low. In many cases animals showed a distinct preference for the grain from soil receiving a moderate fertilizer treatment rather than from those treatments where some element was excessively high, although the soil was producing the highest yield.

DISCUSSION AND SUMMARY

Results of most agronomic researches are measured in terms of increased yields as bushels or tonnage of crops per acre. Biological assays now point out that these measures may not be accurate when agronomic products are to render their service in sustenance for animals. The values of improved varieties, of fertilizer treatments, of rotations, or soil management practices are based primarily on the number of bushels or pounds as increase over others that will be produced during a period of years by a new variety or practice. Other visible factors, such as quality, resistance to disease, and drought resistance, have been considered of secondary importance. Little or no attention has been given to chemical differences in the feeds or foods caused by different agronomic changes that could profoundly influence the animals and humans that consume these plant products.

The data of animal gains presented herewith demonstrate that forages and grains from the same soil given different treatments have varied widely in their capacities to produce animal gain. When the chemical composition of the feeds was changed by the different soil treatments, the animal response was not correlated closely enough to warrant the acceptance of the chemical analyses as an index of nutritive value. There is the strong suggestion that differences in feeds are brought about by soil treatments other than those commonly measured by standard methods of feed analyses. Only through assays with animals can these differences be determined.

On a soil low in lime and phosphorus, addition of phosphorus alone increased the efficiency of forage when fed to lambs. When limestone was added in addition to the phosphate, the nutritive value of the hays was further improved. Differences in the amount of improvement due to the different soil treatments varied from year to year. However, the relationship with reference to soil treatment held true in all trials. It appears that nutritional differences were greatest in seasons unfavorable for plant growth. The protein and mineral contents of these hays did not differ as widely as their efficiencies in producing animal gain. This would indicate that the soil treatments brought about other composition changes not commonly measured. The animals made more gain from each unit of grain consumed as a supplement to the phosphated hay than to the untreated hays, and those fed hay from the soil receiving lime and phosphate made more gain on the grain consumed than did those receiving hay from the land where only phosphate had been applied. All animals fed on the hay from the soil receiving both lime and phosphate had a higher oil and yolk content. There was a significant difference in the nitrogen, sulfur, and phosphorus contents of the wool. Further differences were obtained when the wool was scoured by means of alkali. In the alkali solution the wool from the lambs fed the phosphated hay decomposed while that from the soil receiving both lime and phosphate retained its luster and carded out to give customary fluffiness. It is significant that a simple treatment applied to the soil changed the composition of plants, altered the physiology of animals consuming the hay, and affected the appearance and properties of the wool. Since the wool qualities were changed by soil treatments, it is not unreasonable to assume that other body processes could have been altered so as to affect profoundly the metabolic and reproductive processes in the animals.

The addition of any plant nutrient to a soil without regard to the amount applied as related to the kind and supply of the nutrients in the soil may not always give feed of improved nutritive value. Evidence is presented where the addition of fertilizer or lime brought about an unbalanced nutrient condition in the soil which actually resulted in crops of lower efficiency than where no nutrient additions were made.

Timothy hay grown on soil having an excess of nitrogen, alfalfa with an excess of lime or phosphorus, and soybeans grown on a soil made deficient in potash through excessive applications of lime have all been lower in nutritive value than where no soil treatments were added. However, when these treatments were balanced by the addition of other plant nutrients, the quality of the feed was improved over that from the untreated soil. These results would indicate that tonnage yields are not a complete measure of the value of soil treatment and that maximum feeding value of forages can be obtained only when all soil nutrients are present in the proper ratios.

Since grains are only produced by crops after vegetative growth has been completed, the composition can not be altered as much by soil treatments as can that of forages (8). Nevertheless, the effect of soil treatments on the nutritive quality of grains was demonstrated. Trails with kafir and corn showed that the nutritive values of these grains produced on poor soils may be improved by addition of moderate amounts of the deficient elements. However, when some elements are added in excessive quantities, the nutritive value may be reduced below that of the untreated grains. Pressure tests have shown that the hardness of corn may be markedly influenced by soil treatment. It is not unreasonable to assume that grains varying in hardness will contain different organic compounds that may have a different effect on animal metabolism.

When animals were given a chance to show preference for grains from differently treated soil, wide variations in choice were found. In corn, hardness is one of the principal factors observed to influence choice. However, with such grains as oats and wheat the preference of animals for the grain from a particular soil treatment can only be attributed to chemical properties.

These results all point to differences in the value of plants as animal feed brought about by soil treatments, and that there are other differences in these plant products than are commonly determined by standard feed analyses. It has been well established that lignin accumulates within the plant when some growth factor, such as climate, or lack of fertility produces slow growth of plants. It is possible that this material could prevent the animal's digestive juices from attacking the cell contents and that the feed would pass through the animals undigested.

The functions of the different nutrients in plant metabolism are not well known. Where deficiencies exist, it is possible that some organic compounds, highly essential in animal growth, might not be synthesized within the plant and thus result in a feed of lower nutritive value. Since all results indicate that feeds produced under well-balanced fertility conditions are usually most effectively utilized by animals, it is not unreasonable to believe that an excess of some element might also prevent the synthesis of these compounds essential for animal growth, or that it might cause compounds to be formed that would be injurious.

All of these results point to the necessity of knowing the fertility properties of individual soils. If nutritious feeds are to be produced for animal and human consumption, then the soil on which they are grown must contain not only all the proper elements for plant growth, but these must be presented by the soil in proper ratios. It is only through proper and intelligent management that farm acres can be made to produce high yields of quality products. On soils of low productive capacity, the soil treatment can be expected to give benefits in addition to those of merely increasing the tonnage yields. The full value of these treatments, however, cannot be measured as yet without the use of animal assay.

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