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Evaluation of Potassium Silicate and *Quillaja saponaria* Extract for Control of *Phytophthora cinnamomi* Root Rot of Avocado

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Organic avocado production in California has been increasing in recent years; approximately 5% of acreage is now organic or has the potential to be organic. Avocado root rot caused by *Phytophthora cinnamomi* is still the most important disease, and an organically approved substitute for phosphonate treatments for root rot control would be highly desirable. Work done in South Africa indicated that potassium silicate (a naturally mined substance) appeared to induce at least a temporary tolerance to root rot in mature avocado trees. Some of the avocado growers in California also believe that saponin derived from yucca juice or extract from *Quillaja saponaria* may also have the ability to control root rot. This potassium silicate work was repeated on replant trees in California using 'Hass' grafted on clonal 'Duke 7' rootstocks planted in a grove where mature avocado trees had died from root rot. Trees in the field trial were treated with root drenches just before planting in July 2007 and thereafter three times in 2007 and five times in 2008. The drenches included low and high rates of potassium silicate (1% and 2% Silmatrix, 2 L/tree), low and high rates of *Quillaja* extract (2% and 4% QL Agri, 2 L/tree), a buffered phosphorous acid drench (30 mL/L of 0–28–25, 2 L/tree), and a water control. There were 20 replications for each treatment. Results for the potassium silicate and the *Quillaja* extract were disappointing compared to the buffered phosphorous acid with final tree health ratings (0 = healthy, 5 = dead) as follows: four trees at stage 4 and 5 low rate potassium silicate, seven trees at stage 4 and 5 high rate potassium silicate, four trees at stage 4 and 5 low rate *Quillaja* extract, five trees at stage 4 and 5 high rate *Quillaja* extract, two trees at stage 4 and 5 phosphorous acid, and nine trees at stage 4 and 5 water control. Tree growth (as measured by tree height) was also disappointing for the potential organic treatments.

Phytophthora root rot of avocado caused by the fungus *Phytophthora cinnamomi* is considered to be the most important disease of avocado in California since its description by V.A. Wager in 1942 (Shepherd, 1991). The disease is less important in areas of the world that have calcareous soils, such as the southern Florida commercial avocado production areas, largely due to the suppressive nature of calcium to the fungus (Broadbent and Baker, 1974; Messenger-Routh, 1996; Pegg et al., 1982). A great amount of research has been conducted in searching for (and breeding) more tolerant rootstocks, but progress has been slow and the disease is still an important problem (Menge et al., 1992). It was discovered in the 1980s that fosetyl Al (Aliette[R]) or its breakdown product potassium phosphonate seemed to induce a temporary host resistance to the fungus (Coffey, 1992). Phosphonate is a salt of phosphorous acid and potassium hydroxide, and growers in California often use this material applied either through the irrigation system or as a trunk injection to promote the health of avocado trees. Potassium phosphonate is registered as a fertilizer in California.

Many of the conventional (non-organic) growers in California are using this material if they suspect they have the disease. They must rely on this chemical exclusively and there is a concern that resistance to the chemical may appear if there is not at least one other chemical for them to use in a control program. Resistance has already been noted in South Africa (Duvenhange, 1999). In addition, there is a need for the growing number of organic growers in California to have an organically approved substance that could induce a tolerance to the disease. Potassium silicate has been shown to be a biologically active substance that could induce a temporary resistance to several fungus diseases, a few of which include powdery mildew in cucumber (Adatia and Besford 1986), brown rot in peach (Biggs et al., 1997), and anthracnose in avocado (Anderson et al., 2005). There is one report from South Africa that showed potassium silicate to have activity against *P. cinnamomi* root rot in mature avocado trees that was equal to or better than phosphonate.

Another natural product that might show activity against root rot could be juice from the yucca plant or from *Quillaja saponaria*, plants that are native to desert regions and have high titers of saponins. Saponins have been reported to reduce surface tension in the nutrient solution of hydroponic systems in greenhouses and cause disintegration of the membrane of *Phytophthora* zoospores, with a resultant 100% control of the disease (Nielsen et al., 2006). Some avocado growers in California have been using yucca juice for a natural product control of *P. cinnamomi*, but there is little data to support this as a control method in the field. One of the companies that supplies yucca juice (Desert King International LLC, San Diego, CA) also supplied us with a pure extract juice of *Quillaja saponaria*, a desert plant native to Chile. Although this experiment began with the first treatment of saponins as yucca

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juice, the application was changed to an extract of *Q. saponaria* because the company was interested in marketing this product to agriculture with the name QL Agri.

Materials and Methods

A site was chosen in the Valley Center area of San Diego County for this trial. At this site, a large number of avocado trees had recently died from *P. cinnamomi* root rot (verified by lab tests). The older diseased and dead trees were removed and young nursery trees (‘Hass’/‘Duke 7’ clonal rootstocks) were planted in July 2007. Trees in the field trial were treated with root drenches just before planting and thereafter every other month during the growing season, three times in 2007 and five times in 2008. The treatments were low and high rates of potassium silicate (1% and 2% Silmatrix[R]), low and high rates of saponin extract (2% and 4% QL Agri[R]), a buffered phosphorous acid drench (30 mL/L of 0–28–25) and a water control. Silmatix[R] consists of 29% potassium silicate in water. The first application of saponin extract (before dilution in water to 2% and 4%) consisted of pure yucca juice, but the subsequent applications consisted of pure *Q. saponaria* extract with the trade name QL Agri[R]. All drenches were applied in 2 L water/tree.

There were 20 replications of the six treatments; treatments were randomized within each replication. The soil was a uniform sandy loam with a decomposed granite base.

Results

Tree height of the living trees was measured from the soil level to the growing tip. Measurements were taken four times during the course of the 18-month trial (one time in Nov. 2007 and three times in 2008, concluding with a measurement in Nov. 2008). A tree health rating based on the University of California system for avocado root rot (0 = healthy, 1= mild disease symptoms of the foliage, 2 = moderate, 3 = severe, 4 = almost dead with just a few leaves, 5 = dead) was taken in Nov. 2008. All trees (20 trees/treatment) were included in the tree health rating.

Tree height measurements did not show means that were significantly different ($P = 0.05$) during the first three measurements. During the fourth measurement at the end of the trial in Nov. 2008, the mean from phosphonate-treated trees was significantly greater than the control (non-treated) trees. The other treatments were not significantly different than the phosphonate-treated or the control trees. Likewise, the health ratings for the phosphonate-treated trees were significantly better than control trees, and the other treatments were not significantly different than the phosphonate-treated trees or the control trees (Table 1).

The trial was discontinued after the last measurements in Nov. 2008 when it was determined that several of the treatments had a high number of dead (rating 5) and almost dead (rating 4) trees. The combination of these two categories totaled as follows: four trees for 1% potassium silicate, seven trees for 2% potassium silicate, four trees for 2% *Q. saponaria* extract, five trees for 4% *Q. saponaria extract*, two trees for the phosphonate treatment, and nine trees for the water control (Fig. 1).

Discussion

Results from this trial for the two treatments that could potentially be organically approved methods for avocado root rot control were disappointing. We did not get an equal or better control than the standard phosphonate treatment.

A report from South Africa by Bekker et al. (2006a) indicated that silicon applied at a concentration of 20 mL/L and at a rate of 20 L/tree as a soil drench (three drenches per year) controlled root rot significantly better than phosphorous acid trunk injections and the untreated control (as measured by tree health ratings and root densities). They worked with mature 10-year-old ‘Hass’ on ‘Duke 7’ rootstocks. In our trial, we used young nursery trees (2 years from seed) and we had a sandy loam soil (we are not sure of the soil type at the South Africa location). Both the South African trial and our trial had the same rootstock (‘Duke 7’).

Potassium silicate has been effective against *P. cinnamomi* in in vitro studies (Bekker et al., 2006b). At rates of 20 mL/L and 40 mL/L in potato dextrose agar (PDA) agar plates, they had 100% control of mycelial growth.

It is difficult to speculate as to why our results were not as good in the field study, but it is possible that the *P. cinnamomi* isolate at the California site is more virulent than at the South Africa site, or there could be any number of other circumstances (e.g., more biological control in the soil at the South African site).

Saponins were reported by Zentmyer and Thompson (1967) to be effective in the control of phytophthora root rot in avocado seedlings but only when alfalfa meal (a source of saponins) was mixed into the soil, not when applied on the soil and mixed in. When purified water-soluble saponins were mixed into PDA, 75% of zoospore germination was inhibited at 1000 ppm. In other work, *Phytophthora capsici* zoospores were 100% controlled in hydroponic experiments by adding 20 mL/L saponins (Nielsen et al., 2006) and 100% disease was controlled in pepper plants by using this rate of saponins added to the recirculating water.

Table 1. Summary of treatments, tree height measurements, and number of dead and almost dead avocado trees after 18 months. The experiment began with 20 trees/treatment.

Treatment	Rate of product/tree at time of treatment[z]	Tree ht (cm) after 18 months[y]	No. of dead trees after 18 months (rating = 5)	No. of almost dead trees after 18 months (rating = 4)
Non-treated		126 b	2	7
Phosphonate	62.5 mL/2L	147 a	2	0
1 % Silmatrix	20 mL/2 L	139 ab	0	4
2% Silmatrix	40 mL/2 L	140 ab	2	5
2% QL Agri	40 mL/2 L	136 ab	1	3
4 % QL Agri	80 mL/2 L	133 ab	0	5

[z]Treated trees were drenched 2 d prior to planting in July 2007 and subsequently three times during the summer growing season in 2007 and five times during the growing season in 2008. The trial was concluded in Nov. 2008.

[y]Means within a column group followed by the same letter are not significantly different based on the Tukey-Kramer HSD test, $P = 0.05$.

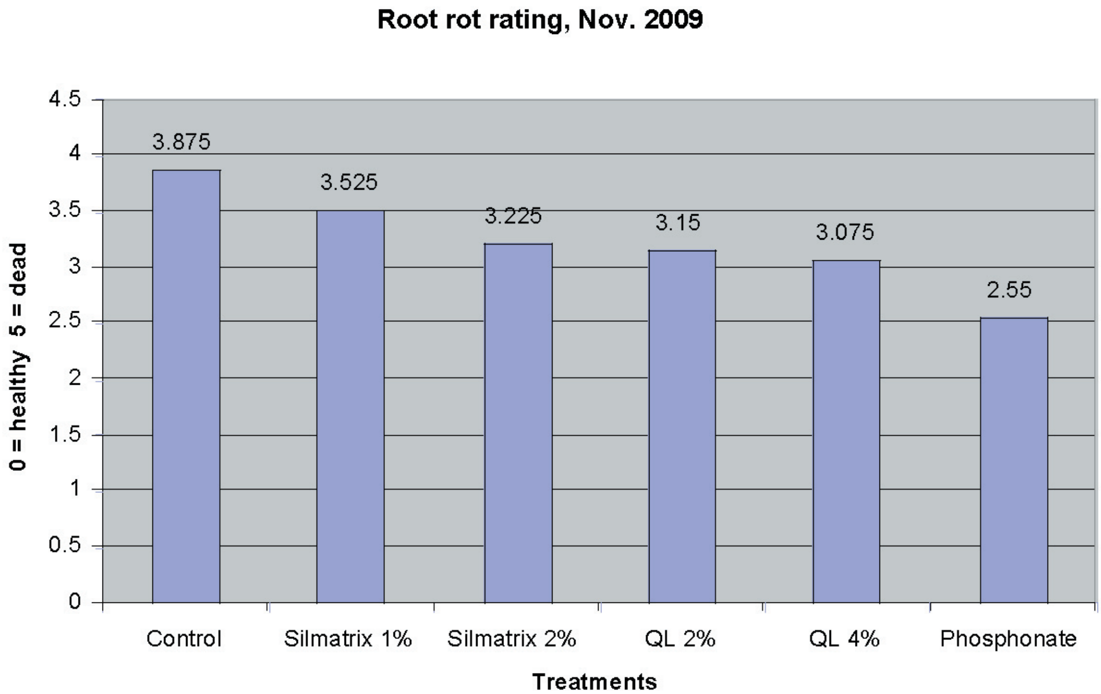

Fig. 1. Tree health rating of avocado trees after 18 months. Health rating according to the University of California rating: 0 = healthy, 5 = dead. The mean for the phosphonate treatment was significantly different than the control ($P = 0.05$) (Tukey-Kramer HSD test). The other treatments were not significantly different than any other treatment.

In the hydroponic systems, the pathogen is constantly exposed to the saponins. In our trials the pathogen was exposed to the saponins once every 2 months (during irrigation). It remains to be seen whether constant exposure in the field would control avocado root rot and whether this method would be economically viable for the grower. Despite the rather poor results in our trial, it may be useful to pursue these two materials and look at higher rates and/or more frequent applications. It could be interesting to look at a combination of these products, perhaps in rotation with phosphonate, in order to reduce the chances of resistance developing to phosphonate alone.

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