INTRICACIES OF USING PHOSPHOROUS ACID FOR POTATO DISEASE CONTROL

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Over the last few years there has been a lot of discussion about the use of phosphorous acid as a foliar application and as a post-harvest application. Many questions have remained about expectations and recommendations on use of phosphorous acid either as a post-harvest application, foliar application or a combination use of foliar and post-harvest. The workshop was presented to highlight some of the known information regarding these uses.

TOP 10 THINGS TO KNOW ABOUT POST-HARVEST APPLICATIONS OF PHOSPHOROUS ACID

#1. What phosphorous acid is NOT.

This material is not the corrosive acid, phosphoric acid, you remember from high-school chemistry class nor a phosphate-based fertilizer, but rather a phosphite molecule. Phosphorous acid is H_3PO_3 and often referred to as phosphate or phosphonate. Depending upon the formulation, the product applied can be mono- and di-basic Na, K and/or ammonium salts of phosphite. Remember: phosphorous acid is not phosphoric acid (H_3PO_4), phosphate (P_2O_5) or phosphorus (P). The phosphorus in phosphorous acid is in a reduced state (lower positive charge) than the phosphorus in phosphate based fertilizers.

#2. Phosphorous acid mode of action.

The phosphite ($H_2PO_3^-$ or HPO_3^{2-}) molecule is known to be active in limiting the growth of water mold pathogens such as those which cause late blight and pink rot. Phosphite has also been shown to induce natural defense reactions in plants. University of Idaho and Miller Research studies have shown that these phosphorous acid based fungicides directly inhibit the growth of the water mold fungi. It is likely that both direct fungicidal activity and promotion of plant defenses play a role in the efficacy of phosphite based fungicides for control of late blight and pink rot. Phosphorous acid has systemic properties within the plant and tuber.

#3. Target organisms for phosphorous acid application.

Multiple studies over many years comparing several potato varieties have shown highly effective control on oomycetes or water mold pathogens such *Phytophthora erythroseptica* (cause of pink rot) and *P. infestans* (cause of late blight) when phosphorous acid is applied as a post-harvest spray application prior to storage (Table 1). Recent research over the last four years has indicated some efficacy against silver scurf although the mode of action is not known (Table 2). Additional research will continue to look at silver scurf suppression with phosphorous acid applications. In summary, an application of phosphorous acid will help control late blight and pink rot and help suppress development of silver scurf in storage. Phosphorous acid is not effective on dry rot. Research is in progress on Pythium leak but previous observations have indicated limited control with phosphorous acid applications.

Table 1. Effect of post harvest applications of phosphorous acid and hydrogen peroxide/peroxyacetic acid (HPPA) on percent potato tuber rot after 77 days in storage (48°F) in a 1-ton bin.[1]

Treatment	Rate/ton tubers	*Late blight (%)*	*Pink rot (%)*
Untreated control		90 a	61 a
HPPA	1:25 dilution	84 a	73 a
Phosphorous acid	1.6 fl oz (1:40 dilution)	26 b	32 b
Phosphorous acid	3.2 fl oz (1:20 dilution)	14 bc	10 b
Phosphorous acid	12.8 fl oz (1:5 dilution)	0 c	0 c

[1] Tubers with typical disease symptoms or showing symptoms of secondary soft rot were counted as rotted tubers. Values in the same column followed by the same letters are not significantly different at p=0.05.

Table 2. Efficacy of post-harvest fungicide on the incidence of silver scurf on potato cv. Russet Norkotah following 6 months in storage at Kimberly, Idaho. Values in the same column followed by the same letter are not significantly different at p= 0.05.

Treatment	Incidence (%)		
	Year 1	Year 2	Year 3
Untreated Control	18 b	69 a	15 a
Phosphorous acid (12.8 fl oz/ ton)	0 c	37 b	5 a
TBZ (Mertect; 0.42 fl oz/ton)	38 a	47 b	NA

#4. Protect healthy tubers not cure diseased ones.

Tubers that have symptoms of late blight and pink rot coming out of the field can contaminate healthy tubers during the harvest and handling operation. This post-harvest application of phosphorous acid works to help keep the healthy tubers from being becoming infected. Use good storage management practices to dry up already diseased potatoes and to decrease chances of spread in storage.

#5. Recommend the 12.8 fl. oz per ton rate.

Repeated small scale studies have shown lower rates (as low as 3.2 fl oz/ton) of phosphorous acid can be effective against pink rot and late blight. When trials are scaled up to mimic a pile of potatoes, the labeled rate of 12.8 fl. oz/ton consistently shows greater control than when lower rates are used (Table 1).

#6. Limited concern of phytotoxicity.

A few years ago there was concern of phytotoxicity on a fresh market thin-skinned potato with a post-harvest application of phosphorous acid. This prompted additional research to evaluate applications to red potatoes at 1 and 2 times the allowable rate. The research was also performed at North Dakota State University. No issue of phytotoxicity, change in skin appearance, or quality was observed. As with any post-harvest spray application, adhere to all label recommendations when using this product.

#7. Okay to apply to seed but not as seed treatment.

Research has indicated limited concerns with applying phosphorous acid as a spray treatment on seed going into storage. There were no changes in seed performance as indicated by similar stem number per plant, rate of emergence, yield and size profile between treated and non-treated seed tubers. Apply some caution to seed of extremely short dormancy varieties that may be sprouting at harvest. Research results strongly recommend to not apply phosphorous acid as a seed treatment. Issues of emergence and seed decay were noted.

#8. Volume of application: 0.5 gal/ton of potatoes.

Our research based information recommends no more than 0.5 gallon of aqueous product (phosphorous acid plus water) per ton of potatoes. That converts to less than half a cup (3.2 ounces) of liquid per hundredweight (cwt) or an increase in 4.25 ounces in weight for every hundred weight (cwt) of potatoes. In order to maximize the usefulness of phosphorous acid, careful application of the rate and volume applied is necessary. Applying less than 0.5 gal per ton of potatoes may result in incomplete coverage and applying greater than 0.5 gal per ton of potatoes may add too much free moisture to the surface of the potato. Stewardship of application may take more time and effort, but the consistency of disease control will be greater. An easy rule of thumb: if the potatoes are shiny or if water is dripping off, you are applying too much volume of solution. The potatoes should be just barely wet as an indicator for proper application (Figure 1).

Figure 1. Post-harvest spray application volumes of 0, 0.25, 0.5, 1.0, and 2.0 gallons/ton, respectively, from left to right. The desired volume of a spray application is 0.5 gal/ton of potatoes.

#9. Method of application: on-line spray or in-storage application.

A post-harvest application going into storage is the recommended method of application for several reasons. The primary reason is that inoculation of the late blight or pink rot pathogens from diseased potatoes to healthy ones occurs during harvest and handling. There is a finite amount of time from inoculation to time of post-harvest treatment for that application to be effective. With general biocides, you have less than an hour to just a few minutes for an application to be effective (Table 3). In comparison, a post-harvest application of phosphorous acid showed excellent control for both pink rot and late blight even 6 hours after inoculation. These studies stress the importance in timing of inoculation and post-harvest application, may explain inconsistencies in conflicting testimonials, and the long-term or "reach back" potential and systemic properties of phosphorous acid. It also stresses the necessity to apply as quickly after an inoculation occurs which is as close to harvest as possible. Waiting several days for an in-storage treatment would be too late to manage late blight and pink rot. Recent research has looked at the potential for in-storage phosphorous acid application via cold-aerosol or humidification systems for the suppression of silver scurf. Preliminary results have shown limited reduction although additional studies will continue.

Table 3. Effect of post-inoculation interval on post-harvest treatment for incidence of pink rot on Russet Burbank tubers.[1]

Treatment	Post inoculation interval (hours)				
(rate/ton tubers)	0	1	2	4	6
Untreated control	87 a	92 a	88 a	90 a	100 a
HPPA (1:50 dilution)	43 b	85 a	87 a	98 a	95 a
Phosphorous acid (12.8 fl.oz)	0 c	0.0 b	3 b	22 b	29 b

[1]Values in the same column followed by the same letters are not significantly different at p=0.05.

#10. No effects on processing quality.

Multiple studies have evaluated processing quality of potatoes treated with phosphorous acid and no effects, either negative or positive, have been seen (Table 4).

Table 4. Effect of phosphorous acid on Russet Burbank tuber processing quality after 158 days in storage.[1]

Parameter	Untreated Control	Phosphorous acid (12.8 fl. oz.)
Glucose (% fwt)	0.035 a	0.033 a
Sucrose (% fwt)	0.103 a	0.097 a
Mean fry color[2]	48.0 a	50.0 a

[1]Values in the same row followed by the same letter are not significantly different.
[2]USDA fry color rating #1≥ 44, #2 < 44 but ≥ 35, #3 = < 35 but ≥26 reflectance

And an additional point #11: Use of a complimentary foliar phosphorous acid program.

Discussed below is the use of phosphorous acid in a foliar program and the incorporation of a post-harvest with a foliar program.

PHOSPHOROUS ACID FOLIAR PROGRAM

Foliar applications of phosphorous acid-based fungicides are effective in protecting tubers from pink rot and late blight. For both diseases applications should begin when the largest tubers are dime sized (described as late June in Table 5).

Table 5. Effect of foliar phosphorous acid (Phostrol) timings on tuber pink rot and late blight development when tubers are inoculated with the pathogen after harvest (Johnson et al., 2005).[1]

	Phostrol Rate	
Timing	10 pt/a	8 pt/a
1 Untreated check (no Phostrol)	60 a	60 a
2 Late June, early July, late July	0 b	25 b
3 Early July, late July, early August	5 b	20 b
4 Late July, early August, late August	15 b	15 b

[1]Values in the same column followed by the same letters are not significantly different at p=0.10.

LATE BLIGHT

Late blight is best managed with foliar applications of fungicides during the growing season. Many different effective, relatively inexpensive fungicides are labeled for use in Idaho. Additionally, weather conditions during the growing season have not been favorable for the development and spread of the late blight pathogen in recent years.

Phosphorous acid fungicides are not effective in managing the foliar phase of late blight. As mentioned above, several other less-expensive fungicides can be used for late blight. As a result, it is not practical to apply phosphorous acid as a foliar application primarily to target late blight. But if phosphorous acid fungicides are being used to manage pink rot, then tubers will have some protection against late blight throughout the growing season and into storage. This is a good secondary benefit from using phosphorous acid in-season.

PINK ROT

Pink rot was effectively controlled by metalaxyl/mefenoxam based fungicides (e.g. Ridomil Gold products, Ultra Flourish, MetaStar, etc) in Idaho until the late 1990's. At that time, resistance to metalaxyl/mefenoxam in pink rot pathogen population was found in eastern Idaho. In the last decade resistance has spread to most areas of Idaho. Phosphorous acid-based products are one of the few viable alternatives for effectively managing pink rot in these situations.

Managing pink rot requires an integrated approach, and relying on fungicides alone will not be successful. Certain varieties such as Premier Russet and Russet Norkotah are more susceptible to pink rot than Russet Burbank or Ranger Russet and require more intensive management. Additionally, fields with more intensive potato production (1-2 years between potatoes) will have a higher disease pressure. Growers who are able to grow less susceptible varieties and plant in longer rotations (over 4 years) may not need to use fungicides for pink rot control.

A fungicide trial sponsored by the Idaho Potato Commission and other private chemical companies showed three applications of phosphorous acid (Resist 57 in this case) to be as effective as the metalaxyl (MetaStar) and mefenoxam (Ridomil Gold Bravo) programs (Table 6). The pathogen population in the field was mixed with about 30% of the isolates being resistant to metalaxyl/mefenoxam.

Table 6. Effect of fungicides on pink rot of potato (cv. Western Russet, Minidoka, ID; 2010).[1]

Fungicide applications and timings					
May 11 In-furrow	May 25 Hilling	June 23 Dime-size (DS)	July 7 DS + 14	July 21 DS + 28	Pink Rot Incidence
1. (No fungicides applied; untreated check)					8 a
2. Ranman	Ranman	Phostrol	Phostrol		8 a
3. Ridomil Gold					4 abc
4.		Resist 57	Resist 57	Resist 57	3 bc
5.		MetaStar	MetaStar		2 c
6.		Ridomil Gold Bravo	Ridomil Gold Bravo		3 bc
7.	Ranman	Phostrol	Phostrol		6 ab

[1]Values in the same column followed by the same letters are not significantly different at p=0.10. Products were applied at the full labeled rates at each application.

Growers who have used foliar applications of phosphorous acid in low water volumes (i.e. aerial applications) have occasionally observed phytotoxicity. The phytotoxicity appears as a crinkling of the leaves and has not been observed with chemigation applications. A research project sponsored by the Idaho Potato Commission evaluated three different phosphorous acid programs for efficacy in controlling pink rot. The goal was to apply 30 pints throughout the season using differing rates, timings, and numbers of applications. Applications were made at a spray volume representative of ground application (about 15 gallons/acre). The standard rate and timing (10 pt applied three times, beginning when the largest tubers are dime-size) was the most effective, but applying 5 pt six times with a 7 day application interval was equally effective. Applying 5 pt on a 14-day interval was also reduced pink rot, but was not as effective as the standard rate and timing (Table 7). Phytotoxicity was not observed in this trial.

Table 7. Effect of different phosphorous acid programs on natural pink rot incidence in

the field, storage, and combined; Minidoka, ID 2008.

	% Tubers with Pink Rot[1]		
	Field	Storage	Total
1 Untreated check	14.0 a	2.5 a	15 a
2 Phostrol, 10 pt/a on a 14 day interval	0.5 c	0.8 a	1 c
3 Phostrol, 5 pt/a on a 14 day interval	1.4 bc	1.5 a	2 bc
4 Phostrol, 5 pt/a on a 14-day interval	2.7 b	2.3 a	3 b

[1] Natural disease presence. Values followed by different lowercase letters are significantly different from each other at the 90% probability level.

VALUE OF "RESCUE" TREATMENTS

On occasion, growers have found pink rot in a field that had no prior history of pink rot. The question is often asked if a "rescue" treatment would be effective. The use of the term "rescue" means that no fungicide applications have been made prior to finding pink rot in the field. Once pink rot is found, fungicide is applied. In another trial sponsored by the Idaho Potato Commission the value of rescue treatment was put to the test. Crop-phite (the phosphorous acid used in treatment 2) and Ridomil Gold Bravo (used in treatment 3) were applied after pink rot had already been found in the plot (cv. Russet Norkotah). Pink rot was found on July 25 and the first rescue fungicide treatments were made on July 28. In a separate treatment Ridomil Gold Bravo and Ridomil Gold MZ (treatment 4) were applied at the correct foliar timing (largest tubers dime-sized and two weeks later). The only treatment that reduced pink rot was the Ridomil Gold applications made before pink rot had been identified (Table 7). Applying fungicides after pink rot has been found is not effective and growers would be better off saving money by not applying anything.

Table 7. Effect of "rescue" treatments on pink rot incidence with Russet Norkotah.

Description			% Tubers with Pink Rot[1]		
Trt	Treatment	Rate	Field	Storage	Total
1	Untreated check		22 a	25 a	40 a
2	Crop-phite Rescue treatment	10 pt/a	22 a	32 a	46 a
3	Ridomil Gold Bravo Rescue treatment	2 lb/a	21 a	23 a	38 a
4	Ridomil Gold Bravo Ridomil Gold MZ Label timing	2 lb/a 2.5 lb/a	9 b	7 b	15 b

[1]Values in the same column followed by the same letters are not significantly different at p=0.10.