Greater Phosphorus Efficiency Results From Improved Mobility and Prolonged Availability

Two California studies demonstrate the complexation of phosphorus (P) with organic acids results in prolonged availability, plus more movement away from point of application.

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Phosphorus fertilization of crops is notoriously inefficient. Phosphorus fertilizer reactions determine the dominant, potentially-labile P forms in soils and hence the proportion of soil P that can be released to the soil solution. In broad terms, P binding to soil particles results from surface adsorption or precipitation. The relative contribution of these two processes is related to soil properties, fertilizer form, and cultural practices. Production agriculture is experiencing increasing scrutiny regarding applied P rates versus crop P demand. Improved P availability allows growers to more closely match application rates to crop demand.

In this era of increasing environmental awareness and cost consciousness, applied P fertility research is still under way. Two similar field studies completed in California demonstrate that the complexation of P with organic acids derived from leonardite in a patented, proprietary technology results in prolonged P availability with more movement away from the point of application.

Mendota, California

This was the site of one study conducted by Dr. Husein Ajwa of the University of California in an off-station field. Its soil was a Cerini clay loam with a pH of 7.8, $NaHCO_3$-P of 12 ppm, and about 1.5% $CaCO_3$. The field was bedded up for processing tomatoes on 60-inch centers on 200-foot-long plots.

Methodology. Standard herbicides were used to eliminate weeds and no crop was planted so no roots took up soil P. The soil was pre-irrigated to ensure moisture uniformity. Fertilizer treatments to moistened soil were made once through drip irrigation lines for one hour. Fertigation was followed by 4-3/4 hours of irrigation to ensure all fertilizer was out of the lines and applied uniformly. Further irrigations were applied twice weekly in amounts calculated to generally replace moisture lost to evaporation. Over the six-week duration of the trial, this amounted to about 6 acre-inches of water.

At specified time intervals, soils were sampled in a 3” x 3” grid pattern down and away from an individual drip emitter at right angles to the drip line. Soil samples were taken to the lab, extracted by each of four different methods to test the many soil P fractions present. Fractionation methods include extraction with:

- water or dilute salt solution
- buffered alkaline solutions (sodium bicarbonate)
- dilute concentration of strong alkaline solutions (sodium hydroxide
- dilute concentration of strong acids coupled with heat (HCl).

The water-extractable fraction represents the P present in the soil solution. This available P fraction is very small, but readily accessible to plant roots. The sodium bicarbonate-extractable fraction represents the adsorbed P and the highly soluble calcium phosphate pool in the soil, accounting for one to five percent of the total soil P. The sodium bicarbonate-extractable P method was developed for estimation of plant-available soil P, and is commonly used in alkaline soils as an index of soil P status to determine fertilizer P requirements. The sodium hydroxide-extractable fraction represents the P bound in iron oxides. The organic P and total P fractions can be extracted by boiling with NaOH and with HCL in a digestion block, respectively. The lab methodology used resulted in excellent P recovery, accurate to 0.25 ppm. Samples were taken at 2, 14, 28, and 42 days after the application.

The trial was conducted with four replicates of each of the following treatments in a randomized block design:

- 50 lbs/A P_2O_5 from ammonium polyphosphate (10-34-0)
- 50 lbs/A P_2O_5 from ortho phosphate-merchant grade phosphoric acid (0-52-0)

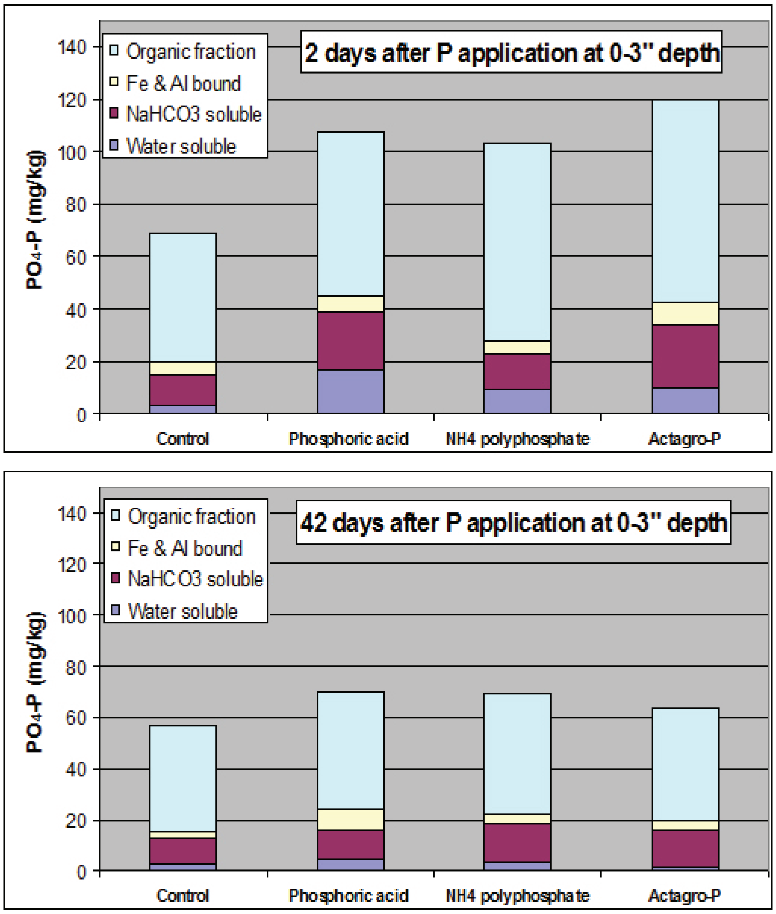


Figure 1. Phosphorus fractions in soil under drip tape (0-3 inches) after 2 days (top) and 42 days (bottom) following drip application of three liquid fertilizers.

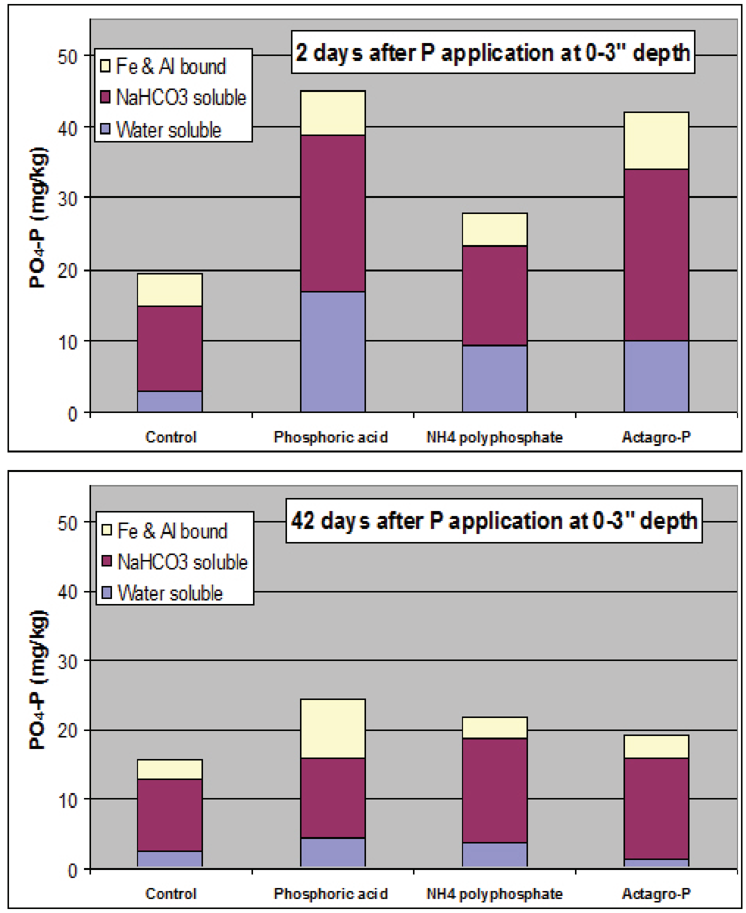


Figure 2. Phosphorus fractions in soil under drip tape (0-3 inches) after 2 days (top) and 42 days (bottom) following drip application of three liquid fertilizers.

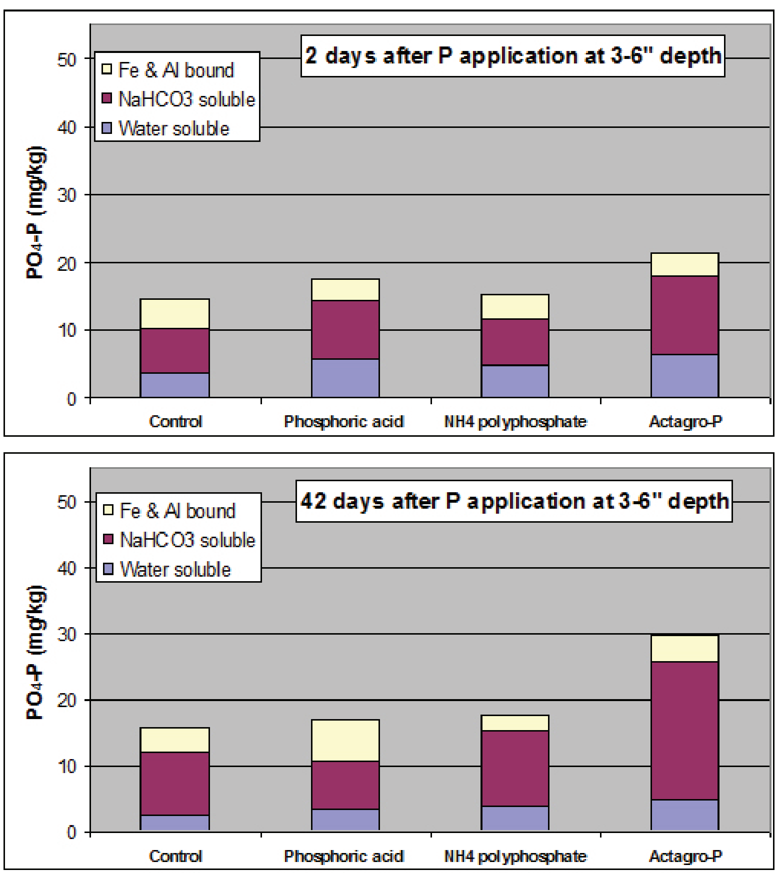


Figure 3. Phosphorus fractions in soil at 3-6 inches depth under tape after 2 days (top) and 42 days (bottom) following drip application of three liquid fertilizers.

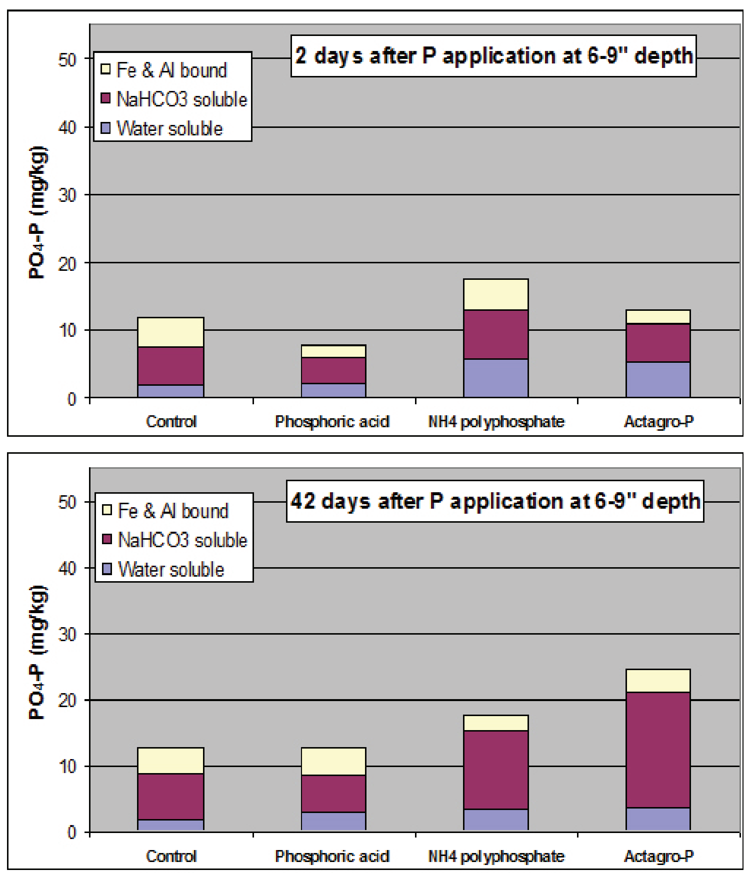


Figure 4. Phosphorus fractions in soil at 6-9 inches depth under tape after 2 days (top) and 42 days (bottom) following drip application of three liquid fertilizers.

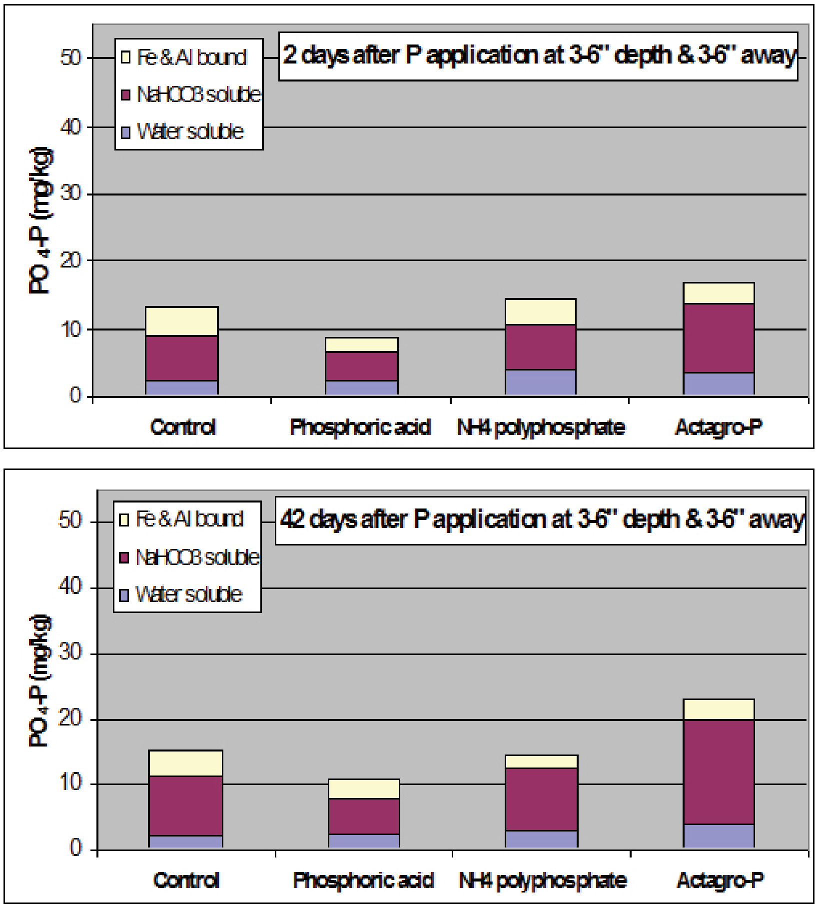


Figure 5. Phosphorus fractions in soil at 3-6 inches depth under tape and 3-6 inches from the tape after 2 days (top) and 42 days (bottom) following application of three liquid fertilizers.

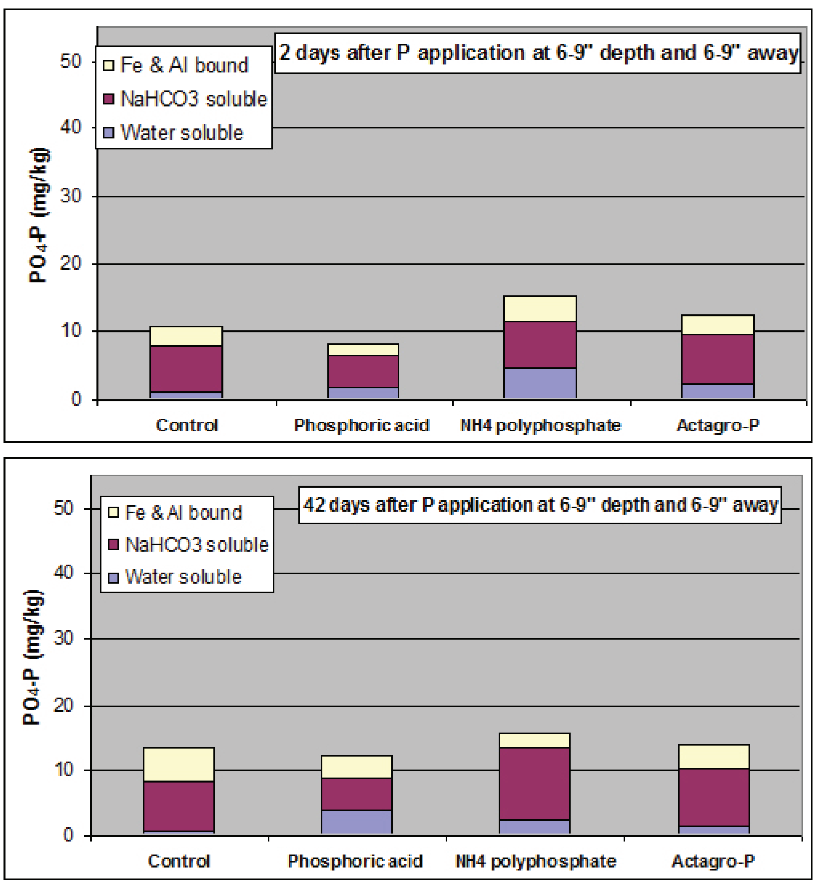


Figure 6. Phosphorus fractions in soil at 6-9 inches depth under tape and 6-9 inches from the tape after 2 days (top) and 42 days (bottom) following drip application of three liquid fertilizers.

- 50 lbs/A P_2O_5 from Actagro Organic Acid phosphate – "Structure" (7-21-0)
- Water-only control.

Trial results. Two days after application, by the $NaHCO_3$ test, the organically-bound P had moved about twice as far as the next best source, which was 0-52-0. All treatments contained similar concentrations of total P (acid digestion) and P in soil organic matter (hot NaOH extract). The application of organically-complexed (reacted) ammonium phosphate (Actagro-P) or ammonium polyphosphate resulted in higher P fraction in the NaOH extract relative to the untreated control. The P fraction in the phosphoric acid treatment was not significantly different from the untreated control, possibly due to dissolution of Fe oxides and Ca compounds in soil after application of phosphoric acid and consequent precipitation when the pH was raised during the extraction with NaOH. The organically-complexed (reacted) ammonium phosphate did not react readily with soil constituents.

After 42 days, however, all treatments contained similar amounts of the NaOH fraction.

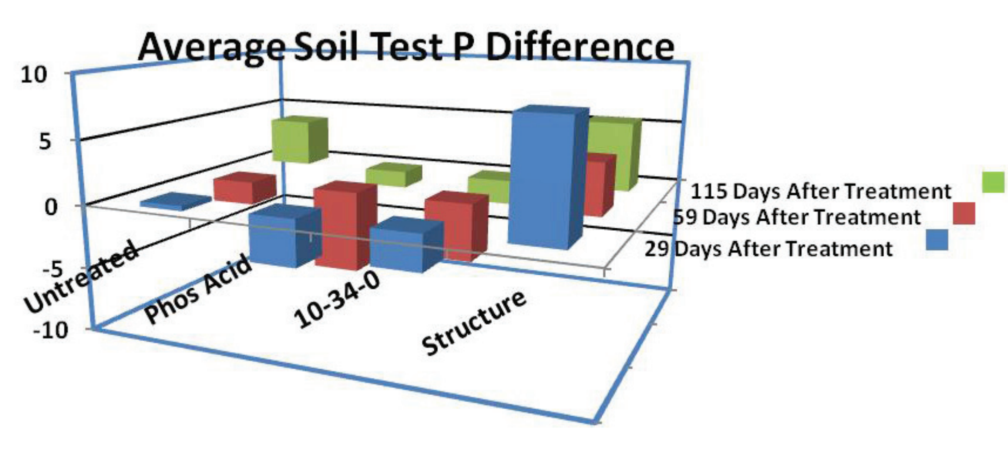
Application of ammonium polyphosphate did not change the plant-available phosphate content at 2 days under the drip tape (depth 0 to 3 inches) as indicated by the Olsen P concentration (Figures 1 and 2). Application of phosphoric acid increased plant-available P shortly after the application and only at depth and distance up to 3 to 6 inches from the drip tape. Application of organically complexed P (Actagro-P) resulted in a higher Olsen-P concentration at a depth greater than 6 inches.

After 42 days following fertilizer application and multiple irrigations, significantly higher concentrations of plant-available P were detected in the Actagro-P treatment compared to other treatments (Figures 3 and 4). The P applied in Actagro-P fertilizer seemed to move twice the distance as compared to the other two fertilizers. There were numerical increases from organically complexed phosphate and ammonium polyphosphate, but not significant differences in P contents among treatments in the 6- to 9-inch depth and 6- to 9-inch distance (Figures 5 and 6).

Fresno, California

This was the site of a study conducted by Dr. Charles Krauter on a campus farm at California State University Fresno. The site selected was a Hanford Sandy Loam soil with a pH of 7.2 and 0.5 percent limestone. Olsen's PO_4-P was 48 ppm.

Methodology. Prior to the trial initiation, two tons of very fine lime (<200 mesh) was spread on the soil and incorporated by cross disking to a depth of about 6 to 8 inches with two passes of an offset double disk. Soil was sprinkler irrigated two days later with half-inch water to speed up chemical reactions. Flat soil was pulled into beds on 5-foot centers. Fifteen days later, pretreatment soil samples were taken. A special 12-inch x 12-inch x 1.5-inch box soil sampler was used to determine P movement down and away from the surface drip line. The sampler was driven into the soil with a mallet at right angles to the drip line. The full sampler was dug out with a shovel, opened, and soil segmented into sixteen



	Untreated	Phos Acid	10-34-0	Structure
29 Days After Treatment	-0.4	-3.7	-2.8	8.6
59 Days After Treatment	-1.9	-6.6	-4.6	4
115 Days After Treatment	3.9	-1.4	-2	5.5

Figure 7. Average soil test change over time.

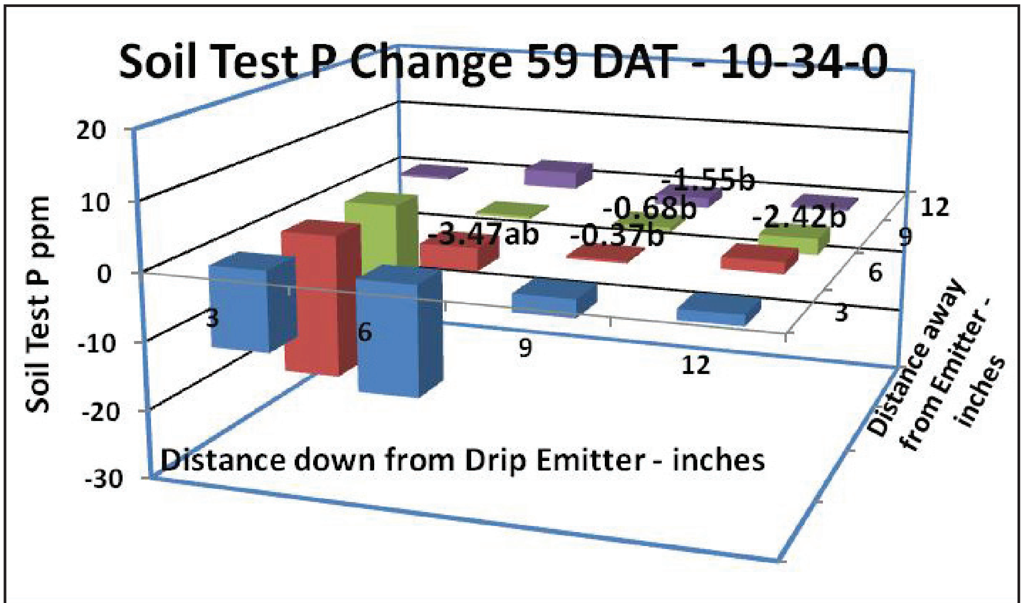


Figure 8. Average Soil P Change in 12"X12" grid - 59 days after treatment.

Inches down and away	UNTREATED 3	6	9	12	Inches down and away	PHOSPHORIC ACID 3	6	9	12
3	-9	-16.57	-7.08	-2.22	3	-28.13	-28.37	-6.23	-2.58
6	-2.02	-2.78ab	-0.83	1.38	6	-27.72	-18.08b	-6.23	2.17
9	-0.32	1.23ab	0.53b	-2.42b	9	-5.12	-3.35b	8.03a	-2.3 b
12	2.6	3.83	4ab	-1.27	12	4.75	-0.05	5.45a	1.48

Inches down and away	10-34-0 3	6	9	12	Inches down and away	ACTAGRO 7-12-0 3	6	9	12
3	-11.88	-21.83	-14.97	0.42	3	-20.57	7.32	11.57	-4.15
6	-16.05	-3.47ab	-0.38	2.68	6	-15.82	7.52a	2.35	16.38
9	-2.58	-0.37b	-0.68b	-1.55b	9	4.15	10.1a	12.28a	11.5a
12	-1.52	1.7	-2.42b	-0.42	12	6.12	10.85	8.08a	-2.92

Values followed by different letters are statistically different at p=0.10

Table 1. CSUF Average Soil P Change Down and Away from Emitter, 59 days after treatment.

3-inch x 3-inch squares and removed for analysis. Each replicate's soil sample consisted of three subsamples, the following treatments applied in six replicates:

- 150 lbs/A P_2O_5 from 10-34-0 (Ammonium Polyphosphates)
- 150 lbs/A P_2O_5 from 0-52-0 (Phosphoric acid)
- 150 lbs/A P_2O_5 from 7-21-0 Actagro Organic Acid-P ("Structure")
- Water-only control

Application to moistened soil was made over 30 minutes through a small plot fertigation apparatus to each 5' x 40'-long plot in a replicated block design. Treatments were applied simultaneously with the drip irrigation water. Water was applied three additional hours after fertigation and then subsequently applied twice weekly to replenish what was lost to evaporation. Post application irrigations totaled 8.5 acre-inches. The soil was regularly weeded to prevent P uptake by plant roots.

Soil samples were taken at 2, 29, 59, and 115 days after application. Samples were analyzed for $NaHCO_3$-P and pH at the CSUF laboratory. Individual soil P values down and away from emitters were compared by treatment and date as well as the change in soil P levels from the initial post-treatment levels. At the 10 percent level there was intermittent statistical significance in the results both as to change in soil P from the pretreatment levels and simply as soil test P levels.

Trial results. Phosphoric acid reduced available P under the emitters. The acidity from the P treatments may have enhanced P solubility, especially directly under the emitter. There may have been some P leaching in this area as the soil P level reduction is greatest under the emitter where water volume was highest. Alternatively, the acidity of this treatment may have dissolved more applied lime faster and resulted in the formation of limited solubility calcium phosphates. Overall performance evaluation indicated limited improvement over the Control, just at 59 days (Figures 7 and 8). Available P was highest overall with the Organic Acid complexed phosphate. As demonstrated by the significant positive changes in soil test P at 59 days, there were areas of the 16 block sample grid where higher levels of available P were maintained over a longer time. When the 16 soil test values from a sampling date were averaged, there was a strong trend toward the Actagro material maintaining the highest level throughout the 1 foot x 1 foot grid for the longest duration. There was a high level of variability in soil pH and P samples, which likely resulted from the short time for lime reaction and the lack of thorough soil mixing with large heavy implements. This variability limited obtaining more significant treatment differences from the apparent trends. In contrast to Dr. Ajwa's work, 10-34-0 performed similarly to the control in most all evaluations (Table 1).

Benefiting environment

Improved P availability would allow growers to more closely match application rate to crop requirement to the environment's benefit. Many of the potential benefits of greater P mobility and prolonged P availability revolve around greater P efficiency. This seems a natural fit with reduced tillage and no-till cropping. Surface application or shallow placement of such an efficient P material would see needed P move down into the soil with rainfall or irrigation, not simply be carried off the field adhered to soil particles. Applied beneath the soil surface, greater efficiency P fertilizer maximizes crop response for the pounds applied.

Grower benefits:

- More P availability/mobility allows flexibility with application timing and methods
- Increased P availability improves crop P nutrition for yield and quality
- Increased P mobility allows better P nutrition in all reduced tillage situations.
- Reduced soil tie-up of P means more of applied fertilizer makes it into the crop.

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