A Preliminary Report on the Relative Efficiency of Some Phosphate Fertilizers on Calcareous Soil

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KNOWLEDGE OF THE REACTIONS that take place when phosphate fertilizers are applied to soils is of great scientific and practical value in crop production. Most of the investigations have been made with acid soils. It has been shown that some of the phosphate applied to such soils may be tied up with the soil and rendered unavailable to plants. Therefore, much consideration has been given to time of application and placement of the fertilizer. Some of the conclusions reached from studying acid soils have been erroneously applied to calcareous soils.

Unpublished fertilizer investigational work by the University of Idaho has indicated that some reduction in availability may occur when phosphate fertilizers are added to calcareous soils. However, succeeding crops were able to utilize a large portion of the phosphate held in the soil. This would indicate that the so-called fixation in calcareous soils is not as significant a factor in determining time and placement of fertilizer as it is in acid soils.

Field and greenhouse tests have further shown that phosphate fertilizers, having much of their phosphate in the water-soluble fractions, were more effective than those containing a large part of their available phosphorus in the citrate-soluble form.

These facts are very important to the farmers and to the fertilizer industry in the intermountain west. The Simplot Fertilizer Company of Pocatello, Idaho, made available a fellowship at the University of Idaho during 1947 for further study of:

1.—Extent of so-called fixation and/or reversion of phosphate fertilizers in calcareous soils.

2.—The extent to which the fixed or reverted phosphate, if any, may be available for crop use.

3.—The types of phosphate fertilizers best suited for use on calcareous soils.

4.—The extent to which these facts may influence time and method of applying phosphate fertilizers to calcareous soils.

This paper is a brief preliminary progress report of the findings, which should be of value to the sugar beet industry of the intermountain areas and other agricultural areas where the soils are calcareous.

Soil.—The soil used in this study is described in the Blackfoot-Aberdeen Area Survey Report, 1943, as Bannock loam. It was obtained from

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a portion of an alfalfa field which had not received phosphate fertilizer. A fertilizer trial on the field showed the soil to be very deficient in phosphorus available for plant use.

A chemical analysis of the well-mixed soil before starting the investigation gave the following:

pH: 7.8
Calcium carbonate equivalent: 6.1 percent
Available P_2O_5: 8.3 pounds/acre.

Procedure.—Two methods were used to determine the available phosphorus level in the soil, i.e., biological—the growing of Romaine lettuce by the method of Jenny,[2] and chemical—the carbon-dioxide extraction method.

Romaine lettuce has been used by Jenny as an indicator plant in determining nutrient levels of soil in greenhouse-pot studies. It has been observed that the growth of Romaine lettuce was in correlation to the amount of available plant nutrients in the soil. Thus it appeared that the relative growth of Romaine lettuce would be an excellent biological method of determining the availability of phosphate if nitrogen and potash requirements were met.

Previous work at Idaho[3] has established a good correlation between plant growth and available phosphorus, as determined by the carbon-dioxide method.

Four phosphate carriers were used in this study: Single superphosphate, trebel superphosphate, fused tricalcium phosphate and c.p. precipitated tricalcium phosphate. Two rates of application were used, 50 and 100 pounds of available P_2O_5 per acre, based on the manufacturer's guaranteed analysis (table 1).

The four phosphate carriers, at two rates of application, were each mixed with 35 pounds of soil, brought up to field-moisture capacity, and incubated for various periods of time. Incubation refers to the number of days, following fertilizer application and preceding planting, that the soils were held at optimum moisture conditions.

The following incubation periods were used:

1. Zero or no incubation—soil moistened, planted, and soil samples taken as soon as possible.
2. Thirty days.
3. Sixty days.
4. Ninety days.

Soil samples were taken from each incubation period at the following time intervals: Immediately, 1, 4, 8, 12, 20, 30, 60, and 90 days. Available phosphorus at each time interval was determined by the carbon-dioxide extraction method. The results are shown graphically in figure 1.

[2] Jenny, H. "Nutrient Level Determination by Greenhouse Pot Studies." Mimeograph.
[3] Ensminger, L. E., and Larson, H. W. E., 1944—"Carbonic Acid Soluble Phosphorus and Lime Content of Idaho Soils in Relation to Crop Response to Phosphate Fertilization." Soil Sci., 58, No. 4.

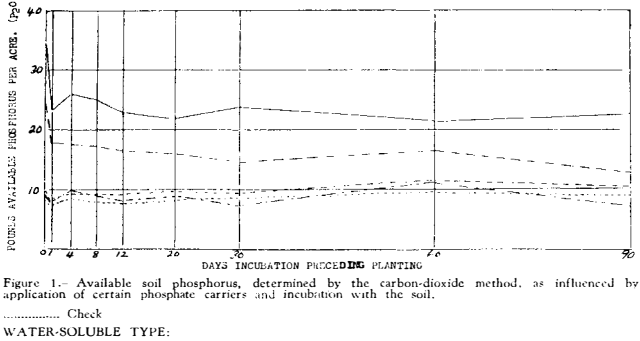

Figure 1.– Available soil phosphorus, determined by the carbon-dioxide method, as influenced by application of certain phosphate carriers and incubation with the soil.

..... Check

WATER-SOLUBLE TYPE:

—— 100 pounds available P_2O_5/acre. - - - - 50 pounds available P_2O_5/acre.

CITRATE-SOLUBLE TYPE:

– · – · – 100 pounds available P_2O_5/acre. · · · · 50 pounds available P_2O_5/acre.

At the end of each incubation period, 1,600 grams of soil from each treatment were placed in 6-inch flower pots and Romaine lettuce transplanted to each pot according to the method of Jenny. Nitrogen and potassium were added to remove any possibility of these becoming limiting plant growth factors. The lettuce plants were allowed to grow 6 weeks. They were then harvested, oven dried, and weighed. A second crop was planted without disturbing the soil in the pots. Nitrogen and potassium were added, as at the start, and the same procedure followed.

It was observed, during the progress of this work, that both the growth response of lettuce and the available phosphorus remaining in the soil, after fertilizer treatments, readily divided the fertilizers into two groups according to the proportion of water-soluble or citrate-soluble phosphorus they contained. This was substantiated later by statistical methods. Therefore, the results presented in this paper are expressed in terms of the averages obtained from the water-soluble phosphate carriers, the citrate-soluble phosphate carriers, and the check soils.

Discussion

Data in figure 1 show that when various types of phosphate carriers were added to a calcareous soil an immediate reduction in availability took place. This reduction was practically completed within 24 hours, after which a fairly constant level of availability was maintained throughout the balance of the incubation periods.

The 100-pound applications of the water-soluble-type phosphate fertilizers maintained a level of available phosphate at 22 to 25 pounds per acre and the 50-pound applications maintained a level of 13 to 18 pounds

per acre. The citrate-soluble-type phosphate fertilizers applied at both rates gave a level of 8 to 10 pounds per acre which was not statistically different from approximately 8 pounds in the check.

Past work with alfalfa at the Aberdeen Experiment Station and unpublished data on calcareous soils from various sections of southern Idaho have shown that a level of 25 to 30 pounds of available phosphate per acre (as determined by the carbon-dioxide method) is required to obtain high crop yields.

The yield data from the greenhouse tests correlates very closely with the conclusions arrived at by the carbon-dioxide extraction method (figures 1 and 2). The higher yields of the first crops on soil which had no incubation, when compared with the first crops on soil which had 30- and 60-day incubations, indicate a drop in available phosphorus after the soil has been incubated, and a leveling off where the equilibrium of phosphorus in the soil solution has been established. The yield data on the second crop indicate that the supply of phosphorus present was being gradually depleted by crop growth.

The 100-pound applications (available P_2O_5) of the water-soluble-type fertilizers caused the greatest plant response. The next greatest response resulted from the 50-pound applications of the same material. Neither the 100- nor the 50-pound applications (available P_2O_5) of the citrate-soluble-type fertilizers showed significant increase in plant response over the check.

As shown in figure 3, Romaine lettuce plants were able to extract much more phosphorus from soil to which water-soluble-type fertilizer had been added than they could from soil to which the citrate-type fertilizer had been added. There is a gradual depletion of the water-soluble supply of phosphorus in the soil as a result of continuous cropping.

Various implications and conclusions can be derived from the study of available phosphorus in the soil with different phosphate carriers, as determined chemically (carbon-dioxide method) and from plant yield data.

High levels of available phosphorus in the soil solution of calcareous soils can be maintained by addition of water-soluble-type phosphate fertilizers. An indication of the need for phosphate fertilizer can be made by analysis for available phosphorus by the carbon-dioxide method.

The level of available phosphorus reaches equilibrium so rapidly in calcareous soils, when water-soluble-type phosphate fertilizers are applied, that the time of application of these fertilizers is less important than formerly thought. The rapidity of this reduction in availability makes it impossible even to get seeds germinated before this action has been largely completed and the phosphorus equilibrium established in the soil.

It is, therefore, indicated that water-soluble-type phosphate fertilizers can be applied in the fall or any other season on calcareous soils without any further loss of efficiency than would occur if applied immediately preceding the planting of crops. However, there probably will be an advantage to side-dressing water-soluble-type phosphate fertilizers to plants

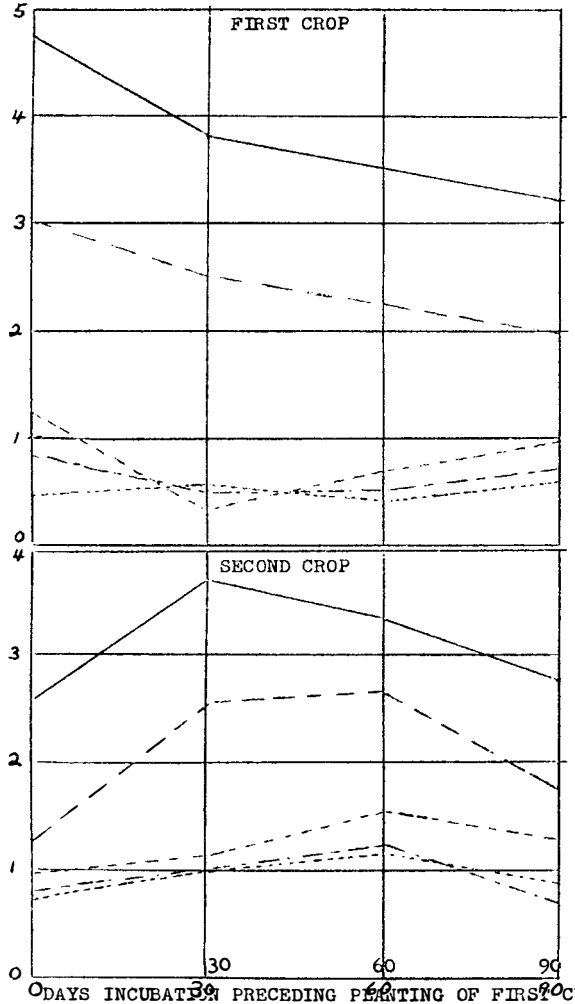

Figure 2.—Yield of romaine lettuce as influenced by certain phosphate carriers and incubation periods preceding planting.

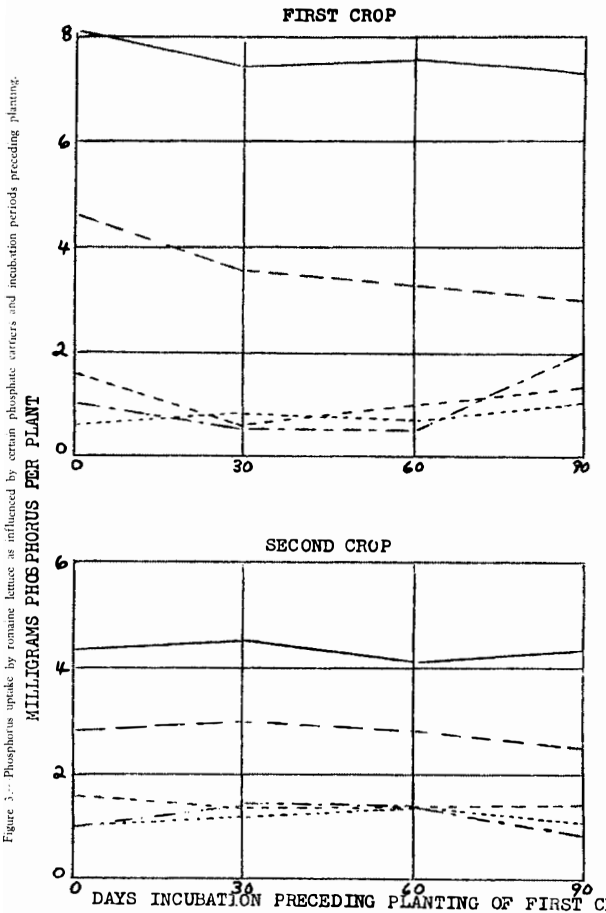

Figure 3.—Phosphorus uptake by romaine lettuce as influenced by certain phosphatic carriers and incubation periods preceding planting.

already growing. This is shown by the response obtained when seedlings were transferred to those soils, to which water-soluble-type fertilizers had been added, at a time when no incubation had taken place. In this instance only was there a decided increase in weight of crop and phosphorus taken up by the plant (figures 2 and 3). However, in all cases where increased crop production occurred in the first crop due to this factor, there was a corresponding decrease in growth of the second crop, as compared with the 30-, 60-, and 90-day incubations.

The pounds per acre of available phosphorus, as shown by the carbon-dioxide method, when compared with the standards established, indicate that only a slightly greater amount of water-soluble-type fertilizers would have been needed in this soil to maintain a maximum level of crop production. This is substantiated further in the available levels produced and crop response obtained from the 50-pound additions, which indicate that slightly more than twice this amount would be necessary for maximum production. The results obtained in crop response and phosphate level from the addition of citrate-soluble-type phosphate fertilizers indicate that perhaps 15 to 20 times more than the 100-pound available P_2O_5 application would be required before good crop response could be obtained from these fertilizers. It is obvious that such additions would not be economically feasible.

Summary

1. The use of water-soluble-type phosphate fertilizers results in the establishment of a much higher level of available phosphorus in calcareous soils than does the use of comparable quantities of citrate-soluble type of phosphate fertilizers.

2. When various types of phosphate fertilizers were added to calcareous soil an immediate reduction in availability took place. This reduction was practically completed in 24 hours and no further significant change took place over a 90-day incubation period.

3. The level of available phosphorus in the soil was altered by the addition of various rates of the water-soluble fractions of the phosphate fertilizers or by the removal of phosphate by crops.

4. The citrate-soluble-type phosphate fertilizers did not cause significant yield increases on calcareous soils nor did they increase the available phosphorus level in the soil.

5. The time of application of the water-soluble-type phosphate fertilizers was not important in calcareous soils when applied previous to planting crops. Some benefit was shown when available fertilizer was added during the early stages of growth.

6. So-called fixation or reversion of phosphate fertilizers in calcareous soils may not take place as such, rather the reduction in availability which

occurs when water-soluble-type phosphate fertilizers are added to these soils appears to increase the reserve of available soil phosphorus, resulting in the establishment of an equilibrium between the amount of phosphorus in the soil solution and that held by the soil itself.

Table 1.--Composition of fertilizers used.

Material	Total P_2O_5 content (percent)	Available P_2O_5 (percent)	Available		Equivalent rate per acre (pounds)	Manufacturer's guarantee analysis (percent)
			Water soluble (percent)	Citrate soluble (percent)		
Water-soluble availability type						
Single superphosphate	19.9	18.9	87	13	556	18
Treble superphosphate	49.1	43.7	87	13	232	43
Citrate-soluble availability type						
Fused phosphate	25.0	18.0	8.0	92	556	18.8
Tricalcium phosphate	42.9	13.4	9.0	91	752	--