Incorporation of Phosphorous Acid Products for Controlling Downy Mildew of Grapes

Fritz Westover – Texas AgriLife Extension Service, Texas Gulf Coast Region

Introduction

Phosphorous acid (H_3PO_3) products (also referred to as phosphites or phosphonates) have been used in preventative fungicide spray programs worldwide to control downy mildew (DM) of grapes. Phosphorous acid should not be confused with phosphoric acid (H_3PO_4) or phosphate, which is a source of phosphorus fertilizer, not a fungicide. Phosphorous acid works as a fungicide directly by interrupting metabolic processes of DM (1). Examples of phosphorous acid products include ProPhyt, Rampart, Agri-Phos, Aliette, and Phostrol.

Figure 1. Downy Mildew spores on underside of grape leaf.

Downy mildew, caused by the fungus *Plasmopara viticola,* is a significant disease of grapes in Texas (Figure 1). Several studies in the eastern US have demonstrated the efficacy of phosphorous acid fungicides applied alone or combined with other DM fungicides, such as strobilurins (e.g. Pristine, Abound, Sovran), or with Mancozeb, Captan, or Ziram. Studies at Cornell University have shown good control of DM with the use of phosphorous acid at 10 to 14-day spray intervals; however it was not as effective as strobilurin fungicides under high disease pressure (4), and current recommendations are to shorten spray intervals to 7-10 days under high disease pressure. A study by Penn State in 2005 showed that both incidence and severity of DM infection was significantly reduced by adding phosphorous acid to a standard control program of protectant fungicides (Captan, Mancozeb, Ziram) at 14-day intervals (2).

Advantages of Phosphorous Acid

- Generally less expensive
- Systemic activity
- Unique mode of action
- 0-day pre-harvest interval

Phosphorous acid products have some notable advantages. They are generally less expensive than other DM fungicides and have the ability to provide amphimobile systemic fungicidal activity. That is, the product moves into plant tissue when sprayed as a foliar fungicide, and then shifts into new areas of growth, such as vine shoot tips, through the xylem and phloem. This form of systemic activity is favorable in grapevines, as the younger vine tissues are most susceptible to DM infection. Most phosphorous acid products have a 0-day pre-harvest interval due to the low toxicity rating of their active ingredients, which makes them well suited for use late in the season when other fungicides cannot be used.

Downy mildew control in Texas vineyards

Frequent and heavy rainfall can occur during some growing seasons in Texas, resulting in increased grape disease pressure. The most widely used protective fungicides (Mancozeb or Captan) to prevent DM are not systemic and are susceptible to wash-off by rainwater. Strobilurin fungicides are "mesosystemic" (absorbed primarily into the leaf or berry cuticle and moved very short distances in that same organ) fungicides used in preventative spray programs for DM and other diseases, and are known for having very good efficacy (4). However, strobilurins are susceptible to resistance development by DM and other pathogens, thus growers limit use to two or three applications per season, usually applied between bloom and veraison.

Metalaxyl and mefanoxam (e.g. Ridomil Gold MZ, Ridomil Gold Copper) fungicides are also very effective against DM, but have a long pre-harvest interval (42-day PHI for Ridomil Gold Copper and 66 days for Ridomil Gold MZ formulation).

Phosphorous acid may provide growers with additional protection for DM during wet growing conditions if tank mixed or rotated with other DM fungicides, and can be used late in the season when other products can no longer be used.

A vineyard field trial was conducted in summer of 2007 to answer two unknowns regarding the use of phosphorous acid in Texas vineyards:

1) What concentration of phosphorous acid can be applied without causing leaf burn symptoms?
2) Can phosphorous acid be tank mixed with Mancozeb (Dithane F-45 Rainshield) or Captan (Captec 4L)?

Phosphorous acid (PA) alone did not cause any noticeable leaf burn symptoms at the concentration of 0.375% PA (3 pints ProPhyt per 100 gallons of water) and rarely at 0.625% (5 pints ProPhyt per 100 gallons of water) on 'Blanc du Bois' and 'Lenoir' wine grapes. Foliar toxicity was observed on vines at the 1.000% concentration (8 pints of ProPhyt per 100 gallons of water) (Figures 2, 3). Symptoms appeared as necrotic islands on the corresponding upper and lower surfaces of leaves or along leaf veins and margins. Necrosis of leaf margins was most severe on the lower margins (facing toward the ground) at the 1.000% concentration, indicating that the phosphorous acid salts were collecting there during run-off.

Strategic Uses of Phosphorous Acid

- Use in rotation or tank-mix to avoid pathogen resistance to strobilurins or protectant fungicides
- Use during rainy periods when non-systemic fungicides wash off
- Use close to harvest when other fungicides with long pre-harvest intervals cannot be used

A tank mix of phosphorous acid (0.625% PA) with the 2 quart/acre rate of Dithane F-45 or Captec 4L did not result in leaf burn symptoms in this trial. Weather conditions at the vineyard site were hot and humid (90-93°F highs) during the week of the trial. Phosphorous acid also effectively lowered the pH of the spray solution. The pH of the well water in this trial was 7.07. Additions of ProPhyt reduced the pH to 6.14 (0.375% PA), 6.04 (0.625% PA), and 6.00 (1.000% PA).

Figure 2. Leaf toxicity symptoms on 'Blanc du Bois' one week after spraying with 1.000% phosphorous acid solution.

Figure 3. Toxicity symptoms on leaf margins of 'Lenoir' one week after spraying with 1.000% phosphorous acid solution.

Preventing foliar toxicity with phosphorous acid products

Phosphorous acid fungicides consist of a solution of either potassium and/or sodium salts of phosphorous acid, therefore it is important to follow label instructions to avoid phytotoxicity or 'leaf burn' caused by excessive salt concentrations in the spray solution (1). Trials in Texas showed that phosphorous acid can cause symptoms of leaf burn at concentrations >0.6%. If growers follow the labels of phosphorous acid products, the high rate of application should not exceed 0.5%. Use of labeled rates of product will help prevent leaf burn.

Unlike many protectant fungicides, that have application rates expressed as amount of product per acre, phosphorous acid rates on some labels are based on the concentration (percent in solution) of actual phosphorous acid in the spray mixture. Thus a grower should determine the amount of water needed to achieve full coverage of vines per acre and then add the appropriate amount of phosphorous acid to the tank-mix to reach the correct concentration of active ingredient. For example, if a grower applies the high rate of ProPhyt (4 pints) in 100 gallons of water, the total concentration will be 5.0%. Using any less than 100 gallons of water would increase the concentration of phosphorous acid and therefore the chance of leaf burn.

Tank mixing of phosphorous acid with copper should be avoided to reduce foliar burn known to occur with copper spray mixtures of low pH. In the Texas trial, a decrease of nearly one pH unit occurred in well water adjusted with 0.375% ProPhyt solution. Foliar applications of copper-based fungicides such as Kocide have been known to cause foliar burn if applied in an acidic solution because copper becomes more available for plant uptake at low pH (1). Therefore, depending on the pH of the final spray solution, the mixing of phosphorous acid with copper should be either tested on a small number of vines or avoided in order to reduce foliar burn from copper.

Spray timing for phosphorous acid

Approximately 0.1 inch of rainfall and a temperature of 52^{o}F or higher is required to initiate DM infection, and if conditions remain favorable (cloudy, damp), lesions can develop as soon as 5 days post-infection (4). When sporulating lesions are present on leaves, the disease is well beyond the initial infection stage and cannot be controlled using protectant fungicides such as Mancozeb or Captan. This is why most fungicides are sprayed preventatively to control DM well before symptoms of white spores are present on leaf undersides or developing flowers.

Studies in Australia have shown that both phosphorous acid and metalaxyl are effective at controlling DM, when applied prior to, or within 3-4 days post-infection. For best results, phosphorous acid should be sprayed just before or just after an infection period and before spores of downy mildew are abundant.

Studies have also demonstrated that phosphorous acid suppresses active sporulation of DM, but is not as effective as metalaxyl (Ridomil Gold-Copper) (3,4). The efficacy of Ridomil on active DM lesions was observed in 2007 in Texas during an early season field trial comparing Ridomil Gold Copper with ProPhyt (0.375% PA concentration) on 'Lenoir' wine grapes (Figure 4).

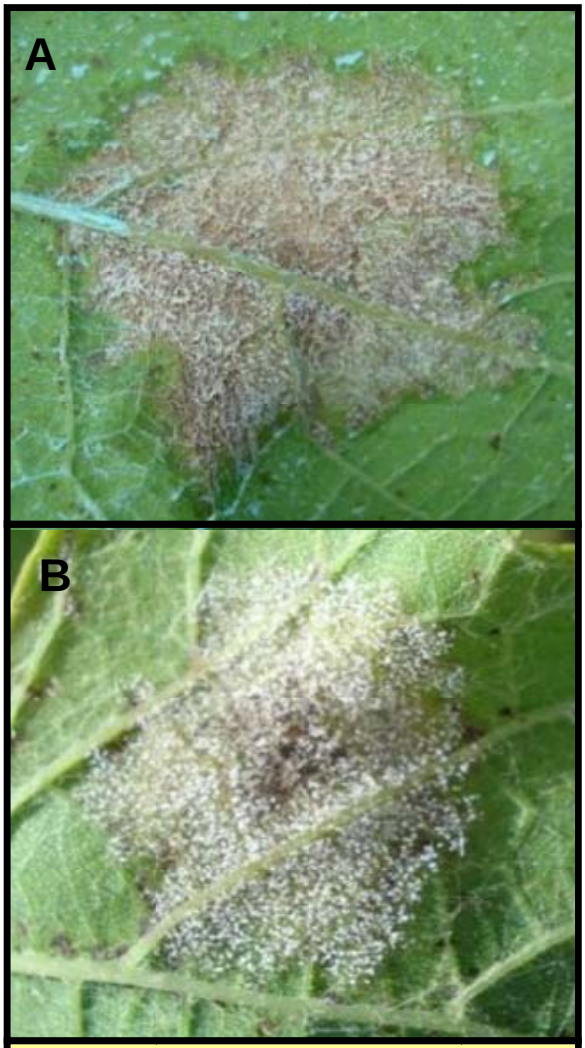

Figure 4. 'A' DM lesion 1 week after treatment with Ridomil Gold Copper and 'B' 1 week after treatment with 0.375% phosphorous acid. Notice spores are still active on 'B.'

ProPhyt was not effective in this visual comparison. As with all other fungicides, phosphorous acid should not be relied upon for eradication of DM.

Eradication of a severe DM outbreak has risks. Metalaxyl is highly susceptible to resistance development by DM. Spraying Ridomil or any fungicide on a large population of spores increases the chance that a population might develop resistance, making it no longer useful for future DM control. Avoiding resistance development by fungal diseases is an important strategy in any spray program.

Although a grower may be able to 'fix' a DM outbreak in their vineyard in one instance, there is no guarantee that the same approach would work again in the future if pathogen resistance develops.

Determining phosphorous acid rates for various tank sizes

Not all phosphorous acid fungicides contain the same phosphorous acid equivalent. The label provides a rate recommendation with a given amount of water, which should result in a solution somewhere between 0.4 and 0.6% phosphorous acid. The two tables below (Table 1, 2) illustrate the difference in mixing rates for two common phosphorous acid products*.

	Pints of ProPhyt to produce:		
Tank size	Low rate	High rate	Toxic
Gallons	0.375%	0.500%	1.000%
100	3	4	8
75	2.25	3	6
50	1.5	2	4
25	0.75	1	2

Table 2. Measuring table showing tank size and rates of phosphorous acid needed to produce low, high, and toxic rates of ProPhyt.

	Pints of Rampart to produce:		
Tank size	Low rate	High rate	Toxic
Gallons	0.375%	0.500%	1.000%
100	3.23	4.31	8.62
75	2.43	3.23	6.46
50	1.62	2.15	4.31
25	0.81	1.08	2.15

Table 2. Measuring table showing tank size and rates of phosphorous acid needed to produce low, high, and toxic rates of Rampart.

*Rates are slightly higher for Rampart (which has 3.9 lbs/gallon phosphorous acid equivalent) than for ProPhyt (4.2 lbs/gallon phosphorous acid equivalent).

Conclusions

Phosphorous acid fungicides provide a good option for DM control early in the growing season, and especially later in the growing season when other DM products are not usable due to long pre-harvest intervals. Early season use of these products in rotation or tank mixed with protectant fungicides would also fill a niche for additional systemic control of DM prior to bloom. Phosphorous acid tank mixed with strobilurins mid-season introduces multiple modes of action and thus reduces resistance development in DM. During dry weather conditions, protective materials such as Mancozeb or Captan are typically sufficient for DM control. If rain is predicted, phosphorous acid products can be tank mixed with Mancozeb or Captan, or sprayed alone (for DM control only).

Phosphorous acid fungicides should be mixed to the appropriate concentrations to avoid burning grape tissues and are best applied just before or just after a DM infection period. Some phosphorous acid products are not compatible with surfactants, thus growers should read the label for proper mixing instructions.

References

1) Schilder, A. M. C. Phosphorous Acid Fungicides, Michigan State University http://www.oardc.ohio-state.edu/grapeweb/OGEN/06032005/PhosphorousAcidFungicide_Ellis.pdf

2) Travis, J. W., Halbrendt, N. O., Lehman, B., and Jarjour, B. 2005. Evaluation of cultivars and phosphorous acid products for control of downy mildew and powdery mildew in grapes. Plant Disease. B&C Tests Vol 21:N008

3) Wicks, T. J., Magarey, P. A., Wachtel, M. F., and Frensham, A.B. 1991. Effect of postinfection application of phosphorous (phosphonic) acid on the incidence and sporulation of *Plasmopara viticola* on grapevine. Plant Dis. 75:40-43

4) Wilcox, W. F. 2009. Grape Disease Control. Cornell University. http://blogs.cce.cornell.edu/grapes/files/2009/04/wilcox-grpdis-409.pdf