Effect of Type of Phosphate Material and Method of Application on Phosphate Uptake and Yield of Sugar Beets[1]

W. R. SCHMEHL, STERLING R. OLSEN, AND ROBERT GARDNER[2]

The availability of various types of phosphate fertilizer to crop plants has been studied with new vigor since radioactive phosphorus has become avaliable as a research tool for field experimentation, and this research has contributed greatly to the knowledge of the availability of phosphate fertilizers in calcareous soils.

Xhe national shortage of cheap supplies of raw sulfur, which caused the War Production Board to reduce superphosphate production in 1952 by 10 percent (l)[3], has stimulated investigations of phosphate fertilizers not requiring sulfuric acid which may be used as substitutes for superphosphate. There also has been a trend toward the increased sale of ammoniated phosphates which have not been adequately tested for calcareous soils. This paper reports the results of experiments conducted to determine the relative efficiency of various types of phosphate fertilizer materials and methods of application on calcareous soils of Colorado.

Materials and Methods

1950 experiment.—The experiment was conducted on Las Animas clay soil near Rocky Ford, Colorado, on one of the American Crystal Sugar Company farms. The soil contained approximately 7 percent $CaCO_s$ and 0.2 percent gypsum in the surface eight inches of soil.

The phosphate materials[4] used in the experiment were concentrated super phosphate, two ammoniated concentrated superphosphates (1.4 and 3.3 percent NH_3), and three calcium metaphosphates (minus 10, minus 40 and minus 100 mesh). The water solubility of the ammoniated phosphates was 80 and 67 percent for the low and high degrees of ammoniation, respectively.

Two methods of application were used for each phosphate material: 1) rototiller placement—the fertilizer was mixed with the soil in a band four inches wide and four inches deep and the seed was planted in the rototiller band; 2) concentrated band—the fertilizer was applied in a single concentrated band four inches deep and four inches to the side of the seed. The phosphorus was applied at 40 pounds $P_2 0_5$ per acre and nitrogen was applied uniformly to all treatments at 60 pounds per acre. All fertilizer was added at the time of planting. The experiment was conducted as a factorial with three replications.

Radioactive phosphate fertilizer was applied in a small area in each plot, and beets grown in the radioactive area were sampled on May 22,

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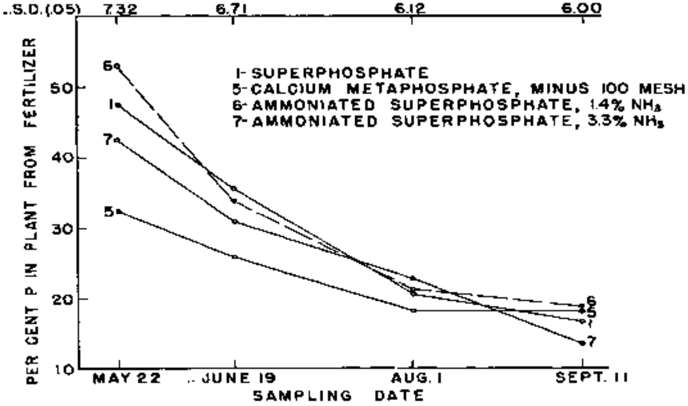
[2] Assistant Agronomist, Colorado Experiment Station; Soils Scientist, U. S. D. A. BPI, and Agronomist, Colorado Experiment Station, respectively.

[3] Numbers in parentheses refer to literature cited.

[4] The non-radioactive and radioactive phosphate fertilizers for the 1950 experiment were prepared by the division of fertilizer and agricultural lime and the division of soil management and irrigation, the Bureau of Plant Industry, Soils and Agricultural Engineering, Beltsville, Md. The radioactive fertilizers can be identified by the following lot numbers: concentrated superphosphate, No. 2787a: ammoniated concentrated superphosphates, Nos. 2788 and 2789; calcium metaphosphate, Nos. 2791a, 2791b and 2791c. The radioactive phosphorus was supplied by the Atomic Energy Commission.

June 19, August 1 and September 11. The plant material was analyzed for radioactive phosphorus according to methods of MacKenzie and Dean (3, 4).

1951 experiment.—The experiment was conducted on Fort Collins loam soil on the Agronomy farm near Fort Collins, Colorado. The soil contained approximately 3.5 percent $CaCO_3$ in the surface eight inches and was deficient in available phosphorus.



PERCENTAGE OF PHOSPHORUS IN SUGAR BEETS DERIVED FROM THE FERTILIZER AS AFFECTED BY SOURCE OF PHOSPHORUS ON LAS ANIMAS CLAY (1950)

Figure 1.—Percentage of phosphorus in sugar beets derived from the fertilizer as affected by source of phosphorus.

The experiment was designed as a factorial with type of phosphate material and rate of application as variables. There were six replications. Phosphorus was applied at rates of 50 and 250 pounds P_2O_5 per acre. Nitrogen was added uniformly to all treatments. The phosphate materials[5] were concentrated superphosphate, two nitric phosphates (13-33-0), calcium metaphosphate (minus 40 mesh), and dicalcium phosphate (minus 40 mesh). The nitric phosphates were made by acidulating phosphate rock with a mixture of nitric and phosphoric acids. Processes for the manufacture of nitric phosphates are described by Hignett (2) and Rogers (6).

The fertilizer was broadcast and plowed under on March 17, and sugar beets were planted on April 13. No radioactive phosphorus was used in the 1951 experiment.

[5] The phosphate fertilizers for the 1951 experiment were manufactured and supplied by the Tennessee Valley Authority. The laboratory numbers of the fertilizers are: concentrated supernhosphate, No. 11,304; nitric phosohates, Nos. 10,986 and 10,861; dicalcium phosphate, No. 8878; calcium metaphosphate, No. 65,653.

Results and Discussion

Effect of type of phosphate on the percentage of phosphorus in the plant derived from the fertilizer.—The results of the 1950 experiment are shown *in* Figures 1 and 2. The two ammoniated superphosphates supplied about the same amount of phosphorus to the plants throughout the season as did superphosphate. The plants absorbed more phosphorus from concentrated superphosphate than from calcium metaphosphate during the early part of the growing season, but absorbed about equal amounts from

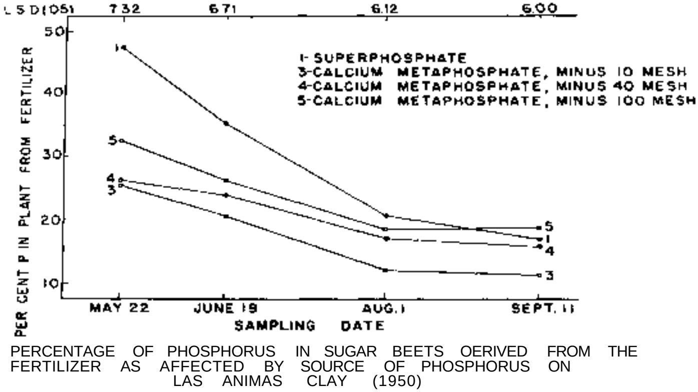


Figure 2.—Percentage of phosphorus in sugar beets derived from calcium metaphosphate as affected by particle size.

each material the latter part of the season. The results with calcium metaphosphate are similar to those reported by Olsen, et al. (5) .

The absorption of phosphorus by the plants from calcium metaphosphate of different particle sizes (Figure 2) shows a consistent trend throughout the season for the absorption of the fertilizer phosphate to increase as the particle size decreases.

Effect of type of phosphate on the yield of beets and sugar.—The yields of sugar beets are shown in Table 1 for the 1950 experiment and in Table 2 for the 1951 experiment. There was no significant difference in yield between type of phosphate material in 1950, but the difference between the average yield of phosphated and non-phosphated treatments was significant at the five percent level. Inasmuch as only a slight phosphate deficiency existed in the field, the amount of phosphate supplied by the least available material apparently was sufficient to produce the maximum yield of sugar beets.

In the 1951 experiment (Table 2) the crop showed a response to all phosphate materials but the yield with dicalcium phosphate was significantly less than the average yield for the other phosphate treatments. Within the limits of experimental error, the nitric phosphates, calcium metaphosphate and superphosphate performed equally well on this soil for sugar beets. The results show that there is an important difference between dicalcium phosphate and the nitric phosphates, although dicalcium phosphate is considered to be a major constituent of the nitric phosphates (2, 6) .

The greater availability of calcium metaphosphate in the 1951 experiment as compared with the 1950 experiment or with the published results of Olsen, et al. (5) , may be due to the difference in the method of application. The phosphate fertilizer was applied at the time of planting in the 1950 experiment and in the experiments of Olsen, et al. Even so, it was noted that the relative availability of superphosphate and calcium metaphosphate, as determined by radioactive tracer techniques, was nearly the same by mid-summer. In the 1951 experiment the fertilizer was plowed under 4 weeks before planting. The additional time of contact between fertilizer and soil may have increased the hydrolysis of the metaphosphate, thereby increasing the availability to the crop during the early part of the growing season and giving increased yields.

Statistical analysis of the data showed no interaction between phosphate material and rate of application. The increase in average yield for all materials due to the increase in rate of application was highly significant.

Table 1.—The Yield and Sugar Content of Beets as Affected by Type of Phosphate Material. 1950 Experiment, Las Animas Clay.

Type of phosphate	Sugar Content	Yield of beets (tons per acre)
	%	
Concentrated superphosphate	15.0	21.1
Calcium metaphosphate, minus 10 mesh	15.0	22.4
Calcium metaphosphate, minus 40 mesh	14.8	22.4
Calcium metaphosphate, minus 100 mesh	14.9	21.3
Ammoniated conc. superphosphate, 1.4% NH_3	15.2	21.1
Ammoniated conc. superphosphate, 5.3% NH_3	14.9	22.4
No phosphorus	15.1	20.0
Average, phosphated treatments	15.0	22.1[1]

[1] Significant increase at 5% level compared to no phosphorus treatment.

The sugar content of the beets was not greatly affected by applications of phosphate in the 1950 experiment (Table 1). In the 1951 experiment the sugar content of the no-phosphorus treatment was significantly less than the average for the phosphated treatments (Table 2) , but there was no significant difference between phosphate materials. The average yield of sugar for the phosphate treatments was 3.32 tons in 1950 and 2.38 tons in 1951.

Effect of method of application of phosphate.—The fertilizer in the 1950 experiment was applied in a band and by mixing with the soil (rototiller placement). The uptake of fertilizer phosphorus as affected by method of application is given in Table 3. At the time of thinning (May 22) the uptake of phosphorus was greatest from fertilizer mixed with the soil, but at all later samplings phosphate uptake was greatest from the band application. The effect of method of application in this experiment was apparently largely a matter of positional availability. Fertilizer applied with the rototiller was highly available early in the season when a large portion of the root activity was in the rototilled zone of the soil, but later

Table 2.—The Yield and Sugar Content of Beets in the 1951 Experiment on Fort Collins Loam.

	50 lb. P_2O_5	250 lb. P_2O_5	Average[1]	Sugar Content
				%
Conc. superphosphate (47.6% P_2O_5)	13.8	15.9	14.8	15.8
Nitric phosphate (17-22-0)	14.7	15.4	15.5	16.0
Nitric phosphate (12-33-0)	15.4	15.7	15.5	16.0
Calcium metaphosphate, minus 40 mesh (62.9% P_2O_5)	15.7	15.4	15.5	16.0
Dicalcium phosphate, minus 40 mesh (46.0% P_2O_5)	12.7	14.8	13.7	15.7
No phosphorus	......	......	11.4	15.5
Average all phosphated treatments	14.5	15.4[2]	......	15.9[4]
Average, all phosphated treatments except dicalcium phosphate	....	...	15.2[3]	......

[1] L. S. D., phosphate materials; (.05) = 1.05, (.01) = 1.40.
[2] Significant increase at 1% level compared to 50 pound rate.
[3] Significant increase at 5% level compared to no phosphorus treatment.
[4] Significant increase at 1% level compared to dicalcium phosphate treatment.

in the season a smaller proportion of the root activity would be in the roto-tilled zone. On the other hand, although the plant roots would not contact the band-placed fertilizer as early in the season, root activity at a four-inch depth would be relatively greater the latter part of the season. Similar results have been reported for experiments on Fort Collins loam soil (5). Due to the lack of a phosphate deficiency in the soil, no yield differences between methods of application were noted.

Table 3.—The Percentage of Phosphorus in Sugar Beets Derived from the Fertilizer as Affected by Method of Application. 1950 Experiment, Las Animas Clay.

Method of application[1]	Percent of plant phosphorus derived from the fertilizer May 22	June 19	Aug. 1	Sept. 11
Concenrated band	21.4	46.8	24.1	20.7
Rototiller	55.0	10.4	13.8	11.3
L. S. D. (.01)	5.9	5.3	3.6	3.8

[1] See text for description of method of application.

Summary

Concentrated superphosphate and two ammoniated concentrated superphosphates (1.4 and 3.3 percent ammonia) were equally available, within the limits of experimental accuracy, as shown by radioactive phosphorus studies. The availability of calcium metaphosphate to sugar beets increased as the particle size of the fertilizer decreased from minus 10 mesh, to minus 40 mesh, to minus 100 mesh. Calcium metaphosphate was not as available as concentrated superphosphate during the early part of the season when both materials were applied at the time of planting, but the two materials were about equally available the latter part of the season.

The yield of beets on a Fort Collins loam soil deficient in available phosphorus was about the same when concentrated superphosphate, calcium metaphosphate and two nitric phosphates were broadcast and plowed under four weeks before planting. The use of dicalcium phosphate fertilizer produced a yield increase over the no-phosphorus treatment but the yield was significantly below the average yield for the other phosphate fertilizers.

At the time of thinning, the uptake of phosphorus from fertilizer applied with a rototiller was greater than uptake from fertilizer placed in a concentrated band, but uptake of phosphorus was greater from the band-placed fertilizer for the remainder of the season.

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