Using Phosphorous Acid for the Control of Phytophthora

Dr. Gary Bender
Farm Advisor-Subtropical Horticulture
Fallbrook, CA

100 Years

What is phosphorous acid?

- Phosphorous Acid
  - A solid that when mixed with water forms **phosphonic acid**.
  - Phosphonic Acid has a pH so low that it will burn plants (en.Wikipedia.org)

What is phosphorous acid?

- **Phosphites** are formed when phosphorous acid is mixed with a basic compound.
- Mixed with potassium hydroxide, the pH can be raised and the product is now called **potassium phosphite** (safe for plants)

Be Careful!

Phosphate vs. Phosphite

- Phosphate is a plant nutrient and is found in fertilizers such as ammonium phosphate. These do not have an effect on plant diseases

Phosphate vs. Phosphite

- Phosphonates and Phosphites are not good plant nutrients, but they do have a direct effect on reducing plant diseases caused by oomycetes (these include *Phytophthora and Pythium)*

Phosphate vs. Phosphite Facts

- Phosphorous acid is not a fungicide, but a fungistat.
- It turns on the defense mechanisms of the plant to ward off certain pathogens.
- Root rot is not caused by a fungus, but a brown algae with fungus-like properties.
- Phosphonates only work against Phytophthora and Pythiums

Terminology and History

- An organic chemical that contains a phosphorous acid is known as a phosphonic acid.
  - When neutralized, a phosphonic acid is called a phosphonate.

Terminology and History

- Phosphites are a salt of phosphorous acid and do not contain an organic chemical.
- Most commercially available phosphorous acid based products are phosphites, such as a 0-29-26 fertilizer like Formula 1, Phosguard or Nutriphite.

Terminology and History

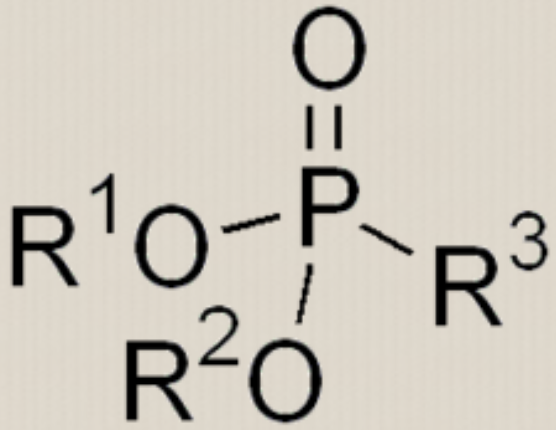
- An aluminum phosphonate salt is known as fostetyl-Al (the chemical name).
  - The trade name for this particular one is Aliette and was produced by a French company Rhone-Poulenc.

Terminology and History

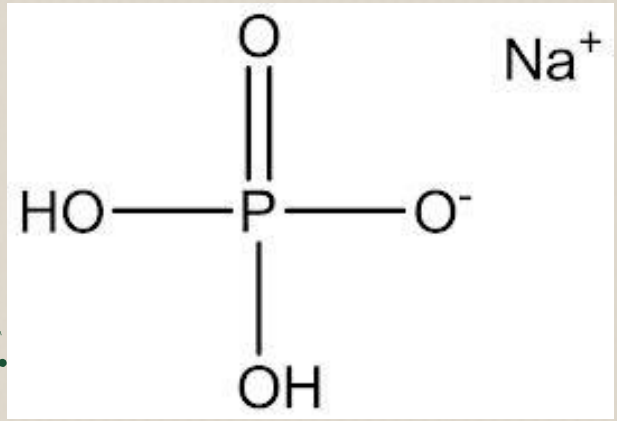
- South African plant pathologists were the first to show that Aliette and phosphorous acid could control root rot in avocado. (Darvas, J.M. et.al 1984)

Phosphorous Acid

Just a one oxygen difference!



- Phosphonate

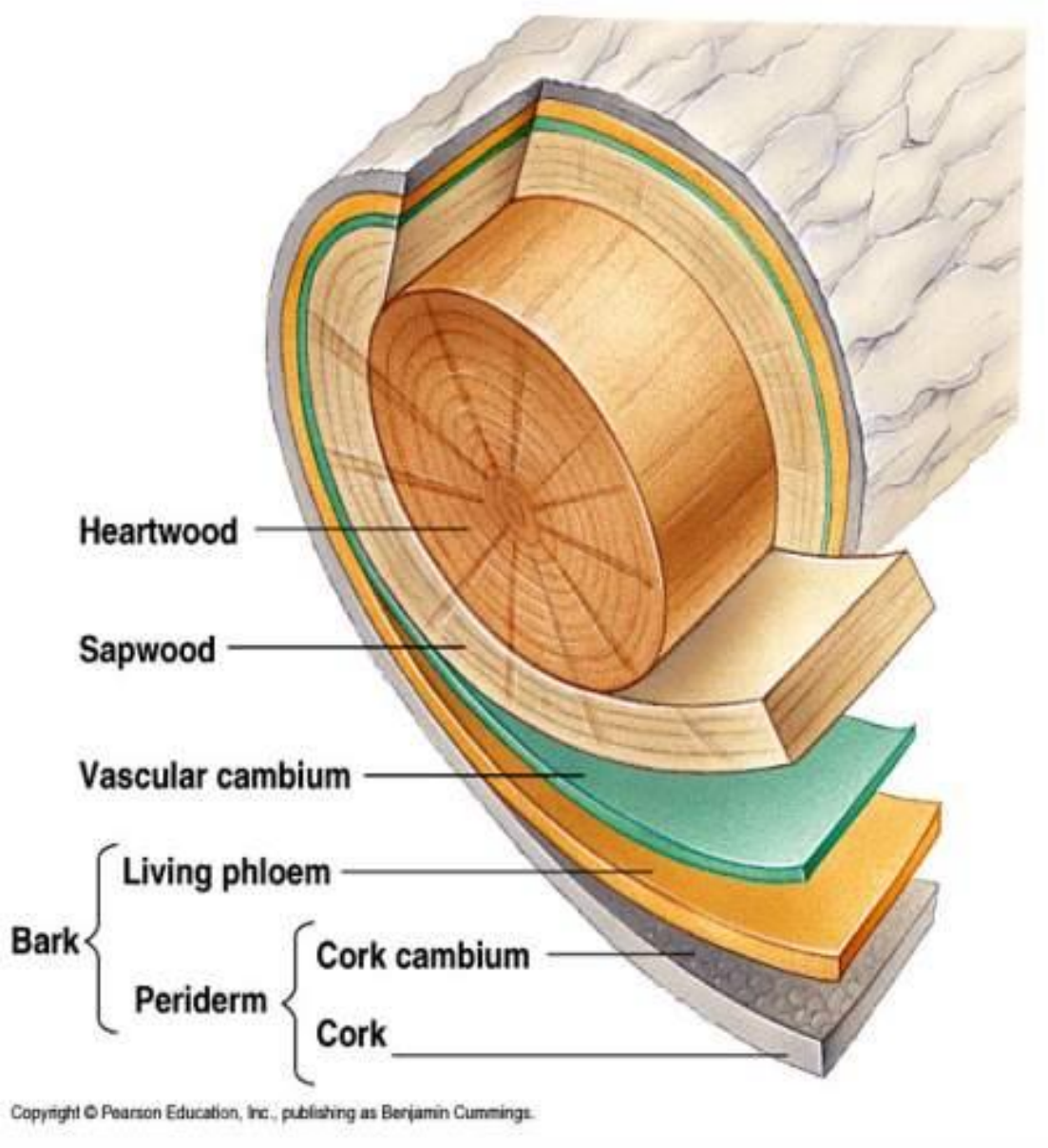


- Phosphate

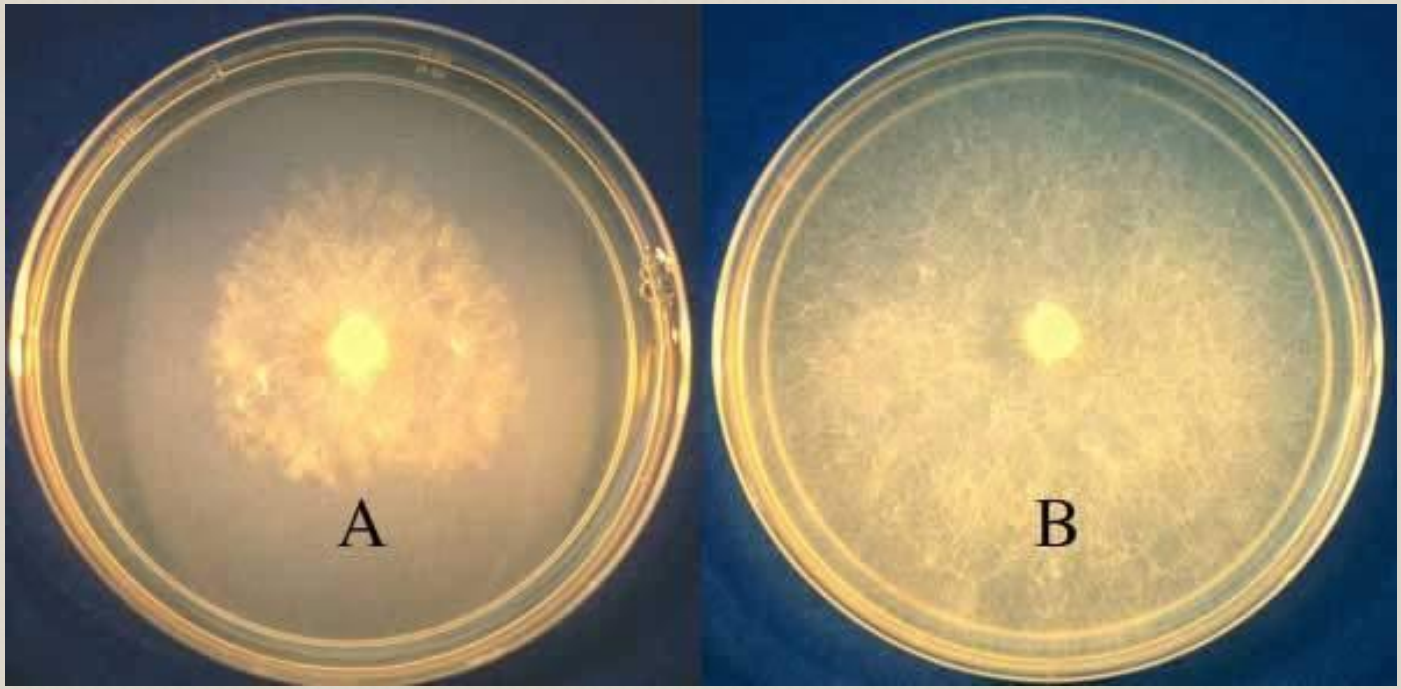
Phosphorous Acid

- Phosphorous acid is not a very good fertilizer, but it has some interesting fungicidal properties.
- When injected into the xylem (the water-conducting tissue), it moves up to the leaves in the water stream; then, it moves back down to the roots in the phloem (the sugar-conducting tissue just inside the bark).
- This is a unique product; most chemicals move up to the leaves and stay in the leaves.

Phosphorous Acid



Pythium aphanidermatum with phosphite vs no phosphite



More History

- Aliette was registered briefly in California as an emergency Section 18 registration for trunk injection in the late 1980's.
- Rhone-Poulenc soon lost interest in pursuing a full pesticide registration when it became apparent that other researchers believed phosphorous acid could be registered as a fertilizer.

More History

- The company held onto the patents for the product and the breakdown phosphonate products that were useful in root rot control.
  - This effectively stopped companies from pursuing a pesticide registration for phosphorous acid.

U C Riverside Research

- In 1990, Dr. Carol Lovatt (Dept. of Botany, U.C. Riverside) published a report that indicated applications of phosphite could replace phosphate in the fertilization of avocados suffering from phosphorus deficiency in pot culture (Lovatt, 1990).

U C Riverside Research

- Lovatt indicated that microorganisms are not required for the conversion of phosphite to phosphate, and speculated that aerobic conditions could slowly oxidize phosphite to phosphate, thus providing a slow-release form of phosphorus to the tree.

U C Riverside Research

- This meant that phosphite injected into a tree will slowly turn into phosphate, a plant nutrient.
- However, South African researchers found three genera of bacteria in avocado root and leaf samples that were capable of converting phosphite to phosphate (Bezuidenhout et al. 1987).

U C Riverside Research

- The information from Lovatt provided the basis for the registration of phosphorous acid as a fertilizer in California.
- Phosphorous acid has been sold in this capacity since the early 1990's.

How does it work?

- The exact mode of action has been a mystery to scientists for some time.
- When the phosphate content is too high in the agar media, the phosphite cannot enter the fungus.
- Therefore, it was thought that phosphite didn't affect fungi.

How does it work?

- It was long thought that the phosphite must somehow stimulate the defense system of the plant.
- Later, it was found that when phosphate is low, phosphite enters the fungus and inhibits key enzymes in *Phytophthora.*
- Fungus growth is stopped.

But, what just a minute!

- In 2000, it was reported the phosphonate-injected plants formed disease-prevention phytoalexins.
- In Eucalyptus, they found that low levels of phosphonate in roots stimulated the host defense system.
  - High levels did not, but high levels had a negative effect on the fungal growth in the roots.

But, wait just a minute!

- Both direct effect on the fungus and host defense systems are working.
- The conclusion (from the authors):

  "These studies are hard to conduct due to the detection of very low levels of complex phytoalexin chemicals in the roots."

What about resistance?

- Despite a lot of use in turfgrass to control *Pythium,* there are no reports of resistance developing in the fungus to the phosphonates.
- In avocado, there have been reports of resistance in *Phytophthora cinnamomi.* (Duvenhange, J.A. 2001, S. African Avocado Growers Yearbook, 24:13,15)

What about resistance?

- Not as many reports as you would expect.
- This is probably due to the combination of the direct effect on the fungus and the host resistance, just too many factors for the fungus to overcome.
- But, it is possible!

Research in Australia

Whiley, Saranah, Langdon, Hargreaves, Pegg, Ruddle - 1992

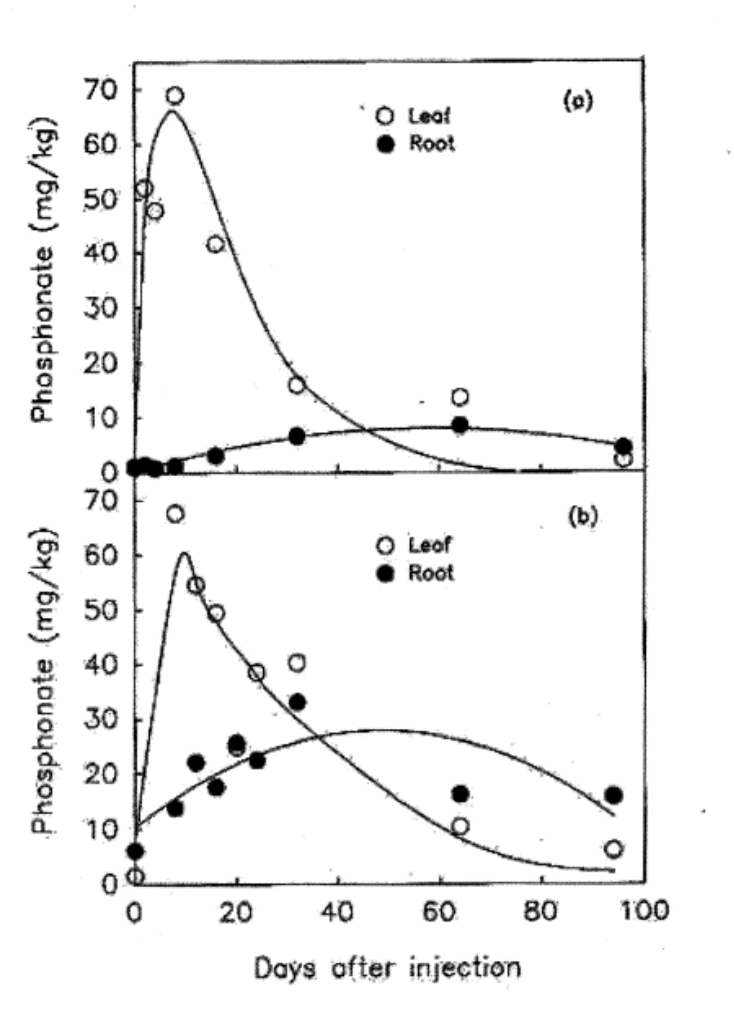
- Avocado trees were trunk injected with 20% phosphonate.
  - Phosphonate was detected in the leaves 24 hours after trunk injection with concentrations peaking at 10 days after injection.
  - Concentration in the roots was dependent on sink/source status of leafy shoots.

Research in Australia

- Trunk injection at the beginning of spring growth resulted in phosphonate conc. in roots of <9mg/kg.
- Trunk injection after transition (leaves turning green from reddish) resulted in >28mg/kg in roots.
- At the time, Wiley et.al thought that phosphonate levels in roots should be above 20 mg/kg to be effective.

Research in Australia

- Injected during spring flush
- Injected just after spring flush during transition from red leaves to green leaves



Mode of Action of Phosphite:

Evidence for Both Direct and Indirect
Modes of Action on Phytophthora (Smilie, Grant and Guest 1989)

- At high concentrations, phosphonate retards fungal mycelial growth (but does not completely kill it).
- At low concentrations, phosphonate stimulates plant defense mechanisms.
- At low concentrations, phosphonate reduces fungal sporulation (Guest et.al 1995).

Phosphorous Acid

Phosphonate Trunk Injections and Bark Sprays

Giblin, Pegg, Thomas, Whiley, Anderson, Smith 2007

- Potassium phosphonate can be applied by soil, trunk injection, foliar, and trunk sprays.
- Highest rate in the tree obtained by trunk injection

Phosphorous Acid

Phosphonate Trunk Injections and Bark Sprays

- Timing in relation to tree phenology is crucial to obtaining longest-lasting in the roots.
  - It's best when leaf flushing is almost over (reddish leaves turning to green) and root flushing is beginning.

Phosphorous Acid

Phosphonate Trunk Injections and Bark Sprays

- Injury to trunks (from injection) is a concern.
- What about trunk sprays with organo-silicate bark penetrants?

Phosphonate Trunk Injections and Bark Sprays

- It has been determined that 25 – 40 ppm of phosphonate in roots is required to protect roots.
- Trials can be set up to compare application methods to achieve the desired amount in roots.
- Pentra-bark is an organo silicate product that has been developed for bark sprays using phosphonate against *Phtophthora ramorum*

Trial 1

- Applied at early vegetative flushing
- Injection (15 ml/m trunk canopy, 20% solution)
  - More in the leaves
  - More in the roots

Trial 1

- Bark spray
  - Less in the leaves (not being transported upward)
  - Less in the roots (transported directly down in the phloem), but a more consistent supply

Phosphorous Acid

Hass/Duke 6 treated Feb, 2005
Both treatments at industry standard rates

	Feb 05*		Mar 05*		Jun 05*	
	R	L	R	L	R	L
Trunk	30.4	220	47.1	228	47.4	40.6
Bark	9.1	5	15.3	9	12.1	5

Trial 2

root mass measured 4 months after treatment

	root mass
Injection	2.14 b
Trunk spray	2.86 a

(1 = roots sparse, few roots, 2= roots present, network not developed, 3 = roots abundant, network developed)

Trial 3

applied to 4 yr old Hass/Velvick
applied after leaf and root flushing

	Improvement in health %
Untreated	0
Trunk injection	15.8
Bark spray	12.2

Bark spray gave lower levels in roots, but enough to provide improvement for 6 months

Occurrence in Nature

Is there hope for organic growers?

- 2-aminoethylphosphonic acid is the first identified natural phosphonate.
- The naturally-occurring phosphonate 2-aminoethylphosphonic acid was first identified in 1959 in plants and many animals, where it is localized in membranes.

Occurrence in Nature

- Phosphonates are quite common among different organisms, from prokaryotes to eubacteria and fungi, mollusks, insects and others.
- They were first reported in natural soils by Newman and Tate (1980).

Occurrence in Nature

- The biological role of the natural phosphonates is still poorly understood.
  - Bis- or polyphosphonates have not been found to occur naturally.

Are there Alternatives to Phosphorous Acid?

Dixon, Dixon, Cotterell, Elmlsy, 2008, New Zealand Avocado Grower's Association

- Compared
  - No treatment
  - 20% phosphorous acid applied using syringes
  - Sodium metasilicate 100 ppm as a 30L/tree soil drench
  - Sodium metasilicate 200 ppm as a 30L/tree soil drench
  - AV1 applied with Primaxa injector (Stemex Stemshot injector to apply all of the Phos acid in one shot using high pressure)
  - AV2 applied with Primaxa injector

Are there Alternatives to Phosphorous Acid?

- After 6 months feeder root decay was reduced in all treatments except control
- After 13 months root decay was reduced in only phos acid by syringe and the AV1, the other treatments were similar to the control

Phosphorous Acid

Root Rot

Healthy

Have Fun Drilling the Holes!

Summary

- The inclusion of phosphorous acid in fertilizer application is different than using phosphorous acid as a fungistat.
- Buffer material is important to use so as to not burn the trees.