Applying Phosphorus Through Drip Systems

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The permanency of the water delivery systems such as drip irrigation systems and of some crops makes it desirable, if not essential, to have the capability of applying fertilizer through the irrigation system. Such a method of fertilizer application saves labor and energy and allows crop demand to determine the timing of nutrient application.

The application of nitrogen fertilizer through irrigation systems is common practice. However, the application of phosphorus fertilizer through drip or sprinkler irrigation systems is not commonly recommended because of the possible precipitation of phosphates in irrigation pipe and emitters and because it is generally assumed that phosphorus does not move freely into the root zone when applied to the soil surface.

Studies by Rolston *et al.* (*California Agriculture*, August 1974) and others have shown that organic phosphate compounds can move through several cm of soil before the compound is enzymatically hydrolyzed and undergoes soil reactions common to the orthophosphate ion. Several features of organic phosphates make them especially useful as phosphate fertilizers capable of being applied through an irrigation system. Glycerophosphoric acid, for example, is infinitely water soluble and the Na and Ca salts are soluble at the rate of 70 and 2 g/100 ml, respectively. Glycerophosphate does not undergo chemical hydrolysis, and has a relatively high P analysis. It is hydrolyzed enzymatically in soils, thus preventing leaching below the root zone. These features are the primary requisites for a phosphate compound that might be suitable for injection through a drip irrigation system without precipitation in the system while placing phosphorus in the root zone from surface applications.

Field and laboratory investigations were conducted in 1974 to determine if glycerophosphate could be used to supply phosphorus to crops, to compare the efficacy of phosphate application through a drip system with the most efficient mechanical method of phosphorus placement, and to evaluate the movement of inorganic and organic phosphates in soils when applied through a drip irrigation system.

Plant uptake

Initial soil samples (Panoche clay loam at University of California West Side Field Station) indicated a relatively low bicarbonate soluble P level of approximately 7 ppm. Tomatoes (*Lycopersicum esculentum* var. Cal Ace) were grown with two rows per bed, using six beds, 12 meters long, per plot. The drip lines were placed in the middle of each bed between the two rows with an emitter situated every 90 cm for the length of the plot for a total of 72 emitters per plot.

The experiment consisted of six treatments with four replications in a randomized complete block design. The treatments were: no applied P; 60 kg of P_2O_5/ha. as treble super phosphate (TSP) applied in a band below the seed; and four treatments using glycerophosphate applied in split applications through the drip system by injecting P solutions into the manifold drip line of each plot by means of a positive displacement pump. The three applications were made with 50 percent at early vegetative stage, 25 percent two weeks later, and 25 percent two weeks after the second application. Because sufficient quantities of reagent grade glycerophosphate were difficult to obtain, a substitute material which contained approximately 50 percent of the P in the orthophosphate form was used in the first application. Reagent grade calcium glycerophosphate was used for the next two applications. The total amount of P coming from both organic and inorganic sources for the drip-applied treatments was 25, 50, 100, and 200 kg/ha. of P_2O_5. Approximately three-fifths of the total P applied was in the organic phosphate form.

Field studies of P uptake by tomato seedlings sampled at thinning show that when P was applied through the drip system at a rate of 60 kg of P_2O_5/ha., the P content of tomato seedling leaves was

The disadvantages of clogging drip lines and assumed lack of movement have prevented the application of orthophosphate through drip irrigation systems. Orthophosphoric acid can be applied without these disadvantages when extreme care is used. Organic phosphates such as glycerophosphate will move farther in soils, are easily applied through the drip system without clogging, and P is readily used by plants.

Irrigation

greater than if the same rate had been applied in a band beneath the seed at planting. Application through the drip system at rates of 15 and 30 kg of P_2O_5/ha. resulted in the same P content in the leaves as the banded treatment at 60 kg of P_2O_5/ha. As the seedlings matured, the difference between treatments diminished probably as warmer soil temperatures increased the soil solution P content and root volumes increased.

By the time of the first harvest (only ripe tomatoes harvested), no differences in plant growth were observed. There was an increased yield of ripe tomatoes from applied P. However, there were no statistically significant differences between rates of applied P, indicating that the lower rates applied through the drip system were as effective in influencing maturity as the higher rate applied in the conventional manner. There was no difference between treatments in total yield of both ripe and immature fruit for either the final harvest or the combined harvests.

A second field experiment, conducted to evaluate possible differences in P uptake from drip-applied glycerophosphate and phosphoric acid, showed that P was supplied to the plants equally well when either source was applied through the drip system.

Movement in soil

Soil samples were obtained from selected plots of the field experiment to which P was applied either as orthophosphate or as glycerophosphate through the drip system. A grid was used starting with the emitter as the zero point and collecting soil at 5 cm intervals to a distance of 35 cm in the horizontal and vertical plane at right angles to the row. Bicarbonate soluble phosphate determinations were made on the air dry samples.

Contrary to the common assumption that the orthophosphate ion moves very little from point of contact with the soil, five- to tenfold increases in movement were observed when P was applied

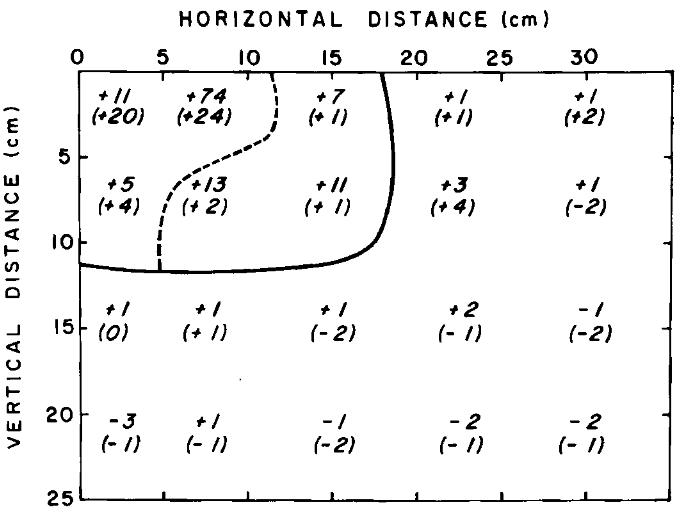

Fig. 1. Influence of source on P distribution beneath an emitter in the field for a Panoche clay loam soil. The broken and solid curves are the approximate maximums for P movement for orthophosphoric acid (values in parentheses) and glycerophosphate (values without parentheses) applications at a rate of 15 kg of P_2O_5/ha.

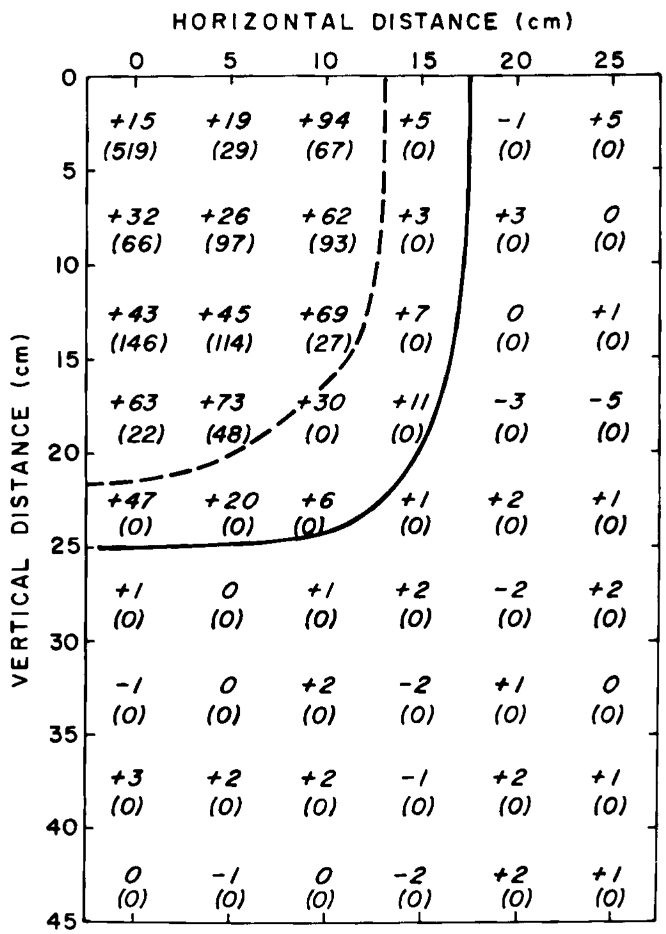

Fig. 2. Influence of source on P distribution beneath a simulated emitter in the laboratory for a Yolo loam soil. The broken and solid curves are approximate maximums of P movement for orthophosphoric acid (values in parentheses) and glycerophosphate (values without parentheses) at an application rate of 30 kg of P_2O_5/ha.

through the drip system at rates comparable to those applied uniformly. The extent of movement was determined by rate of application. At the rate of 90 kg of P_2O_5/ha., the movement of P was 25 cm laterally and 30 cm in depth, compared with 10 cm laterally and 10 cm in depth for the 15 kg of P_2O_5/ha. rate. The drip system has a much greater effective application rate because it applies phosphorus on a very small surface area, creating greater movement. For example, at 7,200 emitters per ha., a uniform application rate of 15 kg of P_2O_5/ha. applied through the drip system would give an application rate equivalent to 66,000 kg of P_2O_5/ha., assuming the P was applied within a 1 cm radius of the emitter. For an 8 cm radius, which is comparable to the amount of horizontal movement of inorganic P observed in the field and laboratory for the same rate, the effective rate of application is 1,000 kg of P_2O_5/ha. This is comparable to the movement caused when high rates of P_2O_5 are applied on the soil surface.

Furthermore, calculations of the volume of soil to which increased P levels have been attained from a uniform broadcast application are of the same order of magnitude as the volume of soil to which elevated P levels are observed when it is applied through a drip system. Consequently, it is logical that the chemistry of P reactions in a given soil would dictate that the volume of soil in which increased levels of P are measurable should be similar no matter how the P is applied.

Glycerophosphate applied through an emitter moved approximately 5 to 10 cm farther (fig. 1) in the horizontal plane than did orthophosphate, according to field measurements. The organic phosphate moved farther than the inorganic phosphate because of the delay in release of the orthophosphate ion from the organic moiety which requires an enzymatic hydrolysis. Although organic phosphate moved slightly farther than inorganic phosphate, the plant uptake of P was not greatly affected by 5 cm of increased movement as indicated in the discussion on plant uptake.

A laboratory experiment was designed to evaluate the extent of phosphorus movement when applied to soils in a way duplicating drip irrigation placement. In a laboratory experiment orthophosphoric acid containing radioactive P (^{32}P) was slowly dripped onto the soil surface at one spot in the center of a box filled with Yolo loam soil. The ^{32}P was used to distinguish the applied P from the soil P which may have dissolved as a result of the acid application, and to unmistakably determine the extent of inorganic P movement under these conditions. The rate of P application was equivalent to 30 kg of P_2O_5/ha. and at the same emitter density (72 per plot) as in the field studies. The same procedure was used to apply calcium glycerophosphate. The glycerophosphate did not contain ^{32}P.

After two days, the soil was sampled on a 5 cm grid in both the horizontal and vertical plane, using the point of application as the zero point. The P and radioactive P content was measured in bicarbonate extracts of the soil samples. The movement of orthophosphoric acid was ascertained from the distribution of ^{32}P. The movement of glycerophosphate was ascertained from the increase in bicarbonate soluble P above the background level. Glycerophosphate moved approximately 5 cm farther both horizontally and vertically than inorganic phosphate (fig. 2)—movement similar to that observed in the field.

Both phosphoric acid and glycerophosphate apparently move far enough below emitters at small application rates to be a satisfactory means of placing P in the root zone of drip irrigated crops. However, the problem of inorganic phosphate precipitation clogging drip lines is of great concern and can only be prevented by careful adjustment of the pH of the irrigation water receiving the inorganic phosphate. Glycerophosphoric acid and its soluble salts cause no such concern since the phosphate ion is only hydrolyzed enzymatically in the soil; this also allows sufficient movement in the soil for the P to be placed in the root zone. Furthermore, in other types of irrigation systems where concentrated applications cannot be achieved (as with drip irrigation), the movement of the organic phosphate can be utilized to achieve the desired P placement.

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WALNUT

Walnut blight, caused by the bacterial organism *Xanthomonas juglandis*, is a disease of worldwide importance on walnuts. In northern California, blight may occur on a number of commercial varieties of English walnuts, although late-blooming varieties generally escape infection by leafing out after most of the spring rains are over.

Buds, catkins, leaves, shoots, and nuts of current season's growth are all susceptible to infection. On leaves, the parenchyma tissues, midrib, lateral veins or the rachis and petiole may all be involved; dark brown to black irregular-shaped spots on young leaflets cause malformed older leaves.

Nut infection accounts for a major part of the economic loss. Rain during pollination commonly results in blossom-end infection of young nutlets. The first sign of blight appears on the stigma in the form of a rapidly enlarging black spot which might subsequently involve the entire fruit. Occasionally infection enters the young nutlet, causing a breakdown of the internal tissues with only limited ex-

TABLE 1. EFFECTIVENESS OF MATERIALS AGAINST BLIGHT ON ASHLEY WALNUTS, SACRAMENTO VALLEY, 1974.

Material*	Rate/ 100 gal.	Mean % infected nuts†
Copper-Count-N	3 gal.	18 a
Bordeaux mixture	8:5:100	18 a
PQ8	2 pt.	31 b
Untreated check	—	32 b

* Sprayed by air-blast sprayer at the rate of 100 gal./acre on April 16 and May 2, 1974.

† Three hundred nuts per replicate were evaluated on May 23, 1974 (1200 nuts/treatment). Values followed by a common letter are not significantly different at the 0.05 level, according to Duncan's multiple range test.