Fertilizers for Legumes
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FERTILIZERS
FOR
LEGUMES

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SECTION OF SOIL SCIENCE

EAST LANSING

PERTINENT POINTS

1. Biennial and perennial legumes which fill the soil with roots as do alfalfa, sweet clover, red clover and alsike are soil-building because they add humus to the soil and take nitrogen from the air.

2. These crops are large users of potash, lime, and phosphoric acid and, hence, deplete the soil supply of these elements more rapidly than do other crops.

3. To be truly soil-building, these crops should be heavily fertilized, otherwise they may become soil-depleting.

4. On the heavy soils where legumes are seeded with small grain nurse crops, apply 300 to 400 pounds of 0-14-7 or 0-20-10 fertilizer at the time of seeding. When large quantities of manure have been recently applied, superphosphate alone may be sufficient.

5. On the better sandy loams where seedings may be also made with a nurse crop, apply 0-12-12 fertilizer at the same rate per acre. On the lighter soils where seedings should be made without a nurse crop, the recommended analyses are 0-12-12 and 0-9-27, the latter for the extremely light soils.

6. Good results may be expected from top-dressings of fertilizer on established stands of alfalfa. Such applications are recommended after the second harvest year. The same analyses as recommended above for seedings should be applied at the rate of 200 to 300 pounds per acre.

Fertilizers for Legumes

By R. L. COOK and C. E. MILLAR

LEGUMES HAVE BEEN RECOGNIZED as soil-building crops for centuries. Columella, a Roman agriculturist of the first century, advised farmers to raise lupines to enrich the soil. It was not until the 16th century, however, that the nodules on the roots of legumes were mentioned in the literature, and not until 1886 that the role of the bacteria within the nodules was discovered. Since that time, much research has been conducted at various institutions to determine how much nitrogen is taken from the air, by the billions of bacteria contained in the nodules (Fig. 1) on the roots, of an acre of some of the more common leguminous plants. The results show that the quantity varies greatly and depends on such factors as, the strain of bacteria, completeness of inoculation, kind of legume, and the lime content and fertility level of the soil. Broadly, it has been estimated that biennial or perennial legumes, with their nitrogen-fixing bacteria functioning normally, obtain two-thirds of their nitrogen from the air and one-third from the soil. A three-ton alfalfa crop, considering the roots and crowns as possibly an additional ton, would thus contain about 130 pounds of nitrogen taken from the air. This is as much nitrogen as is contained in 600 to 800 pounds of the commonly used nitrogen fertilizers. This large quantity of nitrogen which may be added to the soil if the crop is plowed under as a green manure, together with a huge mass of active organic matter makes such a legume a good soil-building crop insofar as nitrogen and humus are concerned.

Experiments, over a period of years in many locations, have shown that legumes have a beneficial effect on the crops which follow. On the Morrow plots at the Illinois station, for instance, corn yields have averaged 48 bushels for the period 1888 through 1938, where the crop was raised in rotation with oats and clover compared to 37 bushels, where it was raised in rotation with oats only.

In all types of agriculture, farmers recognize the value of leguminous crops in a soil improvement program. Many farmers would testify that without clover and alfalfa, they could not maintain the fertility of their soils and would soon be unable to raise sufficiently large crops on the land to provide a living for their families.

In recent years so much has been written concerning this role of legumes in soil improvement (soil maintenance is not sufficient), that

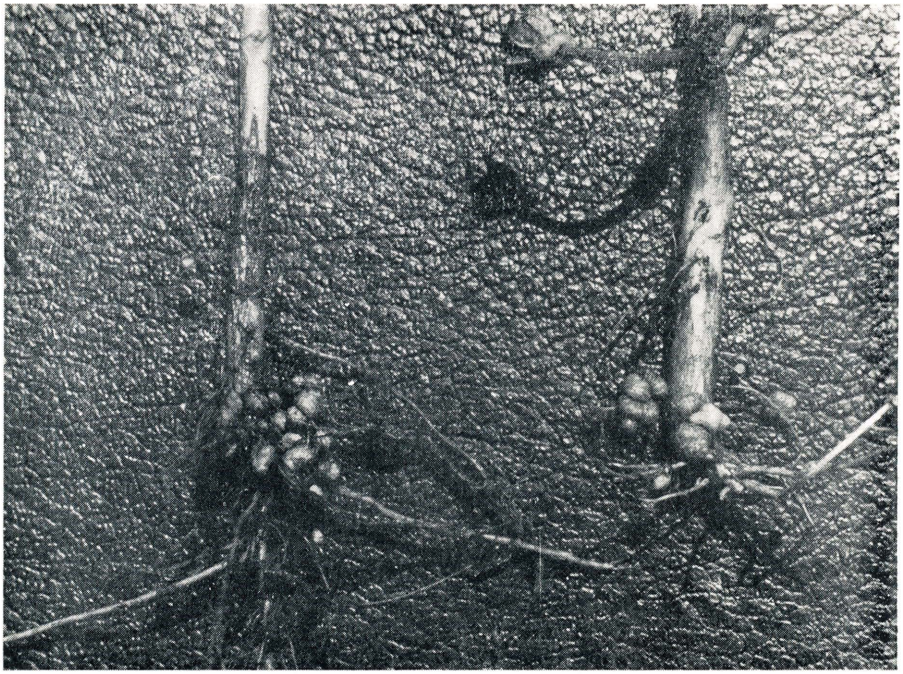

Fig. 1. These nodules furnish homes for the billions of bacteria which change atmospheric nitrogen to a form which becomes readily useful to plants.

many farmers have been led to rely TOO MUCH on the production of these crops to maintain soil fertility. During a recent Farmer's Week at Michigan State College, one farmer answered the question of another "Is fertilizer any good?" by the remark, "No, you might better buy clover seed". In reality, that is like telling a ragged barefoot boy who is about to buy a pair of shoes that he might better buy a new shirt or a pair of gloves. He needs several articles of clothing, but if his feet are bare the shoes should come first.

Where the stand is good and where a legume makes a good growth, it builds up the soil with respect to organic matter and nitrogen but adds nothing in the way of minerals. All the minerals in the crop come from the soil and, when the crop is plowed under, are returned to the soil. One reason why legumes make good feed is because they contain such a high percentage of minerals (Table 1). A ton of average alfalfa or clover hay contains about 10 pounds of phosphoric acid and 40 pounds of potash and enough calcium and magnesium to be equivalent to 90 pounds of pure limestone. There is twice as much potash and about 10 times as much calcium and magnesium as is contained in timothy hay. A three-ton crop of alfalfa hay would then remove from the soil as much phosphoric acid as would be contained in 150 pounds of 0-20-20

TABLE 1—*Comparison of the nutrient content of alfalfa with that of several other crops*

Crop	Yield	Pounds of plant nutrients			
		Phosphoric acid	Potash	Calcium	Magnesium
Corn	50 bushels plus stover and cobs	27.6	55.2	14.6	5.6
Oats	50 bushels plus straw	18.0	40.8	9.1	5.4
Wheat	25 bushels plus straw	16.6	21.0	5.8	3.5
Alfalfa	*3 tons*	*30.0*	*126.0*	*83.5*	*21.3*
Potatoes	150 bushels	13.5	45.0	1.8	2.7
Sugar beets	10 tons—roots only	13.4	56.2	....	....

fertilizer and as much potash as would be contained in 600 pounds of the same fertilizer.

On soils where the quantity of phosphoric acid and potash available for plant growth, in any one season, is less than the amount needed by the crop, these elements would become limiting factors and yields would be curtailed. Thus, the quantity of feed produced would be decreased, the mineral content of the feed would be lowered, and the value of the crop as a builder of organic matter would be lessened. Soil-building crops cannot "build" unless they are well-supplied with the mineral nutrients necessary for their growth.

Experimental results obtained during recent years show that fertilizers properly applied, and selected on the basis of the crop requirements and the nature of the soil type on which the crop is grown, may be expected to increase greatly the yield and soil-building value of many legumes. It is the purpose of this publication to give the results of a number of these experiments.

SYMPTOMS OF NUTRIENT DEFICIENCIES

For some time, livestock men have been able to tell from the behavior and appearance of their animals whether their diet was deficient in certain essential ingredients. Rickets, for instance, may be due to a deficiency of calcium. Likewise plants inadequately supplied with nutrients may fail to develop or they may develop abnormally. In many cases, the abnormality may be described as being characteristic of that caused by a deficiency of some certain nutrient.

A lack of available phosphorus in a soil under legumes results in slow growth and retarded seed production. There are no definite leaf symptoms which may be safely used for diagnostic purposes, but if growth is slow and both the soil and the green plant test low in phosphorus, it is likely that the supply of phosphorus is inadequate. This would be a safer assumption on heavy than on light soils.

Potash deficiency is often indicated by definite leaf symptoms. White beans and soybeans first show evidence of potash deficiency by a yellowing of the tips and edges of the leaflets (Figs. 2a and 2b). The yellowing then progresses toward the center and base of the leaflets, and the tips and edges gradually turn brown. The yellowing is usually accompanied by a crinkling of the leaflets. If such plants are treated with potash soon after the first symptoms appear, the new leaves come out and reach maturity without exhibiting the characteristic yellowing. The affected leaves, however, do not recover.

Potash deficiency in clover and alfalfa is also indicated by a yellowing of the leaf tips and edges but may be preceded by the appearance of small white dots near the edges of the leaves. The alfalfa leaf, shown in Fig. 3a, was taken from a plant grown in the greenhouse on Plainfield sand. It showed the typical potash deficiency symptoms: yellowing at the tips and along the edges of the leaflets with rows of white dots between the yellow and green areas. Plants grown on the same soil treated with potash were perfectly normal in color. The plant shown in Fig. 3b also showed typical symptoms of potash starvation. It was grown on Warsaw loam where potash was definitely a limiting factor.

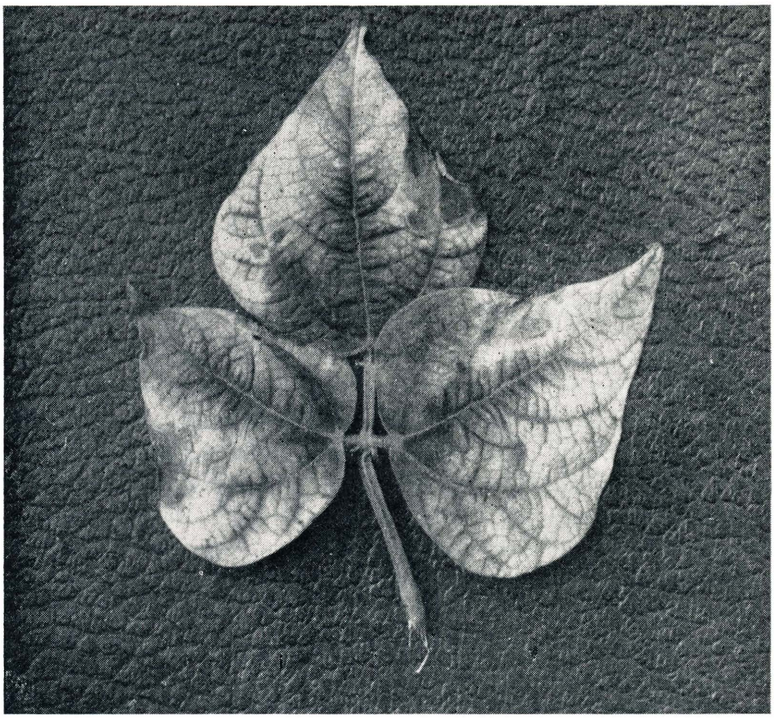

Fig. 2a. White bean leaf.

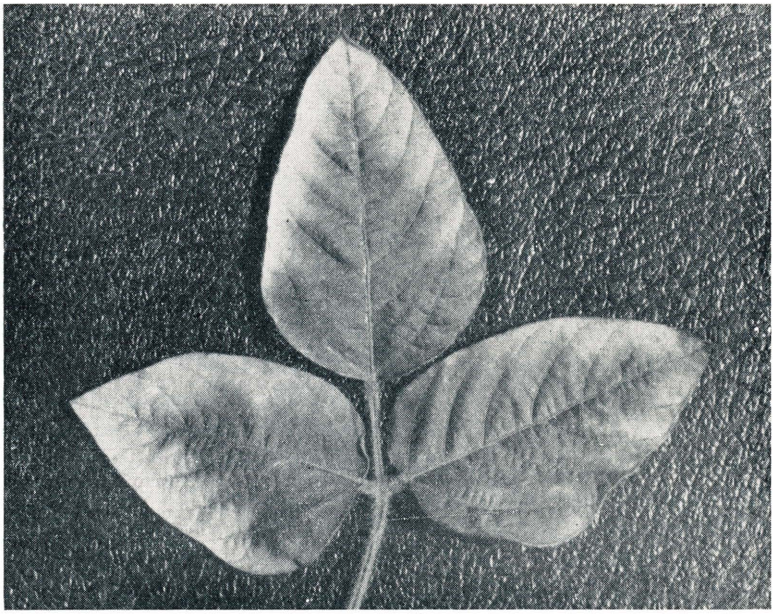

Fig. 2b. Soybean leaf.

White beans and soybeans first show evidence of potash deficiency by a yellowing of the tips and edges of the leaflets.

A chemical test of the green plant-tissue indicated a very low potash supply, and a soil test showed that the upper 8 inches contained only 0.150 milli-equivalent of exchangeable potassium per 100 grams dry soil as compared with 0.371 milli-equivalent in the surface layer of another field on the same farm where alfalfa showed no deficiency symptoms.

Soils deficient in boron for some crops are rather widespread in Michigan. When boron is lacking in the soil, or is not available, the leaves of alfalfa and the clovers turn a red or bronze color on the under side and near the tips. From there the color spreads to the entire leaf, which finally turns yellow and dies. At times and on some fields, the yellowing is more noticeable than the reddening. The younger portions of the plant are first affected. The internodes of the new growth are shortened. This gives a characteristic rosetting along with the abnormal color. Work is in progress in Michigan to determine the advisability of including borax in the fertilizer for alfalfa and clovers.

EXPERIMENTAL

Fertilizer usage for legumes varies with the different crops and with different soils. Heavy soils usually need some potash but are chiefly lacking in phosphoric acid. Sandy soils may also be deficient in phosphoric acid, but the first limiting factor is very likely to be potash. Variations in methods of management also make necessary differences in fertilizer usage on the two classes of soil.

SEEDINGS ON HEAVY SOIL

ALFALFA

On heavy soils, alfalfa and the clovers are usually seeded with a small grain companion crop. This means that the fertilizer applied for the legume at planting time must be applied also for the small grain. In other words, both crops must be supplied in one fertilizer application.

Many good stands of alfalfa fail to come through the first winter. This is generally due to lack of vigor as a result of competition from the companion crop or to a shortage of nutrients in the soil. Fertilizers greatly stimulate the early growth of this crop. This was markedly demonstrated on a Miami silt loam in Tuscola County. Barley was

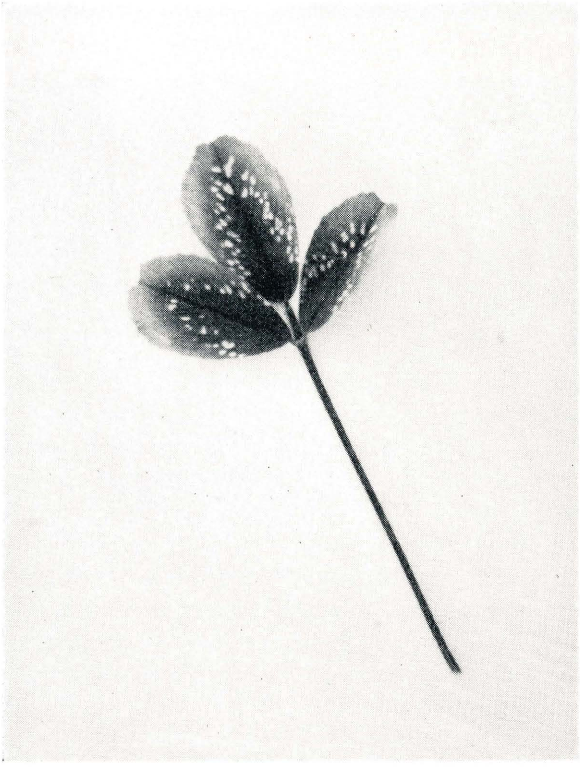

Fig. 3a. Leaf from an alfalfa plant grown in the greenhouse on Plainfield sand deficient in potash.

Fig. 3b. A portion of an alfalfa plant grown in the field on Warsaw loam where potash was the limiting factor in plant growth.

fertilized in the row with 250 pounds of 4-16-4 fertilizer. Alfalfa seed was scattered broadcast ahead of the drill. The plants growing directly in the barley rows, 50 days after planting, were several times larger than the plants growing between the barley rows. The difference in growth is illustrated in Fig. 4. It is easy to imagine that the larger plants were more vigorous in the fall and were more likely to survive the winter than were the small plants. The plots which received the 4-16-4, and from which the plants shown in Fig. 4 came, averaged 4,592 pounds of dry hay per acre as compared to a yield of 2,768 pounds per acre on unfertilized land.

A good illustration of the effect of fertilizers on the stand of alfalfa was furnished by an experiment on Wisner silt loam. The picture shown in Fig. 5 was taken where 500 pounds of 4-16-8 fertilizer applied for the previous wheat crop caused an increase in yield of 3,390 pounds of dry alfalfa per acre. So large an increase in yield would not have oc-

Fig. 4. The effect of fertilizer on early growth of alfalfa. The plants in the large bundle were taken directly from barley rows fertilized with 4-16-4. The plants in the small bundle were taken from between the barley rows. The difference in size was due to delay in reaching the fertilizer which had been placed in the row at planting time, 50 days earlier.

curred, if there had been a good stand of alfalfa on the unfertilized plot. Increases in yield, however, do not always come as a result of improved stand but often as a result of a more luxuriant growth. This was true on the Ferden farm (Fig. 6), where alfalfa was seeded each spring as a companion crop with wheat. As indicated in Table 2, the greater increase in yield was due to the phosphate applied, but a worth-

TABLE 2—*The effect of fertilizers applied for wheat on the yield of the following alfalfa crop on Brookston silt loam*

Treatment	Yield per acre Average for 6 fields
0-16- 0—250 pounds	3,939 pounds
0-16-10—250 pounds	4,227 pounds
0-16- 0—500 pounds	4,926 pounds
0-16-10—500 pounds	5,502 pounds
None	3,032 pounds

while increase came also as a result of including potash in the fertilizer. As an average for six crops, 500 pounds of 0-16-10 fertilizer caused an increase in yield of 2,470 pounds of alfalfa, surely a very profitable investment, even if all of the fertilizer cost is charged against the alfalfa.

In another field on the farm in Tuscola County, oats planted in 1935

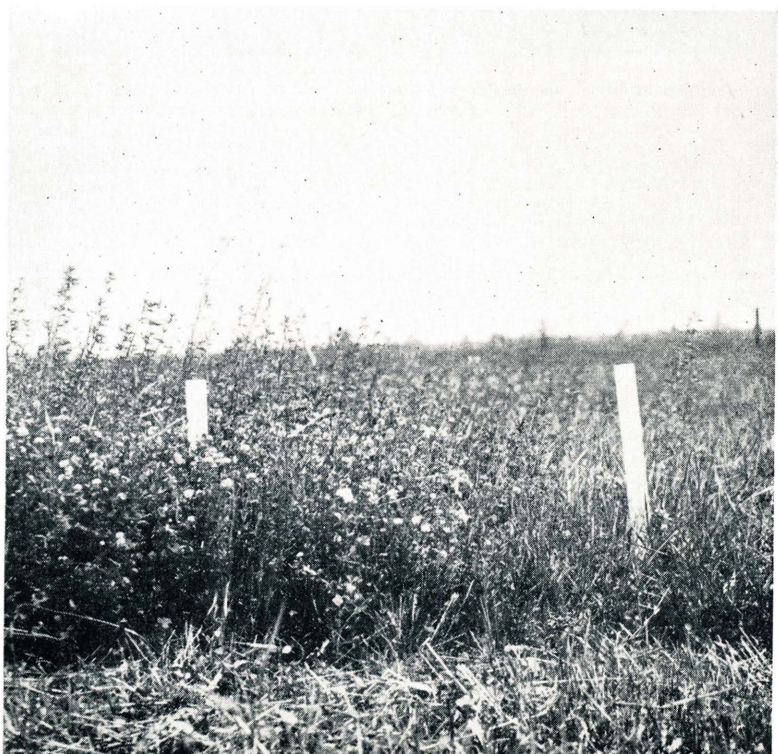

Fig. 5. Fertilizers result in better stands of alfalfa. (Left) 500 pounds of 4-16-8 applied for the previous wheat crop; (right) no fertilizer. Very little alfalfa may be seen on the unfertilized plot.

Fig. 6. Fertilizer applied for wheat resulted in a more luxuriant growth of alfalfa on this Brookston silt loam soil. (Left) 500 pounds fertilizer; (right) no fertilizer.

received 4-16-8 fertilizer at the rate of 250 pounds per acre. A strip consisting of two drill widths was not fertilized and had not been fertilized since 1930. Alfalfa was seeded with the oats. In 1937, the second year for the alfalfa, the yield of dry hay from the unfertilized strip was 2,352 pounds per acre as compared with a yield of 4,720 pounds from the adjoining area treated with 4-16-8 fertilizer in 1935. Piles of hay from 2 square rod areas on these plots are shown in Fig. 7.

CLOVER

The growth of June, or red clover is also greatly stimulated by applications of commercial fertilizer. On the Tuscola farm already mentioned, an application of 250 pounds of 4-16-8 per acre for oats in 1930 increased the yield of clover in 1931 from 2,045 pounds to 3,012 pounds per acre. In another field on the same farm a 4-16-4 fertilizer increased the yield from 3,885 to 5,802 pounds per acre. The soil in the latter field was Conover silt loam. Fertilizer not only increased the yield of this clover but caused it to mature earlier. The picture shown in Fig. 8 was taken on June 12, almost a month before the harvest was made. On the date of the photograph the fertilized clover was fully blossomed, but that which was unfertilized had not started to blossom. If the clover had been harvested earlier (when it would make good quality hay), the difference in yield might have been even greater.

SWEET CLOVER

There is no better place to apply fertilizer in the rotation on heavy soils than for a sweet clover green manure crop. It is essential that sweet clover be plowed under early if the following crop is to do its best. Also, a good growth must be obtained if the crop is to build up the soil appreciably. The sweet clover being plowed under in Fig. 9 had made 32.9 percent more growth where it was fertilized with 250 pounds of 4-16-4 fertilizer (applied for the preceding wheat crop) than where it was not fertilized. Thus, by the time it was necessary to plow for beans, more organic matter was available to plow under and, judging from the chemical analyses made on other crops, more minerals were contained in the organic matter, to be made available to the following bean crop.

In 1940 the yield of alfalfa on the John Dilman farm near Cass City was increased from 1,960 to 3,300 pounds of dry hay per acre by an application of stable manure. The manure was plowed under for oats which served as a companion crop for the alfalfa. A further increase in yield of hay, to 4,220 pounds per acre, was obtained where the oats received superphosphate in addition to the manure. The bet-

Fig. 7. The 1937 alfalfa harvest from a field which was seeded with oats in 1935. (Left) from a plot which received 250 pounds of 4-16-8 at the time the oats were planted; (right) from an unfertilized strip. The piles were from 2 square rod areas.

Fig. 8. Fertilizers increase the yield and hasten the maturity of June clover. (Left) no fertilizer; (right) 250 pounds of 4-16-4 applied for the previous oats crop.

Fig. 9. Sweet clover is especially suitable as a green manure crop on heavy soils. Plenty of plant food makes the crop grow rapidly so that it can be plowed under early, thus facilitating seedbed preparation.

ter stand and increased growth which resulted from the manure and phosphate are shown in Fig. 10.

SEEDINGS ON SANDY SOILS

ALFALFA

On the better sandy loams well supplied with organic matter and lime, it is possible to seed alfalfa and clover with a small grain nurse crop as is customary on heavy soils. Where this practice is followed, however, it is advisable to make a light seeding of the grain and to use a fertilizer which will favor the alfalfa, unless, of course, one is more interested in the grain. For instance, on a limed Berrien sand in Lenawee County, alfalfa was seeded in the early spring in wheat. Where the wheat had received 250 pounds of 0-16-8 fertilizer, the yield increase caused by the fertilizer was 5.5 bushels per acre, and the alfalfa yielded 2,391 pounds more than where fertilizer was not applied. In contrast to these figures, the yield increase on the plot which received 500 pounds of 4-16-8 was 23.0 bushels of wheat but only 1,217 pounds of alfalfa. The smaller increase in the case of alfalfa was because of the poor stand resulting from competition by the very heavy wheat crop. Apparently the soil needed nitrogen for wheat, but the heavy straw growth was fatal to the alfalfa. As the alfalfa was left only one year, the farmer made more money by the larger wheat crop, but if alfalfa had been left for 2 or 3 years the advantage of using a fertilizer

Fig. 10. Alfalfa must have plenty of plant food. (Left) no fertilizer; (right) manure and superphosphate. Miami silt loam soil.

favorable to the alfalfa would have been considerable. It is better to seed alfalfa alone on light sandy soils, such as the Berrien, because better stands are obtained and more hay is produced in 2 years than would be produced in 3 years from a poor stand obtained by seeding in a companion crop.

On the Faunce farm in Monroe County, also on a Berrien sand, fertilizer experiments with alfalfa were conducted over a period of 4 years. An 0-16-16 fertilizer was applied at the rate of 200 pounds per acre at seeding time in 1934 on field 1 and in 1936 on field 2. The effect of the fertilizer on the yield of alfalfa is shown by the data in Table 3.

TABLE 3—*The effect of phosphate and potash fertilizers on the yields of alfalfa on Berrien sand*

Treatment*	Pounds of dry hay per acre							Average increase per year
	Field 1			Field 2				
	1935		1936	1937		1938		
Cuttings..............	1st	2nd	1st	1st	2nd	1st	2nd	
None..................	3,267	1,983	1,688	1,305	1,205	2,058	1,018	
0-16-16—200 pounds...	3,884	2,454	2,120	2,149	1,940	2,108	1,334	868

*Fertilizer applied on field 1 in 1934 and on field 2 in 1936.

The increase in yield was rather consistent and averaged 868 pounds of dry hay per acre per year, a very profitable increase, as only 100 pounds of fertilizer may be charged against the yearly increase in yield.

On a limed Fox sandy loam in Kalamazoo County, alfalfa in 1925 yielded 768 pounds of dry hay per acre. Where 200 pounds of 16-percent superphosphate and 100 pounds of muriate of potash were applied the yield was increased to 1,392 pounds. During the years 1926 and 1927 the land was occupied by crops of corn and oats, after which it was again seeded to alfalfa in 1928. Again, the phosphate and potash fertilizers were applied and the yield of dry hay was increased from an average of 733 pounds on the unfertilized plots to an average of 1,600 pounds per acre on the fertilized plots. The yield records obtained in both years 1925 and 1929 are for only one cutting, after which the alfalfa was plowed under as a soil-building crop. Had the crop been left for two or three years the total increase in hay yield resulting from the fertilizer would have made the application highly profitable.

SWEET CLOVER

Yields of this crop also may be markedly increased by applications of phosphate and potash at seeding time. This is very important when sweet clover is being raised for pasture or as a green manure crop. An application of 200 pounds of 16 percent superphosphate and 100 pounds of muriate of potash increased the yield of sweet clover on Fox sandy loam in Kalamazoo County in 1925 from 496 to 1,324 pounds per acre, and another application on the same land in 1929 increased the yield from 1,400 to 2,680 pounds of dry hay per acre.

Only potash may be needed on some sandy soils. The data presented in Table 4 show that this was true on a Fox sandy loam in Cass County. Yields of sweet clover obtained in 1925 and in 1928, after applications of phosphate and potash fertilizer, separately and in combination, showed that only the potash fertilizer caused an appreciable increase in yield.

TABLE 4—*The effect of phosphate and potash fertilizers on the yields of sweet clover on Fox sandy loam*

Treatment*	Pounds of dry hay per acre	
	1925	1928
None	1,635	1,777
P 200 K 100	2,660	3,627
P 200	1,813	1,860
K 100	3,413	4,160

*Fertilizers applied for each crop.
P = 0-16-0; K = Muriate of potash 50 percent K_2O, rate as pounds per acre.

The plots treated with superphosphate yielded but slightly more than did those which did not receive fertilizer, while those which received potash alone yielded more than those which received both phosphate and potash.

SOYBEANS

In Michigan, soybeans are rather extensively grown as an emergency hay crop; in addition, their production for seed has increased during recent years. On an experimental field in Kalamazoo County where the soil is Fox sandy loam, soybeans were harvested for hay on two fields in 1924 and 1925 and again from the same fields in 1928 and 1929. The soil had been adequately limed, and fertilizers were applied in 1924 and again in 1928. Both fields were planted to corn in 1926 and to oats in 1927. The data obtained during the four soybean years are reported in Table 5. It is at once apparent that all fertilizer mixtures markedly increased the yield of hay. In only one case, in 1929, did a fertilized plot yield less than the unfertilized plot, and the low yields obtained that year bear evidence that the season was not favorable for this crop. In general, it would seem from the data that the mixture of 200 pounds of 16-percent superphosphate and 100 pounds of muriate of potash was the most desirable one to apply. The addition of an extra 100 pounds of muriate of potash caused a further increase in

TABLE 5—*The effect of phosphate and potash on the yields of soybean hay on Fox sandy loam soil*

Treatment*	Pounds of dry hay per acre			
	1924	1925	1928	1929
FIELD 1				
None	1,470	855	927	607
P 200 K 100	2,782	2,291	2,996	1,010
P 200 K 200	2,714	2,291	3,424	999
P 300 K 100	2,171	2,618	2,140	590
FIELD 2				
None	1,134	1,733	1,213	548
P 200 K 100	2,102	2,291	2,782	881
P 200 K 200	2,036	2,946	2,782	1,130
P 300 K 100	1,696	2,952	1,926	835

*P = 0-16-0; K = Muriate of potash 50 percent K_2O, rate as pounds per acre.
Fertilizers were applied, as indicated, in 1924 and in 1928.
The plots were planted to corn in 1926 and oats in 1927.

Fig. 11. Fertilizers in contact with soybean seed may prevent germination. This is what happened in the two center rows on this Conover loam where the fertilizer was 4-16-8 applied at the rate of 300 pounds per acre directly with the seed. Good stands resulted on the other rows where the fertilizer was placed in a band at the side of the seed.

yield on field 1 in 1928 and on field 2 in 1925 and 1929. The additional 100 pounds of superphosphate caused an increase in yield on both fields in 1925.

It is important that fertilizers for soybeans be properly applied. Any appreciable quantity of fertilizer placed in direct contact with the seed is likely to be detrimental to germination. In Fig. 11 are shown two rows in an experimental field on Conover loam where 4-16-8 fertilizer was applied at the rate of 300 pounds per acre in direct contact with the seed. Only a few plants emerged. In the adjoining rows, where the same fertilizer was applied in a band 1¾ inches below and 1 inch to the side of the seed, a good stand was obtained. In some sections machines are available which will plant soybeans and place the fertilizer in this manner. Where such machines are not available, it is better to apply the fertilizer broadcast or apply none at all than to place it in contact with the seed.

SUMMARY AND CONCLUSIONS

From the data here presented and from additional data, it may be concluded that leguminous crops, especially such hay crops as alfalfa and clover, are very responsive to phosphate and potash fertilizers, and that maximum yields of these crops are unlikely on most soils if such fertilizers are not applied. Fertilizers should always be applied for new seedings of alfalfa and clover. On the heavy soils the fertilizer should contain more phosphate than potash, and analyses such as 0-14-7 and 0-20-10 are often recommended. On sandy soils the proportion of potash should be increased. Sandy loams usually require an analysis, like 0-12-12, and on real light sandy soils an 0-9-27 may be used.

On heavier soils where the sod-forming legumes are seeded with small grain nurse crops, the nutrient requirements of the grain crops should also be considered. Under such circumstances, the farmer usually is more interested in a good legume seeding than in obtaining maximum yields of grain. In that case the fertilizer most favorable for the legume should be applied. Certainly, one should never plant a small grain which is to serve as a legume nurse crop without a liberal application of phosphate and potash fertilizer.

TOPDRESSING OLD STANDS OF ALFALFA

Alfalfa, fortunately, does well on hilly land. One cannot, then, make better use of the kind of land shown in Figs. 12 and 13 than to grow alfalfa or an alfalfa grass mixture on it, continuously, or as much of the time as is possible. Where this plan is followed, however, the soil may eventually become so depleted of available phosphorus and potash that the alfalfa will not produce normally. Many experiments on a variety of soils have shown that it pays to apply phosphoric acid and potash in the form of commercial fertilizer on fields of alfalfa

Fig. 12. Alfalfa does well on hilly land. The crop also helps prevent erosion on such land.

Fig. 13. On this Miami silt loam field, more hilly than it looks, continuous alfalfa for 10 years has only been interrupted by two barley crops as nurse crops for reseeding. Yields have been maintained at a high level by liberal use of commercial fertilizer.

where the stand is more than 2 years old. This results in a greater yield of hay and in the production of more soil organic matter. When the field is later broken up and planted to corn or beans, this organic matter, higher in phosphate and potash as a result of the fertilizer, becomes a source of these plant foods in a form easily available to the growing crop. Thus fertilizers applied for legumes play a double role, that of furnishing nutrients for the legumes themselves, and in building up the soil for the crops to follow.

EXPERIMENTS ON HEAVY SOILS

Strangely enough the greatest benefits from the top-dressing of alfalfa have occurred on the more productive heavy soils. In an experiment on the Lincoln Horst farm near Akron, Michigan, where the soil is Brookston silt loam, fertilizers were applied on April 23 to a field of alfalfa which had been harvested two years for hay. The field had been lightly covered with manure during the previous winter. The unfertilized alfalfa averaged 2,248 pounds per acre while that which received 300 pounds of 0-16-0 averaged 3,680 pounds per acre for the two cuttings. With potash applied to make an 0-16-8 fertilizer, the yield was further increased to 4,000 pounds per acre. The increase in growth

TABLE 6—*The effect of fertilizer on the yield of an old stand of alfalfa on Brookston silt loam*

Treatment	Pounds of dry hay per acre			
	1st cutting	2nd cutting	Total	Increase due to fertilizer
FIELD 1				
None	3,597	1,451	5,048	....
0-20- 0—500 pounds	3,800	2,190	5,990	942
0-20-20—500 pounds	4,250	2,385	6,635	1,587
FIELD 2				
None	3,307	1,922	5,229	....
0-20- 0—500 pounds	4,545	2,259	6,804	1,575
0-20-20—500 pounds	4,641	2,143	6,784	1,555

was so marked on this field that it was possible at harvest time to locate the plot boundaries without resorting to measurements.

On a neighboring farm, where the soil type is similar, two fertilizers, 0-20-0 and 0-20-20, were applied on two fields, rather high in fertility and where manure had been applied in the rotation. The yields obtained in this experiment are reported in Table 6. The increases are not large but are probably significant. One field needed both phosphate and potash, while the other needed only phosphate. The potash applied on field 2 did not increase the yield of hay, but it probably increased the potash content of the hay to make it worth more as feed and as

TABLE 7—*The effect of fertilizers on the yield of an old stand of alfalfa on Miami silt loam*

Treatment	Pounds of dry hay per acre*			
	Field 1		Field 2	
	Total yield	Increase due to fertilizer	Total yield	Increase due to fertilizer
0-20- 0—500 pounds	3,367	757	4,050	158
None	2,610	....	3,892	....
0-20-20—500 pounds	3,768	1,341	4,785	828
None	2,427	....	3,957	....

*Yields are averages of three plots on field 1 and four plots on field 2.

green manure. Stable manure produced from such hay would also contain more potash and thus be worth more as a fertilizer.

A similar experiment was conducted on two Miami silt loam fields where manure had not been applied in the rotation. Yield records were kept on only the first cutting after the fertilizer was applied. According to the data presented in Table 7 phosphate and potash fertilizers were needed on both fields. The increase in yield as a result of the 0-20-20 fertilizer on field 1 amounted to 1,341 pounds for only one cutting. Experiments performed on other farms show that benefits from fertilizers on alfalfa may be expected to last at least two years. Even though the second cutting and second year increases may have been smaller than the one recorded, the total increase was still highly profitable. Field 2, apparently, needed potash more than it did phosphate, the increase from the 0-20-20 being 828 pounds as compared with 158 from the 0-20-0. This is an interesting observation since the field had

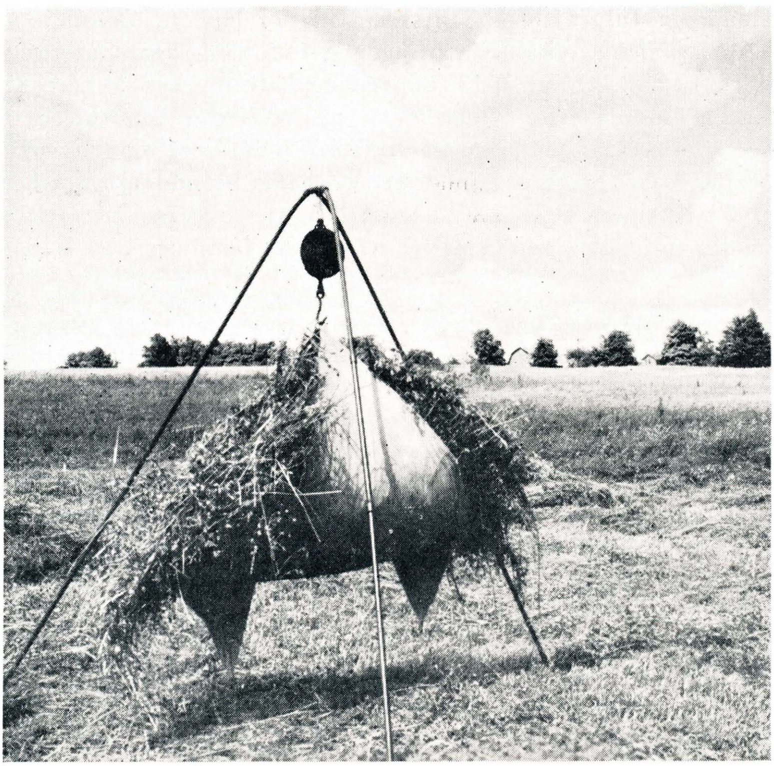

Fig. 14. Weighing alfalfa on an experimental field. This fertilized plot yielded 1,200 pounds more dry hay per acre than did the adjoining unfertilized plot.

not been manured as had the Brookston field where potash did not increase the yield.

On another Miami silt loam field, shown in Fig. 14, 400 pounds of 0-16-8 fertilizer, applied with a grain drill in April, increased the yield of that year's hay by 1,200 pounds, surely a profitable investment when it is remembered that benefits from fertilizer on alfalfa commonly last two or three years.

In an experiment conducted in 1942 on Wisner loam, an application of 200 pounds of 0-16-8 made with a grain drill on April 28 increased the yield of alfalfa hay from 1,706 to 2,187 pounds per acre at the first cutting and, from 1,790 to 2,363 pounds at the second cutting, a total increase in yield of 1,054 pounds of hay for 200 pounds of fertilizer. No doubt, there was a further increase in yield on this field in 1943.

Farmers not in the habit of applying fertilizer on old stands of alfalfa may wonder as to the best time of year for such applications. The data at hand show that on the heavy soils it makes little difference as to the time when the fertilizer is applied. Applications on three soils were made in July after the first cutting of hay, in October, and in early April. Yields obtained during the following years are recorded in Tables 8 to 10. On all fields superphosphate markedly increased the yields. The increases in yield resulting from the application of 300 pounds of 0-16-0 ranged from 987 to 2,426 pounds of dry hay per acre. Further increases were obtained on two fields by adding potash to the fertilizer. Nitrogen was not beneficial to the alfalfa. In fact, on all three fields the yields were smaller where the fertilizer was 4-16-8 than

TABLE 8—*The effect of fertilizers, applied at various dates, on the yield of an old stand of alfalfa on Gilford loam*

Treatment*	Pounds of dry hay per acre				
	1931	1932	Total	Average for fertilizer disregarding date	Average for date disregarding fertilizer
None	2,160	2,482	4,642	4,642	....
0-16-0 July, 1930	2,681	3,568	6,249	7,068	7,000
0-16-0 Oct., 1930	3,346	4,176	7,522		7,226
0-16-0 Apr., 1931	3,322	4,112	7,434		7,160
0-16-8 July, 1930	3,497	4,176	7,673	7,645	
0-16-8 Oct., 1930	3,509	4,240	7,749		
0-16-8 Apr., 1931	3,497	4,016	7,513		
4-16-8 July, 1930	3,206	3,872	7,078	6,673	
4-16-8 Oct., 1930	2,600	3,808	6,408		
4-16-8 Apr., 1931	2,774	3,760	6,534		

*The no treatment yields are averages from 9 plots. The other yields are averages from duplicate plots. Fertilizers were applied at the rate of 300 pounds per acre.

Table 9—*The effect of fertilizer applied at various dates on the yield of an old stand of alfalfa on Miami silt loam soil*

Treatment*	Pounds of dry hay per acre				
	1931	1932	Total	Average for fertilizer disregarding date	Average for date disregarding fertilizer
None	2,042	2,835	4,877	4,877	....
0-16-0 July, 1930	2,841	3,296	6,137		6,043
0-16-0 Oct., 1930	2,484	3,632	6,116	5,864	6,157
0-16-0 Apr., 1931	2,348	2,992	5,340		5,902
0-16-8 July, 1930	2,925	4,064	6,989		
0-16-8 Oct., 1930	2,412	3,488	5,900	6,256	
0-16-8 Apr., 1931	2,775	3,104	5,879		
4-16-8 July, 1930	1,835	3,168	5,003		
4-16-8 Oct., 1930	2,520	3,936	6,456	5,982	
4-16-8 Apr., 1931	3,160	3,328	6,488		

*The no treatment yields are averages from 12 plots. The other yields are averages from duplicate plots. Fertilizers were applied at the rate of 300 pounds per acre.

where the nitrogen was omitted. This is especially interesting when it is remembered that alfalfa is a legume which, through the aid of nitrogen fixing bacteria, is able to make use of atmospheric nitrogen. Failure to obtain increased yields of alfalfa as a result of the application of nitrogen as a fertilizer on sandy soils was reported by Grantham and Millar.*

Table 10—*The effect of fertilizers, applied at various dates, on the yield of an old stand of alfalfa on Brookston silt loam*

Treatment*	Pounds of dry hay per acre		
	1931	Average for fertilizer, disregarding date	Average for date, disregarding fertilizer
None	4,682	4,682	....
0-16-0 July, 1930	5,720		5,614
0-16-0 Oct., 1930	5,675	5,831	5,725
0-16-0 Apr., 1931	6,097		6,037
0-16-8 July, 1930	5,660		
0-16-8 Oct., 1930	5,403	5,846	
0-16-8 Apr., 1931	6,474		
4-16-8 July, 1930	5,463		
4-16-8 Oct., 1930	6,097	5,700	
4-16-8 Apr., 1931	5,539		

*The no treatment yield is an average of those from 9 plots. The other yields are averages from duplicate plots. Fertilizers were applied at the rate of 300 pounds per acre.

*Mich. Agr. Exp. Sta. Spec. Bul. 248, p. 29.

To determine the influence of date of fertilizer application the yields from plots fertilized on the same dates were averaged, irrespective of the analyses of the fertilizers. The results from this study are given in the last column of each of Tables 8 to 10. On the Gilford loam and the Miami silt loam the greatest average yields for all fertilizers were obtained from plots fertilized in October. On the Brookston silt loam the April application resulted in the largest average yield. The differences, however, are not markedly in favor of any particular date. One must conclude from the data, therefore, that if a farmer discovers his alfalfa needs fertilizer he should make the application as soon as it is convenient rather than wait for any certain time of year.

EXPERIMENTS ON SANDY SOILS

Over a period of years many experiments have been conducted on Fox sandy loam, a very extensive soil type in southwestern Michigan. The results obtained on three fields are reported in Table 11. In all cases fertilizers caused marked increases in yield. On field 3 an application of 400 pounds of 0-10-25 fertilizer more than doubled the yield of alfalfa from three cuttings.

On two other Fox sandy loam fields experiments were laid out to study the effect of fertilizer analysis and time of application, much in the same manner as already reported for heavy soils except that applications were made only on two dates, early spring, and in summer after the first cutting of hay was removed. According to the data reported in Table 12, potash fertilizer increased the yields in all cases. Superphosphate caused an increase in yield on one field but not on the other. The greatest increases in yield, however, resulted on both fields from the application of both phosphate and potash.

In general, the summer applications resulted in greater increases in yield than did the early spring applications. In the last column of

TABLE 11—*The effect of fertilizer on the yield of an old stand of alfalfa on Fox sandy loam*

Treatment	Pounds of dry hay per acre*		
	Field 1	Field 2	Field 3
None	3,038	1,600	3,432
0-20- 0—250 pounds	4,406	3,013	....
0-20-20—250 pounds	4,712	3,989	....
0-10-25—400 pounds	....	....	6,963

*One cutting from fields 1 and 2. Three cuttings from field 3

TABLE 12—*The effect of fertilizers applied in spring and summer on the yield of an old stand of alfalfa on Fox sandy loam*

Treatment	Total yield	Average yield per cutting	Increase in yield per cutting
	pounds	pounds	pounds
FIELD 1—Fertilizers applied in spring, 4 cuttings			
None	7,384	1,846	....
0-20- 0—250 pounds	8,078	2,020	174
0- 0-20—250 pounds	8,910	2,228	382
0-20-20—250 pounds	9,129	2,282	476
0-20-40—250 pounds	10,266	2,567	721
Fertilizers applied in summer, 3 cuttings			
None	5,448	1,816	....
0-20- 0—250 pounds	6,875	2,292	476
0- 0-20—250 pounds	6,693	2,231	415
0-20-20—250 pounds	7,556	2,519	703
0-20-40—250 pounds	7,385	2,462	646
FIELD 2—Fertilizers applied in spring, 4 cuttings			
None	11,601	2,900	....
0-20- 0—250 pounds	11,721	2,930	30
0- 0-20—250 pounds	12,607	3,152	252
0-20-20—250 pounds	12,806	3,202	302
0-20-40—250 pounds	12,567	3,142	242
Fertilizers applied in summer, 3 cuttings			
None	7,978	2,659	....
0-20- 0—250 pounds	7,952	2,651	—8
0- 0-20—250 pounds	9,180	3,060	401
0-20-20—250 pounds	10,060	3,353	694
0-20-40—250 pounds	11,148	3,716	1,057

Table 11 is recorded the increase in yield caused by each fertilizer for each cutting. From field 1 the sum of the increases caused by spring applications amounted to 1,853 pounds of hay as compared with 2,440 pounds increase in yield from plots treated after the first cutting. Considering field 2, the difference caused by time of application was still greater, 826 pounds total increase in yield caused by all fertilizers applied in the spring as compared with 2,144 pounds increase caused by all fertilizers applied after the first cutting. Time of application results are not in accord with those obtained on the heavy soils where time of application did not affect the results.

SUMMARY AND CONCLUSIONS

Alfalfa hay removes from the soil large quantities of phosphate and potash. Experiments have shown that it is necessary to apply these plant foods as commercial fertilizer if production is to be maintained at a high level on fields where the crop is continuously grown. On fields where fertilizer was applied at planting time, it pays to make a second application as a top-dressing after the second harvest year, or in the case of sandy soils after the first cutting of the second harvest year. Subsequent applications may be made each two years thereafter as long as the stand remains.

On the loam, silt loam, and clay loam soils, the analysis of the fertilizer should be 0-20-10 or 0-14-7 unless the soil has been recently manured. In that case it may be satisfactory to apply only superphosphate. Since manure is not recommended for alfalfa, because of the waste of nitrogen, it follows that the phosphate and potash mixture is generally recommended—at the rate of 200 to 300 pounds per acre.

On the sandy soils, potash should always be included in a fertilizer for top-dressing alfalfa. As shown by experiments, the treatment most likely to give best results is 0-12-12 or similar grade applied at the rate of 300 pounds per acre. Where the soil is extremely light, the analysis may well be changed to 0-9-27 as more potash is needed on that kind of soil.

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