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A Definitive Test to Determine Whether Phosphite Fertilization Can Replace Phosphate Fertilization to Supply P in the Metabolism of 'Hass' on 'Duke 7'

(A Preliminary Report)

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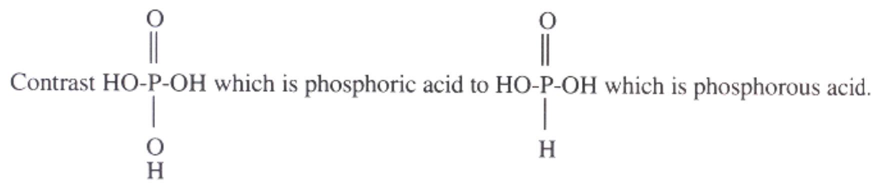
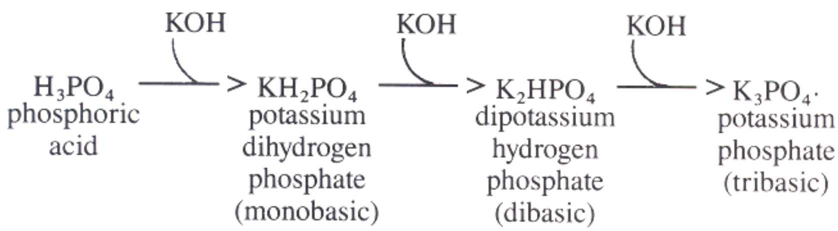
Phytophthora root rot causes extensive damage to feeder roots of avocado. If uncontrolled, it results in a progressive decline in tree health and the eventual death of the tree (12, 14, 15). *Phytophthora* root rot is a major factor limiting avocado production world wide. Effective control *of Phytophthora* root rot of avocado has been achieved with fosetyl-al (Aliette® Rhone-Poulenc, aluminum tris-o-ethyl phosphonate) through either foliar application (1) or trunk injection (5). Coffey and Bower (3) suggested that phosphorous acid was the toxophore responsible for inhibition of *Phytophthora* spp. when host plants were treated with fosetyl-al. Degradation of fosetyl-al to phosphorous acid within plant tissues was confirmed by Saindrenan *et al.* (11). Subsequently, Darvas and Bezuidenhout (4) reported that phosphorous acid was more effective in controlling avocado root rot than fosetyl-al. For avocado growers, potassium phosphite (the salt which results from the neutralization of phosphorous acid with KOH) used as a trunk injection is an inexpensive and effective product for *Phytophthora* root rot control (2). Trunk-injected potassium phosphite initially moves to the leaves via the xylem and then to the roots with the photosynthate via the phloem (7). Thus far, it appears nontoxic at fungicidal dosages to either plants or animals. Potassium phosphite has been used in extensive injection programs with citrus and avocados in South Africa and Australia with no apparent toxicity, to date. In California, neither phosphorous acid, nor its salt, has been registered for use as a fungicide. To my knowledge, no commercial sponsors are pursuing registration. Demonstration that phosphite can replace phosphate fertilizer as a source of P in avocado metabolism may provide a scientific basis for avocado growers to use phosphite.

The element P, atomic number 15 and atomic weight 30.9, has valences of +5 or +3. In phosphoric acid (H_3PO_4), P has a valence of +5. There are three positive charges from the three hydrogens plus the five positive charges from the single atom of P to balance the eight negative charges of the four oxygens. In solution, phosphoric acid dissociates, losing hydrogens to form H_2PO_4-', HPO_4-^{2}, and PO_4-^{3}. HjPCV^1 and HPO_4-^{2} are the forms of phosphorus most readily taken up by plants. In phosphorous acid (H_3PO_3), P has a valence of +3. Thus, the three positive charges from the three hydrogens plus the three positive charges from the single atom of P are balanced, in this case, by only three oxygens, which provide the six negative charges. In solution, phosphorous acid dissociates to H_2PO_3-' and HPO_3-^{2}. PO_3-^{3} does not exist because one of the hydrogens is bound directly to the phosphorus atom and does not dissociate in water.

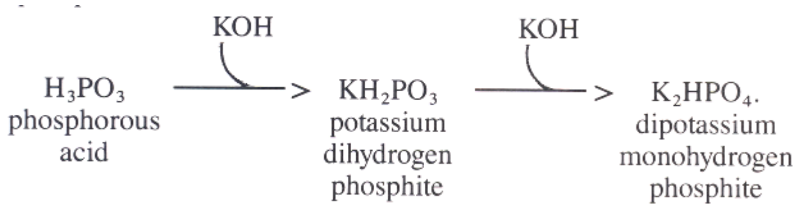


When phosphoric acid (H_3PO_4) and phosphorous acid (H_3PO_3) are neutralized with a base, such as potassium hydroxide (KOH), sodium hydroxide (NaOH), or ammonium hydroxide (NH_4OH), a salt results. The salt of phosphoric acid is a phosphate. For example:



For convenience, all forms of the salt are routinely referred to as potassium phosphate. Potassium dihydrogen phosphate and dipotassium hydrogen phosphate serve as phosphate fertilizers.

When phosphorous acid is neutralized with a base, the salt that forms is a phosphite.



An organic compound containing phosphorous acid is a phosphonic acid. When neutralized, it forms a phosphonate. Fosetyl-al is such a salt: aluminum tris-o-ethylphosphonate.

It is important to note that potassium phosphite slowly oxidizes in air to phosphate (16). Microorganisms are not required for this conversion. Thus, if potassium phosphite is demonstrated to be nontoxic at fertilizer levels and if it can be demonstrated that the conversion of phosphite to phosphate occurs at a reasonable rate in the soil, on the foliage, or within the tree after trunk injection, then it would seem that potassium phosphite might potentially serve as a slow-release phosphate fertilizer.

The effect of phosphorous acid (H_3PO_3) on plant growth has been studied previously (6, 13), because the H_3PO_4 used to convert rock phosphate into concentrated superphosphate fertilizers (so-called "double" and "triple" superphosphates) contains H_3PO_3 in a range up to 5 % of the H_3PO_4 used (6). The response of the plants to phosphite varied. For some species, growth was normal at phosphite to phosphate ratios of 3:1; others grew poorly when phosphite was present even at low levels. Millet grew almost as well with phosphite alone as it did with phosphate alone. Plants that were sensitive to phosphite exhibited chlorosis. Liming the soil intensified this effect during early plant development, but also increased the conversion of phosphite to phosphate, which resulted in improved plant growth over the season. No tree crops were included in the study (6).

Previous work in my lab (8, 9, 10) provided evidence that phosphorus deficiency caused changes in nitrogen metabolism in the leaves of *Citrus* species and summer squash *(Cucurbita pepo* L.): *(i)* leaf nitrate content increased; *(ii)* leaf ammonia content increased; (*iii)* the activity of the pathway for the *de novo* biosynthesis of arginine increased; and *(iv)* leaf arginine content increased. Resupplying phosphate to the phosphorus-deficient plants returned the levels of nitrate, ammonia, and arginine and rate of arginine biosynthesis to that of the phosphorus-sufficient control plants.

In our research on phosphorus nutrition of avocado, we have taken two approaches. The first approach was to withhold phosphorus from a set of young 'Hass' avocado scions on clonal 'Duke 7' rootstocks, less than one year from the bud, to induce phosphorus deficiency and the accompanying changes in nitrogen metabolism, and then to recover the plants from phosphorus deficiency with phosphite or phosphate supplied to the soil or foliage or through stem injection. The second approach was to replace phosphate with phosphite in the fertilization of healthy, phosphorus-sufficient trees to determine if they can be maintained as phosphorus-sufficient plants. If phosphite cannot be utilized as a source of metabolically functional phosphorus, the phosphite-fertilized plants will exhibit the changes in nitrogen metabolism characteristic of phosphorus-deficient plants.

Phosphorus-deficient 'Hass' avocado scions on 'Duke 7' rootstocks receiving weekly soil applications of 500 ml of 1.0 mM potassium phosphate or phosphite or foliar applications of 1 g/liter potassium phosphite sprayed to the drip appeared to be recovering from phosphorus deficiency equally well. No biochemical analyses had been done at the time this progress report was due. Phosphorus-deficient plants injected with 1.0 ml of 6 % potassium phosphite exhibited about 2.5 to 5 cm of shoot-tip dieback from the point of injection only; the phosphorus-sufficient plants did not exhibit any deleterious effects from the injections.

Phosphorus-sufficient 'Hass' avocado scions on 'Duke 7' rootstocks in experiments employing the second approach of replacing phosphate with phosphite applied to the soil or to the foliage appeared no different from the phosphate-fertilized plants after two months of phosphite fertilization.

The results, thus far, show no adverse effects from the use of phosphite as a phosphorus fertilizer at the rates we are applying to the soil or foliage. It is too early in the research to answer whether phosphite can replace i phosphate as a source of P in the metabolism of the avocado.

References

1. Bertrand, A. J. Ducret, J. C. Debourge, and P. Horriere. 1977. Etude s proprietes d'um novelle famille de fungicides: Les monoethy phosphites metalliques: Characteristiques physiochimiques et proprietes hiologiques. Phytiatr-Phytopharm. 26: 3-18.
2. Coffey, M. D. 1987. *Phytophthora* root rot of avocado—An integrated approach to control in California. Plant Dis. 71: 1046-1052.
3. Coffey, M. D., and L. A. Bower. 1984. *In vitro* variability among isolates of eight *Phytophthora* species in response to phosphorous acid. Phytopathology 74: 738-742.
4. Darvas, J. M., and J. J. Bezuidenhout. 1987 Control *of Phytophthora* rot of avocados by trunk injection. S. Afr. Avocado Growers Assoc. Yrb. 10: 91-93.
5. Darvas, J. M., J. C. Toerien, and D. L. Milne. 1984. Control of avocado root rot by trunk injection with phosetyl-al. Plant Dis. 68: 691-693.
6. Maclntyre, W. H., S. H. Winterberg. L. J. Hardin, A. J. Sterges, and L. B. Clements. 1950. Fertilizer evaluation of certain phosphorus, phosphorous, and phosphoric materials by means of pot cultures. Agron. J. 42: 543-549.
7. Piccone, M. F., A. W. Whiley, and K. G. Pegg. 1987. Curing root rot in avocados. Aust. Hortic. 5: 5-115.
8. Rabe, E., and C. J. Lovatt. 1984. *De novo* arginine biosynthesis in leaves of phosphorus-deficient *Citrus* and *Poncirus* species. Plant Physiol. 76: 747-752.
9. Rabe, E., and C. J. Lovatt. 1986. Phosphorus deficiency results in a state of ammoniatoxicity. Plant Physiol. 81: 774779.
10. Rabe, E., and C. J. Lovatt. 1986. Relative phosphorus dependency of citrus rootstock cultivars is reflected in their nitrogen metabolism. J. Amer. Soc. Hort. Sci. 111: 922-926.
11. Saindrenan, P., G. Darakis, and G. Bompeix. 1985. Determination of ethyl phosphite, phosphite, and phosphate in plant tissues by anion-exchange high performance liquid chromatography and gas chromatrography. J. Chromatography 347: 267-273.
12. Stener, R. E., M. R. Kaufmann, and G. A. Zentmyer. 1978. Effect of *Phytophthora* root rot on water relations of avocado: interpretation with a water transport model. Phytopathology 68: 595-602.
13. Thornton, S. F. 1931. Experiments with the Neubauer method for determining nutrient deficiencies in soils. J. Amer. Soc. Agron. 23: 195-208.
14. Whiley, A. W., K. G. Pegg. J. B. Saranah, and L. J. Forsberg. 1986. The control of *Phytophthora* root rot of avocado with fungicides and the effect of this disease on water relations, yield, and ring neck. Aust. J. Exp. Agric. 26: 249-253.
15. Whiley, A. W, K. G. Pegg. J. B. Saranah, and P. W. Langdon. 1987. Influence of *Phytophthora* root rot on mineral nutrient concentrations in avocado leaves. Aust. J.

Exp. Agric. 27: 73-77.

16. Windholz, M. (ed.). 1983. The Merck Index (10th edition). Merck and Co., Inc. Rahway, NJ, p. 1103.