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CALCIUM IN RELATION TO PHOSPHORUS UTILIZATION BY SOME LEGUMES AND NONLEGUMES

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CALCIUM IN RELATION TO PHOSPHORUS UTILIZATION BY SOME LEGUMES AND NONLEGUMES[1]

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THE place of calcium in soil treatment is no longer believed to be merely that of a cheap reducer of the hydrogen-ion concentration in the soil. Nor it is taking its position along with some 15, or more, essential elements as only a building block in plant construction. It has seemingly become more important as one of the essential nutrients by means of which other such elements may be moved into the crop plants. The very common association of phosphorus with calcium in nature, and the greater effectiveness of the former as a fertilizer in conjunction with liming, suggest some possible effects by calcium on the mobilization of the phosphorus into the crops. Previous studies (2)[3] have suggested such for lespedeza. The following is a partial test of such a hypothesis for some of the leguminous and the non-leguminous crops.

PLAN OF STUDY

Since previous investigations (1, 4) have pointed to the degree of saturation of the colloidal clay complex by calcium as a factor in the effectiveness by which a given amount of applied calcium is delivered to the crop, the amounts and placements of calcium carbonate used in this study were varied to represent different degrees of saturation of the soil. The soil used was a Putnam silt loam. Its capacity to absorb calcium was first determined. Then two rates of application, representing complete saturation and half saturation for one-fourth of the soil, were employed. These same amounts of lime were also mixed throughout the entire soil to give lower degrees of saturation corresponding to one-eight and one-fourth of the amounts needed to saturate it. The amount of phosphorus was double that commonly applied as fertilizer, and double this latter amount, representing 100 pounds and 200 (38%) pounds per two million of soil. Sodium phosphate and calcium phosphate were each used singly, and the latter in conjunction with the calcium treatments. Two-gallon earthenware pots were used.

The two phosphorus treatments were mixed into the surface one-fourth of the soil while the balance of it remained untreated. Korean lespedeza and sweet clover were used as the legume crops. Bluegrass and redtop served as the nonlegumes. The growth period was long enough to permit five cuttings of each crop as forage. The data given are for composites of cuttings of 25 separate pots for each crop, except for lespedeza which is represented by 10 pots. The crop weights and compositions were taken on constant moisture bases. Chemical analyses, along with all other measurements, were made by the commonly accepted, more accurate methods.

EXPERIMENTAL RESULTS

For simplicity sake, the data may well be assembled as harvests (a) of crop, (b) of phosphorus, (c) of calcium, and (d) of protein each as pounds per acre, and then as concentrations of phosphorus and of calcium in the crop, expressed as percentage in the dry matter. These are shown graphically in four of the above cases by two figures each. One figure represents the effects of variable calcium, or its combination with different amounts of calcium phosphate as soil treatments, while the other shows the effects by application of only the sodium and calcium phosphates to the soil.

HARVEST OF CROP

Perhaps the outstanding feature of the data is the improved yields of both legumes and nonlegumes on this soil by the use of lime, or calcium. A comparison of Figs. 1 and 2 shows clearly that the yield curves in the former, for soils given calcium, or its combination with phosphates, are higher on the scale for each crop than the curve for the corresponding crop

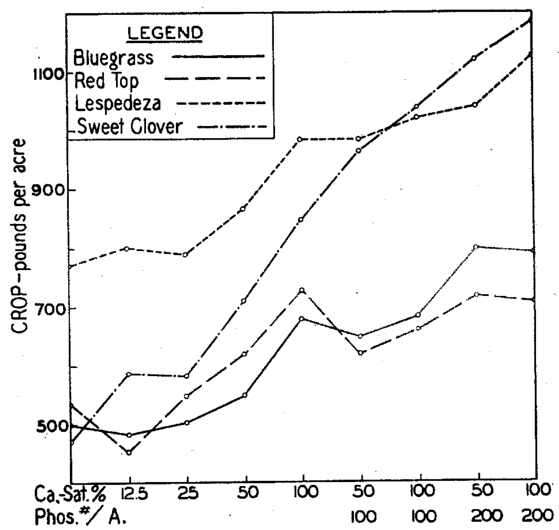

FIG. 1.—Harvests of crops as influenced by different degrees of calcium saturation of the soil or their combinations with phosphate.

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[2]Professor of Soils and Instructor in Soils, respectively.
[3]Refers to "Literature Cited", p. 265.

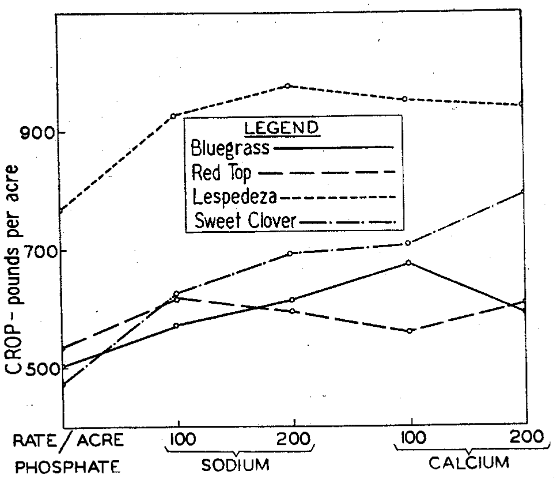

FIG. 2.—Harvests of crops as influenced by phosphates of sodium and calcium at different rates.

in the second figure where phosphates were used without lime. An increase either in the calcium saturation or in the calcium amounts increased the yields almost as much for nonlegumes as for legumes. Doubling the phosphate application in conjunction with a lime application was about as effective for crop yield increase as was the doubling of the application of lime only. Increasing the lime in conjunction with constant phosphate was significant, and likewise the reciprocal, or the increasing of the phosphorus in conjunction with constant lime amounts. This is a distinct feature in that increments of either one serve to increase yields while the other is constant. Doubling the phosphate application in the absence of the lime, however, was not so effective as is shown in Fig. 2 where the phosphates improved the yields only slightly. The small amount of calcium supplied in the calcium phosphate, as compared with the effects by sodium phosphate was without significant effect, save for possibly the one case of sweet clover.

These yield data alone would suggest that the application of phosphate is more effective as a fertilizer on bluegrass, redtop, Korean lespedeza and sweet clover when used in conjunction with calcium, or lime, than when used alone. The limiting factor suggests itself as calcium for its service in nutrition of the plant rather than for its service in reduction of the hydrogen-ion concentration in the soil when the effects by different degrees of saturation are considered. Also, in place of the reduction in phosphorus consumption by the plants through reduced phosphorus solubility when the soil was given the maximum calcium saturation or complete neutrality in a portion of the soil, the very reverse was the case, or there was maximum consumption of phosphorus from the soil by the crop. This seemingly removes the phosphorus "availability" in the soil from the realm of control wholly by the degree of soil acidity. It suggests that as the soil was given more calcium, the phosphorus, existing in the calcium-deficient soil in combination with possibly iron or aluminum, became more usable by the plant.

HARVEST OF PHOSPHORUS

The amount of phosphorus per acre removed by the crop increased as larger amounts of lime or calcium were added to the soil. It is significant, however, to note the importance of the degree of calcium saturation in this connection. When the calcium application was made to a portion only of the soil so as to give a higher degree of saturation by this element, a greater mobilization of the phosphorus into the crop from the constant, original soil supply occurred. These facts are evident from the left hand portions of the graphs in Fig. 3.

As an average of the four crops, the removal of phosphorus by them was increased by less than 10% when the calcium deficiency in the entire body of the soil was lessened by either one-eighth, or by one-fourth. But when an amount of lime corresponding to the former reduction in the entire soil was applied to a smaller portion of the soil so as to lessen the calcium saturation deficiency there by one-half, then the phosphorus harvest increased 28%. When this same soil portion was completely saturated with calcium, then the phosphorus harvest was increased by 36%. Greater calcium saturation in a smaller portion of the soil by the smaller amount of lime was more

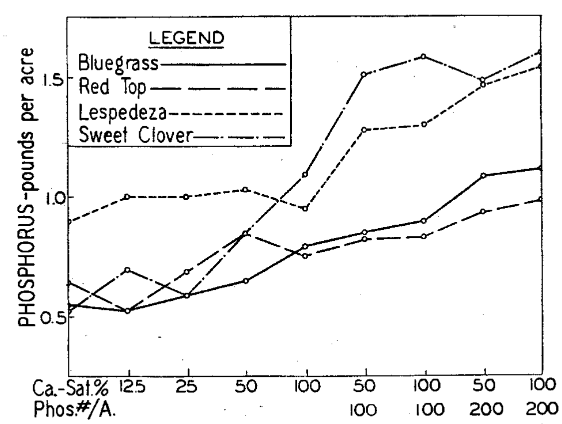

FIG. 3.—Harvests of phosphorus in the crops as influenced by different degrees of calcium saturation of the soil or their combinations with phosphate.

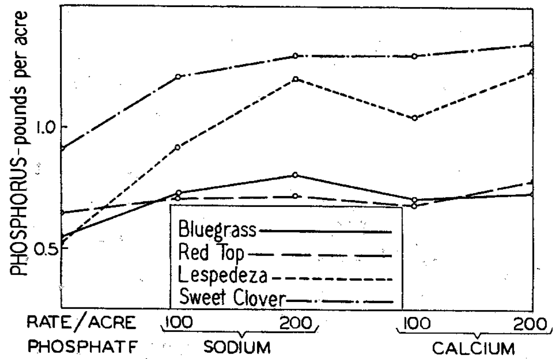

FIG. 4.—Harvests of phosphorus as influenced by phosphates of sodium and calcium at different rates.

effective in delivering larger phosphorus harvest from non-phosphated soil than was the lower saturation by larger amounts of lime in the larger body of soil.

When the two different amounts of phosphorus were each applied in conjunction with half calcium saturation and complete saturation, then the increasing amounts of calcium meant that more phosphorus was taken by the crop. This is shown by the right hand portions of the curves in the same figure. A comparison of these with those in Fig. 4 for the phosphorus harvest where phosphates alone were applied, shows that the phosphorus harvest by nonlegumes given these phosphate treatments only was even below that in these crops given only lime to complete saturation of a part of the soil in the absence of applied phosphates. Thus, in this soil, the addition of phosphorus is not as effective for increasing the phosphorus harvest in the crop as is the addition of only calcium. Also, effective recovery of applied phosphorus is premised on a liberal supply of calcium in the soil.

When the variations in a single treatment such as small limestone applications carrying no phosphorus can shift the so-called "phosphorus availability" for these different crops through a range from one quantity to double this amount, it would seem that any beliefs in the reliability of simple chemical tests for "phosphorus availability" in terms of plant consumption and yield, would be somewhat shaken.

The significance of the lime in connection with the nonlegumes on this soil is noteworthy. The increased phosphorus in this type of crop as a result of liming and of its combination with phosphates points to the need for soil treatment in case of even so commonplace a grass as redtop. The legume crops responded with a far wider range of phosphorus removal from the soil. They indicate their greater possibilities in yield variations by which these crops might reflect lime, phosphate or other fertility deficiencies. As a consequence, fertility deficiencies have been more easily recognized in connection with legume failures than with grass crop failures.

HARVEST OF CALCIUM

In terms of the total calcium taken from the soil by the crops, it is interesting to note again the greater importance of the degree of saturation of the soil by calcium than of the total amount of limestone applied. This held true for both legumes and nonlegumes as shown in Fig. 5. It emphasizes the relative saturation of the soil as the factor determining the efficiency by which the calcium application to the soil is recovered in the crop. The recovery by the legumes is, of course, the higher. All curves show greater recovery for either of the two amounts of limestone mixed into the lesser quantity of soil.

Much as the phosphorus harvest was increased by the calcium application so there was a reciprocal effect by the phosphorus application on the calcium harvest. This calcium harvest was greater from a constant limestone application as more phosphorus was used with it. This is shown distinctly in the right hand parts of the curves in Fig. 5 for the two grasses and the sweet clover, but less so for the lespedeza.

This effect was seemingly impossible when phosphates were used in the absence of limestone, as is shown in Fig. 6. Heavier treatments of phosphates alone failed to get more calcium into the grass crops or lespedeza even when the form of phosphate used

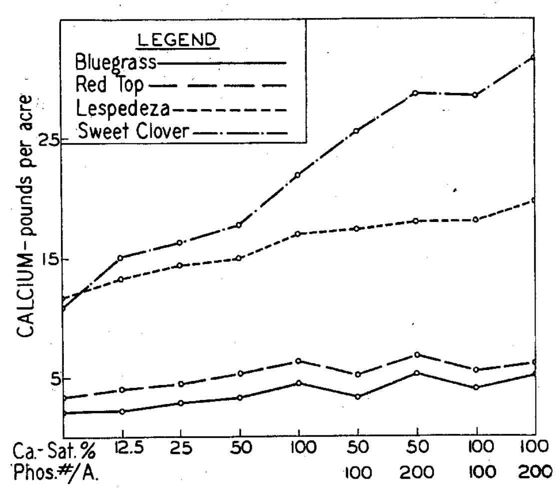

FIG. 5.—Harvests of calcium as influenced by different degrees of calcium saturation of the soil or their combination with phosphates.

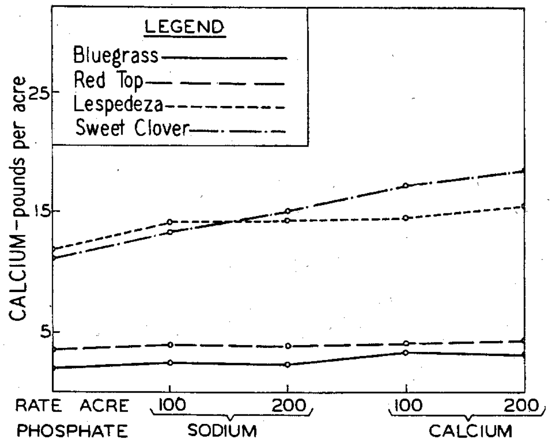

FIG. 6.—Harvests of calcium as influenced by phosphates of sodium and calcium at different rates.

singly was the calcium phosphate. In case of the sweet clover, however, calcium phosphate alone was more effective in delivering calcium harvest. This reciprocal effect on calcium by phosphate application does not appear on this soil when no limestone is applied to it. It suggests calcium as the foremost deficiency in this soil.

It seems, then from the studies of plant composition as well as of forage yield, that calcium was a limiting element holding down the plants' consumption of phosphorus, and likewise that phosphorus was a limiting element at the same time in reducing their consumption of calcium. Perhaps such an interaction in the plants' use of these two nutrient items has connected lime and phosphates more closely in the art of agriculture than we have up to the present connected calcium and phosphorus in its science. It remains difficult to understand how such mutual increased movement into the plant can be brought about.

HARVEST OF PROTEIN

Should we hold to the belief that calcium is without direct effects on plant protein production, then with phosphorus as a protein constituent a study of the protein harvest might reveal indirect calcium effects on it through influences on phosphorus. Comparison of Figs. 7 and 8 points immediately to the significance of the calcium in this plant activity by the higher level of the protein harvest where lime, or lime and phosphates were used, Fig. 7, in contrast to that by phosphates only, Fig. 8. Phosphates alone were more influential in the case of legumes than they were for the grasses.

The close agreement in protein production by redtop and bluegrass, Fig. 7, under lime only, or this treatment coupled with phosphate, is significant. Particular notice might well be taken of the lowered protein production, (below that of the check), by the lesser application of calcium or the lower degree of soil saturation by it, and the increased harvest with higher degree of its saturation of the soil. In contrast to these performances by the two grasses, all the lime treatments for legumes gave increases in protein production beyond that on the soil without treatment.

As to the possible cause for such response by the grass, one might consider the competition by the soil bacteria for the soil nitrogen because of their increased activity through lime additions. Such is not disturbing to the legumes which are able to draw on the atmospheric supply of nitrogen. Heavier liming may overcome this competition by speeding the period in the bacterial cycle when competition prevails. Perhaps similar competition is induced when the smaller phosphate application is added to the limestone. This combination is not so effective in giving protein harvest, as are either more of these two as soil treatments, or the higher degree of calcium saturation as is suggested in the second fall in the curves for the nonlegumes in Fig. 7.

The legumes give far larger response than the nonlegumes as protein harvest. Korean lespedeza responds to liming and gives additional protein from the phosphorus supplement. But this protein increment by phosphorus is by no means equal to that brought through lime. Thus, we might believe lime, or calcium, directly essential for protein production by lespedeza, if it is true that increasing protein harvest goes directly with increasing calcium harvest, Figs. 5 and 7, without the phosphorus harvest showing the

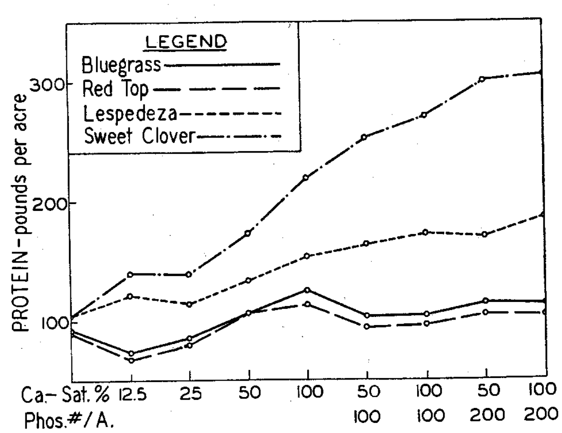

FIG. 7.—Harvests of protein as influenced by different degrees of calcium saturation of the soil or their combination with phosphate.

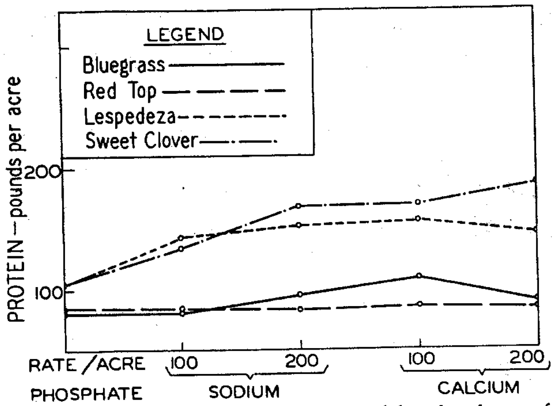

FIG. 8.—Harvests of protein as influenced by phosphates of sodium and calcium at different rates.

corresponding increase, Fig. 3. In case of the sweet clover, the increments of lime as offered in terms of amounts or of higher degrees of saturation meant increased harvests of calcium, of phosphorus, and of protein. Such suggests a combined activity by calcium and phosphorus in producing protein. As a protein producer on this soil, the sweet clover is far superior to lespedeza. Both, however, respond with increased protein production from liming and seem more effective in this respect because the calcium enters the plant along with and in far larger amounts than does the phosphorus.

CONCENTRATION OF NUTRIENTS IN CROP

As for the concentrations of the various nutrients within the crops, the variation by those given both lime and phosphate seemed insignificant as percentage figures. The average phosphorus contents of four crops in these cases ranged from but 0.134 to 0.139%. The calcium in these cases figured similarly varied from 1.46 to 1.49%. When limitations in growth occurred because of limited applications of one or the other treatments then variations in concentrations were greater for these elements. Fluctuations in protein are naturally greater, reflecting differences in plant activity in production of nitrogenous products through nitrogen fixation by legumes, rather than absorption only from the soil. Fluctuations in concentrations fail to reveal the larger significance of treatments in soil fertility where an inventory of total fertility harvest must be considered.

The behavior of non-essential elements lends importance to calcium activity, since analyses of these crops (3) show reduction of silicon concentration by liming, or by increased calcium consumption by the crop. Liming alone reduced the silicon concentration but phosphate alone increased it. Such effect was about the same for legumes and nonlegumes, so that limed plants had but from two-thirds to one-half as high a concentration of iron and aluminum while lime and phosphate suggested the opposite effect.

Such results point to a role by calcium of keeping non-essential elements out of the crop as well as its aid in moving essentials into it.

SUMMARY

A study of the forage production by redtop, bluegrass, Korean lespedeza, and sweet clover points to an importance of calcium in the utilization of phosphorus by these crops. A larger share of the applied phosphorus was recovered in the crop as the degree of saturation of the soil by calcium was greater. This greater recovery resulted more because of larger crop yields than because of higher concentration of phosphorus in the forage.

Increasing the applied phosphorus also served to increase the calcium taken from a constant soil supply and suggested a reciprocal effect by phosphorus on calcium.

When the saturation of the soil with calcium increases the phosphorus taken, it removes the so-called "phosphorus availability" from the realm of its increase by soil acidity. It makes the plant's use of calcium and phosphorus a more complex process by the plant rather than a simple solubility situation in the soil.

The saturation of one-fourth of the soil by calcium increased the phosphorus harvest by 36%, while the corresponding increase was only 10% when this same total calcium supply served to increase the amount of lime in the entire soil by only one-fourth of that necessary for saturation. The concentration of the calcium into one-fourth of the soil more than trebled the effectiveness of calcium as a means of moving native soil phosphorus into the crop. When phosphorus was applied with limestone this same effect by lime was evident. Thus liming becomes a matter of feeding calcium to the plant effectively and of aiding it in getting its phosphorus, rather than one of modifying the hydrogen-ion concentration. The question presents itself whether on some soils in the South where little lime is considered necessary because these soils are not so sour, the lime may not well be used for its effectiveness not only in supplying calcium but also in making the phosphates — and probably other fertilizer items — recoverable as crop yield increase.

The degree of saturation of a limited soil area is more significant in controlling the efficiency of the calcium recovery by the crop than is the total calcium application throughout the soil. This calcium recovery is also influenced by increased phosphorus in the soil.

The total harvest of protein also increased when increased calcium and phosphorus harvests occurred. Increases in calcium utilization by the grasses as red-top, for example, served to lower the silicon concentration, and also that of aluminum and iron(3). Thus, in this study, calcium played seemingly significant roles in giving increased phosphorus utilization by the crop, whether legume or nonlegume were considered.

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