

tage to the internal quality of late-harvested oranges.

An increase in potassium affects some quality factors differently in oranges than in lemons. A higher potassium level increases orange peel thickness and reduces the percentage of orange juice, but decreases lemon peel thickness and increases the percentage of lemon juice. The increase in the percentage of lemon juice, in conjunction with an increase in the acid concentration in the juice (both of which are associated with an elevated potassium level), results in a marked increase in pounds of acid per ton of fresh lemon fruit. This is a particular advantage in lemon fruit used for processing.

Creasing of oranges can be reduced by increasing the potassium level, regardless of the initial level. There are, however, no leaf analysis guides that can be used to predict the incidence of creasing.

#### Potassium application

Potassium fertilizer should not be applied indiscriminately either as a foliar spray or soil application. Leaf values below 0.7% would in most cases indicate a need for potassium. With leaf values above 0.7%, potassium fertilization can be of value where creasing of oranges or small fruit sizes are problems. As indicated in the charts, other factors are also

influenced and should be considered before potassium is applied when leaf levels are above 0.7%.

Suggested rates for foliar applications are 30 lbs of potassium nitrate per 100 gallons of spray (in water only). For a mild deficiency one annual spray suffices, but for a moderate to severe deficiency, two annual sprays are required. Although applications at all times of the year have been effective, somewhat better results have occurred from applications shortly after expansion of the major growth flush of the year.

The nitrogen in the potassium nitrate sprays supplies some nitrogen to the tree, so that the amounts of nitrogen applied in the normal nitrogen program can be reduced.

Unfortunately, soil applications of potassium are sometimes ineffective on California citrus, even several years after a massive application of fertilizer. Five to 10 lbs of potassium sulfate (sulfate of potash) applied in a band around the dripline of each tree, for two consecutive years is sometimes effective, and if so, is likely to remain effective for several years. Leaf analysis can indicate need for repeat applications. On poorly-drained soils, salinity problems have occurred with applications of potassium sulfate greater than 10 lbs per tree.

Although not evaluated experimentally on citrus, potassium nitrate could be applied to the soil instead of potassium sulfate. Potassium nitrate could supply the total amount of nitrogen required since 7.4 lbs of potassium nitrate contains 1 lb of nitrogen, and 2.7 lbs of potassium (which is equivalent to the potassium in 6.1 lbs of potassium sulfate). Where soil applications have been effective, the only difference in response between soil- and foliar-applied potassium has been a more rapid response to the foliar-applied material. Potassium chloride (muriate of potash) should not be used on citrus in California because of the damaging effects that have been encountered from use of this material.

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## GLYCEROPHOSPHATE

### *as a phosphate fertilizer*

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Commonly available commercial phosphate fertilizers move very little from point of contact with the soil—resulting in inefficient utilization of surface-applied materials. An organic phosphate compound, glycerophosphate, has been shown to move through the soil with applied irrigation water. Potential utilization advantages of glycerophosphate as a fertilizer include: possible correction of deficiencies in mid-season; application with the water in sprinkler or drip irrigation systems; and proper placement, and timing of surface applications.

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**A**LTHOUGH THE USE OF inorganic phosphates as a means of supplying phosphorus to plants is well known, much difficulty is encountered in the topical application of these materials as fertilizers. After 60 years of scientific investigation, with several sources of inorganic phosphate, there is little doubt that phosphorus moves very little from point of contact with the soil. Commonly available commercial phosphate fertilizers hydrolyze chemically (on contact with the soil solution) to the orthophosphate ion and are adsorbed or precipitated almost immediately. The situation is especially serious for irrigated agriculture in arid areas of the world inasmuch as the surface 2 to 10 cm (0.8 to 4 inches) of soil dries rapidly, resulting in no active roots in that region of the soil profile. There-

fore, there is inefficient utilization (commonly 5% to 10%) of surface-applied phosphate fertilizers.

A partial solution to the inefficiency of surface-applied phosphate fertilizer has been banding and mechanical placement in the root zone. However, in permanent crops such as alfalfa, orchards, and turf, subsurface applications are seldom used because of damage inflicted upon the root system and the stand of the plants. Also, where irrigation is accomplished by permanent installations such as drip and solid set sprinkler systems, it is physically impractical and economically not feasible to inject phosphorus below the soil surface. Consequently, it seems essential that a fertilizer without the undesirable characteristics of presently available phosphate fertilizers be developed.

Certain organic phosphate compounds have been shown to move through soils and supply the phosphorus requirement of plants. There has been little development of this knowledge to the point where it can be of use because: (1) commercially available means of manufacturing the products were lacking, and (2) inorganic sources of phosphate fertilizers were low in cost. These two conditions have changed along with the development of new cultural management techniques that combine to make the use of a water-soluble, non-corrosive, relatively high analysis source of organic phosphorus (capable of moving through the soil) a desirable phosphate fertilizer. The results of initial research on the movement of such a compound, glycerophosphate, are presented in this report for two soils.

### Hanford sandy loam

Three 60 cm (2 ft) PVC columns, 7.6 cm (3 inches) in diameter were packed with air-dry Hanford sandy loam soil. The soil columns were similar to the one shown in the sketch. Phosphorus (P) was added to one column at the rate of 54 kg of  $P_2O_5$ /hectare (48 lbs  $P_2O_5$ /acre) by mixing glycerophosphate with the upper 15 cm (6 inches) of soil. In a second column, the same amount of glycerophosphate was dissolved in water and applied with 23 cm (9 inches) of irrigation water. No P was added to the third column. The columns were irrigated with 23 cm (9 inches) of water by ponding on the soil surface. As the water reached the bottom of the columns it was removed through porous cup suction probes. The effluent was collected in fractions of 10 to 20 ml and analyzed for total P.

The concentration of total P in the effluent as a function of the volume of effluent collected is given in graph 2. The concentration of P in the effluent for the column with no P added remained at approximately 1.0 ppm throughout the experiment. The concentration of P in the effluent for the column where the P was mixed with the top 15 cm of soil increased to approximately 2.3 ppm after 500 ml of effluent was obtained and then decreased to 1.0 ppm. For the column where the P was added with the irrigation water, the effluent concentration began increasing after 200 ml of effluent was obtained, reaching a maximum of 3.7 ppm at 500 ml, and then dropping back to 1.0 ppm after 700 ml of effluent was obtained.

The results demonstrated that glycerophosphate moved with the water through

60 cm of sandy soil to substantially increase the total P in the effluent. The movement of glycerophosphate initially mixed with the top 15 cm of soil was not as great as for the case when the P was added with the water. The differences in effluent concentrations for the two methods of application were probably due to water flowing predominately in large pores. When the P was mixed with the soil, water would bypass many small pores containing glycerophosphate. When P was added with the irrigation water, the glycerophosphate would quickly move through the large pores to the bottom of the column.

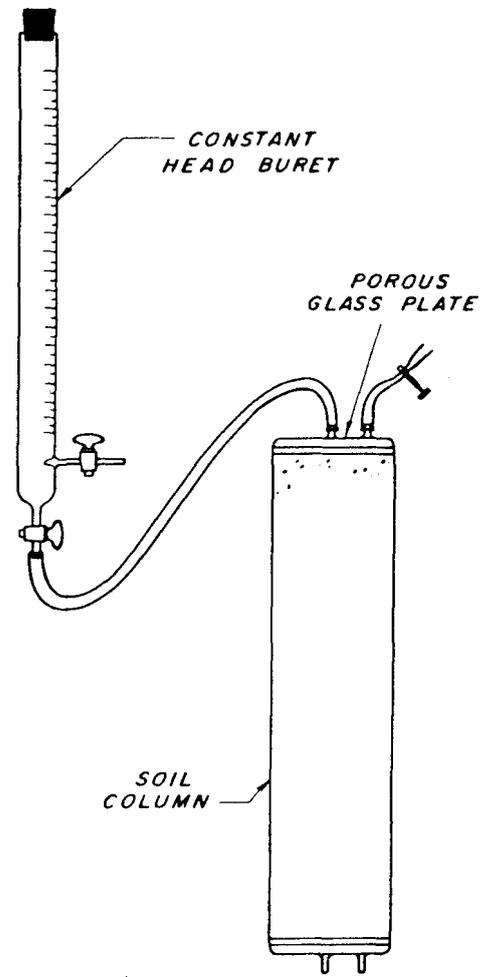
### Panoche clay loam

Movement in a clay loam soil was studied using the same apparatus shown in the sketch. Two 30-cm (1-ft)-long acrylic plastic columns, 7.6 cm (3 inches) in diameter, were packed with air-dry Panoche clay loam soil to a bulk density of 1.20 gm/cm<sup>3</sup>. A solution containing inorganic P (potassium phosphate) equivalent to 150 kg of  $P_2O_5$ /hectare (134 lbs/acre) in 350 ml of water, was infiltrated through the upper porous plate of one column. The volume of solution used was approximately equivalent to a 3-inch irrigation.

A solution containing organic P (glycerophosphate) equivalent to 150 kg of  $P_2O_5$ /hectare in 350 ml of water was infiltrated through the upper porous plate of the other column. The initial and final infiltration rates into the columns were approximately 9 cm/hr (3.5 inches/hr) and 1.8 cm/hr (0.7 inches/hr), respectively. At the termination of irrigation with 350 ml of solution the columns had wetted to 22 cm (8.7 inches). The soil columns were immediately sectioned into 1 cm increments in the upper 10 cm of soil and 2 cm increments below 10 cm. The concentration of water-soluble P in the soil sections was determined.

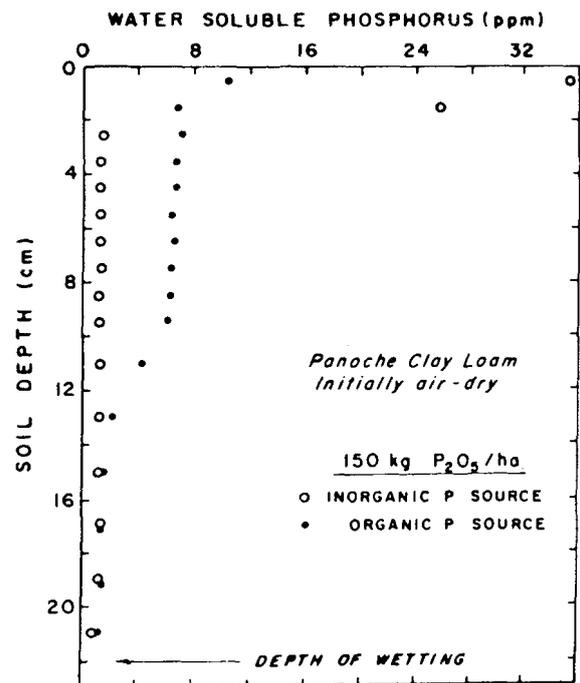
The concentration of water soluble P as a function of soil depth for both the inorganic P source and the organic P source is given in graph 1. The results demonstrate that the inorganic P moved no deeper than 2 cm (0.8 inches) below the soil surface. The organic P moved approximately 13 cm (5.1 inches) into the soil, with increases in water soluble P from approximately 1.0 ppm to 6.5–7.0 ppm over most of that depth. It was apparent that although the glycerophosphate moved quite readily with the water, it did not move as far as the wetting front.

It was postulated that glycerophos-



Apparatus for applying fertilizer solution to soil.

GRAPH 1. CONCENTRATION OF WATER-SOLUBLE PHOSPHORUS WITHIN COLUMNS OF PANOCHÉ CLAY LOAM AFTER INFILTRATION WITH SOLUTIONS OF INORGANIC AND ORGANIC PHOSPHORUS



phate is hydrolyzed enzymatically to the orthophosphate ion by phosphatase enzymes. Thus, with hydrolysis of glycerophosphate to the orthophosphate ion, the material was able to undergo the normal precipitation and adsorption reactions with soil to prevent further movement. Apparently, the hydrolysis reaction was rapid enough to cause complete hydrolysis of the glycerophosphate by the time the solution infiltrated 13 cm (5.2 inches) of Panoche soil, at the infiltration rates of this experiment.

It is expected that the depth of movement of glycerophosphate will be highly dependent upon the infiltration rate, inasmuch as the enzymatic hydrolysis of the material is a time-dependent reaction. Consequently, the initial water content of the soil should also influence the depth of movement.

### Potential usage

It has not been feasible to make corrective applications of phosphorus to plants in mid-season, because of the inability to enter the field with equipment to achieve the proper placement of phosphate. With organic phosphate it becomes possible to achieve placement by topical soil applications, or application in the irrigation water. This capability would be of great value where specialized irrigation such as sprinkler and drip systems make it extremely difficult to achieve placement mechanically. Furthermore, topical soil applications may be "irrigated in," thus, preventing destruction of plants or damage to roots of perennial plants such as orchards, alfalfa, and turf.

Since the normal phosphate fertilizer use is by application of the phosphorus before planting, a greater opportunity for phosphate "fixation" occurs, resulting in low efficiencies. By being able to adjust the time of application more in relation to the nutrient demand of the plant,

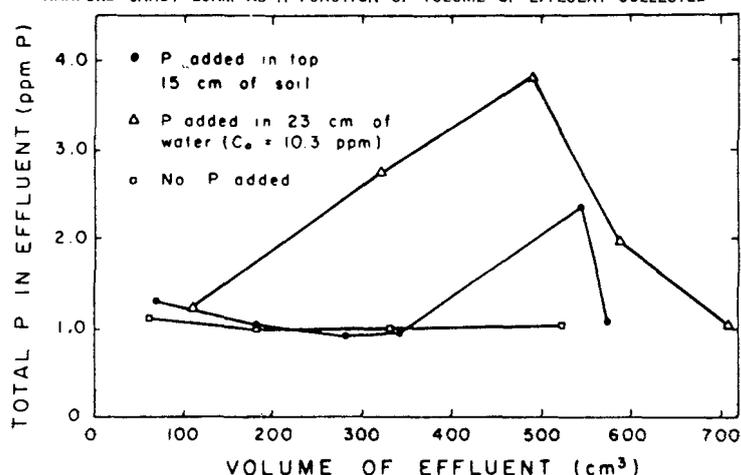
higher efficiencies may be obtained. By proper placement and timing of surface applications, an increased efficiency in the use of a limited natural resource may also be achieved.

In addition, glycerophosphate may decrease a potential environmental hazard in phosphate enrichment of surface waters. Since erosion of the soil surface is one of the contributors of phosphorus to surface waters, the ability of the organic phosphate to move into the soil profile decreases the buildup of phosphorus near the soil surface, thereby decreasing the potential of unwanted environmental change. The rapidity of enzymatic hydrolysis in the soil prevents the movement of the organic phosphate into the ground water.

The projected cost per unit of glycerophosphate P is presently two to three times that of common inorganic phosphorus fertilizers. However, this cost may be reduced with refinements in synthesis techniques. If an increased fertilizer efficiency is attained, the total amount needed to grow a crop would decrease, thus decreasing total costs. In addition, growers may be willing to pay more for phosphorus fertilizer if placement and labor savings can be realized for specialized cropping and irrigation systems. The development of glycerophosphate as a phosphate fertilizer, and learning how to manage its placement, may be extremely beneficial in providing food in the most efficient manner—yet maintaining an obligation to minimize or prevent unwanted environmental changes.

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GRAPH 2. CONCENTRATION OF TOTAL PHOSPHORUS IN THE EFFLUENT FROM THREE SOIL COLUMNS OF HANFORD SANDY LOAM AS A FUNCTION OF VOLUME OF EFFLUENT COLLECTED



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## BORON of the

When the California Aqueduct was completed, it brought high quality water from northern California to replace poor quality local well water, which usually contained high levels of boron and salts and made much of the area unsuitable for many crops.

New experimental and commercial plantings of a variety of crops are continuing to be made to determine whether production, quality and economics warrant more extensive plantings. Grapes are one of the crops receiving wide interest.

This study indicates that suitability of the area for grapes is strongly related to a reduction in soil boron, which accumulated in soils during irrigation or was present from natural causes. Boron can be removed by leaching, although copious amounts of good quality water are needed to remove it. However, good irrigation practices with the new water supply can be expected to reduce boron to acceptable levels within a few years for all crops in well-drained soils. Soil and plant analysis can be used to evaluate the progress in reclamation and to determine soil suitability for planting.

**I**N 1968, 10 NEW GRAPE PLANTINGS (4 to 6 years old) and one old planting (48 years old) in western Fresno County were selected for salinity and boron studies. All vineyards had previously been irrigated only with well water, but a switch to canal water was anticipated. Initial soil samples and plant tissue samples were collected in 1968 from a typical location in each vineyard. Vine appearance and leaf symptoms were also