Comparison of the Availability to Plants of Phosphorus from Mixed Salt and Commercial Type Fertilizers

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Greenhouse experiments were conducted with mixed salt and commercial-type mixed fertilizers to find if there were differences in the availability of phosphorus from these materials. Fertilizers labeled with phosphorus-32, which ranged in phosphate water solubility from about 0 to almost 100%, were applied in mixed and banded placements to five soils. Corn and bean yields and fertilizer phosphorus uptake showed no substantial differences in the behavior of mixed salt and commercial-type fertilizers. These data are of value, because it is difficult to produce well characterized commercial fertilizers having a wide range of water solubility.

Agronomists, using fertilizers labeled with radioactive phosphorus have shown during the last 5 years, that the amount of water-soluble phosphorus in the phosphate fraction of mixed fertilizers has a marked effect on plant absorption of fertilizer phosphorus and in some cases on the yield of crops (*5–11*).

To obtain well characterized fertilizers for such studies, it has been convenient to prepare mixed fertilizers using a slurry mix of solid components, including monoammonium phosphate, anhydrous dicalcium phosphate, potassium chloride, and ammonium nitrate. Diatomaceous earth is generally used as a filler. With these materials, U. S. Department of Agriculture research workers have been able to produce complete fertilizers varying in phosphate water solubility from 1.5 to 97.0%.

In commercial production of nitric phosphate and highly ammoniated superphosphate, significant amounts of dicalcium phosphate and smaller amounts of tribasic (apatite-like) phosphates are formed (*4*). It is believed that not only the quantity, but also the physical and chemical characteristics of these less soluble phosphorus compounds partially control the plant availability of the citrate-soluble phosphorus. For instance, the importance of characterizing the particle size or surface area of dicalcium phosphate has been emphasized by Hill and Caro (*3*). Problems in the production of some mixed salt and commercial-type fertilizers have been recently reviewed by Wieczorek (*12*).

The results of analyses of fertilizers from commercial production indicate the water-soluble phosphorus content varies considerably even among samples of similar analyses (*2*). It has been concluded that many factors in fertilizer production influence phosphate water solubility, including degree of ammoniation, addition of lime or organic nitrogen, moisture content of the fertilizer, and rate of drying and cooling to decrease the water content. The presence of sulfuric acid appears to promote high phosphorus solubility, especially in the absence of lime (*1*).

The question has arisen as to whether the mixed salt or synthetic-type materials are comparable to commercial-type fertilizers in their effects on plants. Considering the variability existent in the water-soluble fraction of commercial materials, it is likely that the nature of the dicalcium phosphate fraction and the assemblage of salts may be different in these two types of fertilizers. This study was undertaken to compare the effect of mixed salt and commercial-type fertilizers on the growth of several crops and their absorption of fertilizer phosphorus when grown under different soil conditions.

Materials and Methods

Fertilizers. A series of mixed salt and nitric phosphate fertilizers, varying in phosphate water solubility from 1.5 to 97.0%, was prepared by the Fertilizer Investigations Research Branch, Agricultural Research Service, U. S. Department of Agriculture. Both series were labeled with radioactive phosphorus. The mixed salt or synthetic materials were prepared in the laboratory by slurry mixing varying amounts of monoammonium phosphate, anhydrous dicalcium phosphate, potassium chloride, and ammonium nitrate. The analyses of these fertilizers were approximately 12-12-12 and their particle size was 28 to 40 mesh. The nitric phosphates were prepared by nitric acid treatment of rock phosphate followed by ammoniation of the slurry. Ammonium nitrate and monoammonium phosphate were also used in varying amounts in order to obtain the water-soluble series and to maintain the nitrogen–phosphorus pentoxide ratio of approximately 1 to 1. The process of evaporation of the slurry mixes assures that all of the calcium hydrogen phosphate in the final product is in the anhydrous form. None of the fertilizers contained sulfate. The nitric phosphates were of a pulverant nature, being 60 to 100 mesh in size. Potassium chloride was added at planting time to produce materials having a 1–1–1 ratio. Each fertilizer treatment was replicated three times.

Soils. Three surface soils—Hillsdale sandy loam, Conover loam, and Sims clay loam—were used in the spring of 1956, while the following year samples of Conover loam and Wisner clay loam surface soils were studied. A compilation of some of the physical and chemical properties of these soils, together with the quantity of soil and fertilizer used and the method of fertilizer placement employed, is presented in Table I. The soils were placed in glazed porcelain pots, thoroughly moistened, and allowed to dry to the moisture equivalent percentage before planting. An attempt was made to maintain this moisture level during cropping by weighing the pots once a week.

Crops. Corn was the test plant in 1956, while field beans were used in 1957. In the Hillsdale soil, corn was seeded on May 5, and subsequent samplings of the above-ground portion of the plants were taken May 28, June 11, and June 25. Corn was seeded in the Conover and Sims soils on May 11, and subsequent samplings were made June 4, June 18, and July 1. The field beans were planted in both soils on April 27 and final harvest of the plants in the well developed pod stage was made on June 18. All plant materials were dried at

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60° C., ground, and stored for analyses.

Analyses. From 2 grams of the ground plant material, briquets were prepared and activity measurements taken using a G-M tube and scaler. These values were then related to the activity of briquets having known amounts of fertilizer phosphorus. The plant material was then wet-ashed using perchloric acid and phosphorus determined using the colorimetric molybdenum blue method.

Table I. Surface Soils Used for Greenhouse Studies

	Soils under Investigation				
	Hillsdale	*Conover*	*Sims*	*Conover*	*Wisner*
Year studied	1956	1956	1956	1957	1957
Crop grown	Corn	Corn	Corn	Beans	Beans
Soil pH	5.5	6.1	6.7	6.0	7.4
Organic matter, %	2.4	3.9	5.8	3.5	7.0
Available P	Low	Low	Medium	Medium	Medium
Soil per pot, kg.	9	9	9	14	13
P_2O_5 fertilizer, lb./acre	50 200	200	200	100	100
Methods of fertilizer placement	Mixed	Banded	Banded	Banded	Banded

Results and Discussion

In the experiment conducted with Hillsdale soil (Table II) it was found that the degree of phosphate water solubility of fertilizers used had little effect on the growth, phosphorus content, and fertilizer phosphorus absorption of corn plants. Lawton *et al.* (*5*) noted similar results for corn grown on a number of mineral soils. These workers suggested that when pulverant fertilizers are well mixed with soils, the slow dissolution of phosphorus from small particles of low water solubility is just about balanced in terms of plant availability by fixation of phosphorus from highly soluble material. Additional evidence for this theory is given in Figure 1, where the specific activity of corn plant tissue is plotted against the per cent of phosphorus in fertilizer which is soluble in water.

It cannot be interpreted that the Hillsdale soil was originally well supplied with available phosphorus, because a marked response to phosphorus was obtained when the application of phosphorus was increased from 50 to 200 pounds of phosphorus pentoxide per year.

Dry matter production of corn from both mixed salt and commercial-type fertilizers in a mixed placement was essentially the same. Similarly, the phosphorus content of corn plants varied but little for the two types of fertilizers. In contrast, a somewhat higher accumulation of fertilizer phosphorus was found in plants grown in soils treated with the mixed salt fertilizer (Figure 1). Approximately twice as much phosphorus-32 per unit of plant material was absorbed by corn when the rate of phosphate application increased from 50 to 200 pounds per acre. Total uptake of fertilizer phosphorus was three to five times greater where the higher amount of phosphate was applied.

A distinctly different condition was

Table II. Effect of Type of Fertilizer on Dry Weight and Phosphorus Content of Corn Plants Grown on Hillsdale Sandy Loam[a]

		P_2O_5/Acre					
Fertilizer Type[b]	*P in Fertilizer Soluble in H_2O, %*	*50*	*200*	*50*	*200*	*50*	*200*
		Dry Weight of Corn Plants, Grams per Pot		*P Content, %*		*Fertilizer P in Corn, Mg. per Pot*	
Mixed salt	1.5	3.4	10.4	0.25	0.25	1.9	8.9
	9.1	4.1	8.9	0.26	0.26	2.2	8.9
	18.2	3.8	9.6	0.26	0.25	1.7	8.7
	29.6	4.8	10.2	0.27	0.25	2.3	8.7
	41.9	5.3	11.6	0.27	0.27	2.5	10.1
	81.6	4.8	10.0	0.29	0.29	2.0	8.0
L.S.D. at 5% level		0.9	1.6			0.3	1.0
Commercial	11.5	4.2	9.9	0.24	0.24	1.5	7.3
	30.7	3.9	9.3	0.26	0.25	1.5	7.8
	40.0	3.7	9.7	0.26	0.24	1.4	7.3
	59.4	4.6	8.5	0.27	0.26	2.2	7.2
	71.7	5.3	10.1	0.27	0.25	2.3	7.5
	97.0	5.0	9.0	0.29	0.30	2.1	7.2
No P		4.0	5.8	0.25	0.22		
L.S.D. at 5% level		1.2	2.1			0.4	0.9

[a] Greenhouse experiment conducted May 5 to June 25, 1956. Data refer to June 25 sampling.
[b] All fertilizers applied in mixed placement.

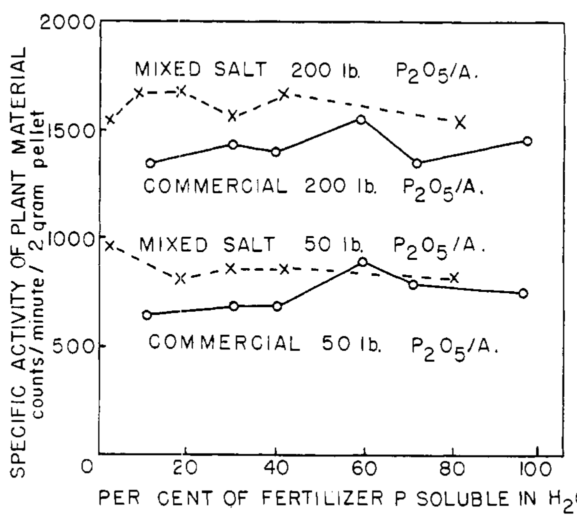

Figure 1. Effect of phosphate water solubility and rate of application of two types of fertilizers on absorption of fertilizer phosphorus by corn plants

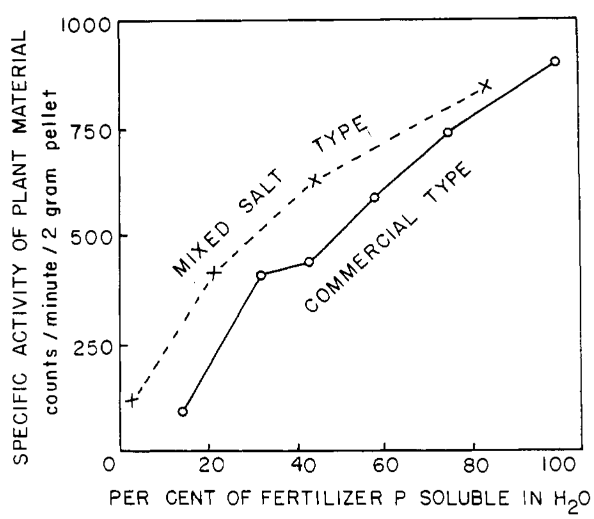

Figure 2. Effect of phosphate water solubility of two types of fertilizers on absorption of fertilizer phosphorus by corn plants

found when fertilizers were banded below and to the side of the corn seed. Data in Table III indicate that the growth of corn plants on Conover and Sims surface soils was greatly improved as the solubility of the phosphate fraction rose from about 10 to over 80%. These soils were also deficient in phosphorus as shown by a comparison of the dry weights of plants grown with and without phosphorus. Similar results have been obtained by other workers (*5, 7, 8, 11*).

The phosphorus content of corn tissues and especially the uptake of fertilizer phosphorus per pot also increased as the phosphate water solubility of the fertilizers increased. The effect of the interaction of localized fertilizer placement—banding—and of the solubility of the phosphate component of the fertilizer on the absorption of fertilizer phosphorus is clearly seen in Figure 2. With both mixed salt and commercial-type fertilizers, the relationship between the activity of corn plant tissue and fertilizer solubility was almost directly linear. Again, phosphorus from the mixed salt or synthetic type was slightly more available than from the nitric phosphate material. Because both the dry matter production and the fertilizer phosphorus content of the crop were a function of the solubility of the fertilizer in water, it is not surprising that accumulation of fertilizer phosphorus increased almost 14 times when data of the commercial type materials of lowest and highest solubility are compared for the Conover soil. Less striking differences were found with the Sims soil.

The results of a comparison between mixed salt and commercial-type fertilizers using field beans as a test plant of fertilizer phosphorus availability are given in Table IV. Both soils studied can be considered as phosphate-deficient under greenhouse conditions, but the growth response to phosphorus on the Conover soil was more pronounced. With minor exceptions the dry weight of bean plants was directly related to the phosphorus solubility of the fertilizer in water. Even more marked was the change in the absorption of fertilizer phosphorus. Whereas dry matter production increased 15 to 50% when comparing the least and most soluble fertilizers, accumulation of fertilizer phosphorus per pot was 4 to 12 times greater when the highly soluble materials were used. Again, no appreciable difference was noted in the behavior of the mixed salt and commercial-type fertilizers with respect to the growth and phosphorus composition of field beans.

The results of greenhouse experiments conducted over a period of 2 years with several soils and crops indicate that no substantial differences were found in the behavior of mixed salt and of commercial-type fertilizers.

Table III. Effect of Type of Fertilizer on Dry Weight, Phosphorus Content, and Fertilizer Phosphorus Uptake of Corn Plants Grown on Two Soils[a]

Fertilizer Type[b]	P in Fertilizer Soluble in H_2O, %	Dry Weight of Corn Plants, Grams/Pot		P Content of Corn		Fertilizer P in Corn Plants, Mg./Pot	
		Conover loam	Sims clay loam	Conover loam	Sims clay loam	Conover loam	Sims clay loam
Mixed salt	9.1	4.2	11.2	0.13	0.21	1.31	5.38
	18.2						
	18.2	4.2	12.3	0.14	0.21	1.85	6.35
	29.6	6.1	10.8	0.12	0.22	2.96	5.71
	41.9	7.0	10.2	0.17	0.26	5.09	7.44
	81.6	9.9	15.5	0.19	0.24	8.30	11.21
L.S.D. at 5% level		1.2	2.3			0.80	1.16
Commercial	11.5	1.9	13.4	0.16	0.22	0.58	7.04
	30.7	3.4	14.1	0.15	0.18	1.83	7.15
	40.0	5.5	11.8	0.19	0.22	4.57	7.36
	59.4	5.0	11.9	0.21	0.24	5.12	11.01
	97.0	6.9	14.9	0.27	0.26	7.99	13.57
No P		1.2	6.9	0.13	0.21		
L.S.D. at 5% level		1.3	2.6			0.62	0.95

[a] Greenhouse experiment conducted May 11 to July 1, 1956. Data refer to July 1 sampling.
[b] All fertilizer applied in banded placement.

Table IV. Effect of Type of Fertilizer on Dry Weight and Fertilizer Phosphorus Uptake of Field Bean Plants Grown on Two Soils[a]

Fertilizer Type[b]	P in Fertilizer Soluble in Water, %	Dry Weight of Plants, Grams/Pot		Fertilizer P in Plants, Mg./Pot	
		Conover loam	Wisner clay loam	Conover loam	Wisner clay loam
Mixed salt	2.5	18.4	20.4	8.8	4.0
	21.6	18.1	21.5	12.2	12.6
	44.3	22.9	21.2	23.1	21.8
	84.4	27.5	23.5	39.5	31.8
L.S.D. at 5% level		2.2	2.5	3.8	4.1
Commercial	11.6	17.3	18.1	6.1	3.0
	32.6	22.3	21.5	21.6	14.6
	43.1	26.0	22.0	29.4	18.2
	58.3	24.8	23.2	32.3	25.9
	75.0	25.2	23.4	33.6	32.9
	100.0	26.5	24.8	39.5	36.0
No P		14.7	17.4		
L.S.D. at 5% level		1.9	2.2	4.2	4.0

[a] Greenhouse experiment conducted April 27 to June 18, 1957. Data refer to June 18 sampling.
[b] All fertilizers applied in banded placement.

Plant availability of phosphorus from mixed salt fertilizers is slightly higher than from commercial types of similar degrees of phosphate water solubility.

It is concluded that the agronomic significance of the content of water-soluble phosphorus of the phosphate fraction of mixed fertilizers can be satisfactorily evaluated through the use of mixed salts or synthetic fertilizers.

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