# Potato Progress

**Research & Extension for the Potato Industry of Idaho, Oregon, & Washington**

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https://www.nwpotatoresearch.com/

*Volume XX, Number 8* | *5 May 2020*


## Effect of Field and Post-Harvest Fungicides for Managing Pink Rot and Leak


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The most effective way to manage any disease at harvest is to manage it during the growing season. The late Walter Sparks (who was a research horticulturist at the University of Idaho) used to say, "A potato storage is not a hospital." You can't put a sick crop into storage and hope it gets better with storage management. The most effective approach is to manage the disease in the field, and then do everything possible to maintain healthy tubers in storage.

Pink rot (caused primarily by *Phytophthora erythroseptica*) and Pythium leak (caused primarily by *Pythium ultimum*) are two important diseases of storage. In many cases, the pink rot pathogen infects stems, roots, or stolons and then grows into the tuber. When this occurs, the symptoms begin on the stolon end of the tuber. The Pythium leak pathogen tends to get established in wounds and infections may start at any location on the tuber. A comparison of these symptoms is shown in Figure 1.

Figure 1. The tuber on the left exhibits symptoms of pink rot. The pathogen has entered through the stolon end of the tuber. The infected tissue in cross-section has a creamy off-white color with some dark tissue on the edge of the infected area. The tuber on the right shows symptoms of Pythium leak. The infection occurred on the side of the tuber. The infected tissue in cross-section is light to dark gray and is wetter and darker than pink rot.

**Pink Rot**

Managing pink rot in the field is best done with the following management practices:

1. Field selection/crop rotation (the longer the better)
2. Adjust soil pH by lime application in low pH soils (lower pH = greater pink rot risk)
3. Plant less susceptible varieties
4. Proper irrigation management
5. Use appropriate fungicides
6. Avoid "disease-favorable" conditions at harvest (saturated soils, warm weather, and wounding = disease favorable)
7. Apply post-harvest fungicides
8. Grade out infected tubers going into storage
9. Reduce tuber pulp temperatures to 55 F or lower as quickly as possible in storage

This article focuses on the use of fungicides in the field and post-harvest (points 5 and 7).

Based on our experience, two classes of fungicide are most effective against pink rot: metalaxyl/mefenoxam and phosphorous acid-based products. Because mefenoxam is a systemic fungicide, it can be applied according to a variety of methods and still provide protection against pink rot. Although mefenoxam is mobile in the soil (Monkiedje and Spiteller, 2002) and may leach from the root zone prior to root development and/or being absorbed by the roots (Miller et al., 2004), applications at planting as a liquid spray in-furrow have been more effective than foliar applications in many areas of North America (Ludy and Powelson, 2003; Mulrooney and Gregory, 2002; Mulrooney and Gregory, 2003; Peters et al., 2004; Taylor et al., 2004). In the U.S. Pacific Northwest (PNW), in-furrow applications of mefenoxam have not consistently controlled pink rot. Foliar applications of mefenoxam-based products have been shown to significantly decrease pink rot in the PNW and elsewhere (Miller et al., 2004; Peters et al., 2003; Taylor et al., 2004).

Significant reduction of pink rot can also result from foliar applications of phosphorous acid (e.g. Phostrol, Resist 57) (Johnson et al., 2005). Three applications (10 pt/acre) starting at initial tuber bulking were required for the most effective pink rot control in the PNW. Control of pink rot with phosphorous acid is not as effective as mefenoxam with respect to control of mefenoxam-sensitive pathogen isolates. Phosphorous acid is effective and useful, however, in reducing infection by mefenoxam-resistant isolates. A total of 65 and 64% of isolates recovered at Miller Research in 2018 and 2019, respectively, were resistant to mefenoxam.

Other fungicide options are available, but results vary. Effective control of pink rot has been obtained with cyazofamid (Ranman) in some trials (Gundersen and Inglis, 2005), but this has not been consistent over multiple locations. Ethaboxam (Elumin) and oxathiapiprolin (Orondis) have also shown efficacy against pink rot (Dankwa et al., 2018; Ge et al., 2019), but these are relatively new with respect to pink rot control.

The rationale behind post-harvest applications of fungicides for pink rot control is the assumption that healthy tubers can become exposed to the pathogen during the harvest operation (Salas et al., 2000). This exposure may occur as tubers are lifted from the soil onto the belt of commercial potato harvesters, as tubers contact each other on the harvester belt, while tubers are piled into trucks for transportation, or when tubers are delivered from trucks to storages or packing. Essentially, whenever healthy tubers are wounded during harvest and handling operations, there is an increased risk of infection. Oospores or zoospores in soil adhering to tubers or from neighboring infected tubers may be present and transferred to healthy tubers during any one of these processes. Post-harvest and pre-storage fungicides are aimed at reducing the viability of these potential inoculum sources on the surface of the healthy tubers prior to infection.

General disinfestants such as chlorine dioxide and hydrogen peroxide/peroxyacetic acid mixtures are labeled for application to tubers as they are being loaded into storage. Research results have not shown these products to be consistently effective (Klimes, 2002; Olsen et al., 2003). On the other hand, phosphorous acid as a post-harvest, pre-storage application has been shown to be effective in controlling pink rot in storage (Miller et al., 2006). Application of phosphorous acid to potato tubers as long as six hours after tubers were exposed to the pink rot pathogen resulted in significant reduction in post-harvest pink rot development. The most common application strategy has been to apply 12.8 fl oz/ton of a phosphorous acid product in 0.5 gallons/ton of water.

Although post-harvest application is effective in reducing pink rot development, the logistics involved to apply the fungicide at this time are difficult. The application volume must be matched to the flow rate of tubers, applications should be made so that all tubers are treated, and care must be taken to ensure tubers do not get too wet. Placing and calibrating the spray bar to meet these parameters can be difficult. Additionally, the application can make belts wet enough that they slip and cause run-off underneath the application area. Overseeing this application also creates another point of management that must be done during the already demanding harvest operation.

In 2019, we conducted a trial evaluating the effect of field and post-harvest applications of phosphorous acid (Resist 57) on pink rot development for eight russet-skinned varieties. Despite inoculation, pink rot development in the field was minimal with almost all varieties having less than 1% incidence (data not shown). Under these conditions, we did not see a significant effect with the foliar application of phosphorous acid.

Healthy tubers from this trial were collected at harvest and challenged with the pink rot pathogen, and then treated with either water or phosphorous acid (Resist 57, 12.8 fl oz/ton). The infection rate for the untreated plants in the field (Field UTC, PH UTC) was at or above 95% for all varieties except Dakota. The field treatment (Field TRT, PH UTC) resulted in a significant reduction in pink rot for Burbank, Norkotah 278, Umatilla, Teton, Clearwater, and Dakota, and did not have an effect in Ranger and Alturas (Figure 2). The addition of a post-harvest treatment (PH TRT) resulted in almost complete pink rot control for all varieties.

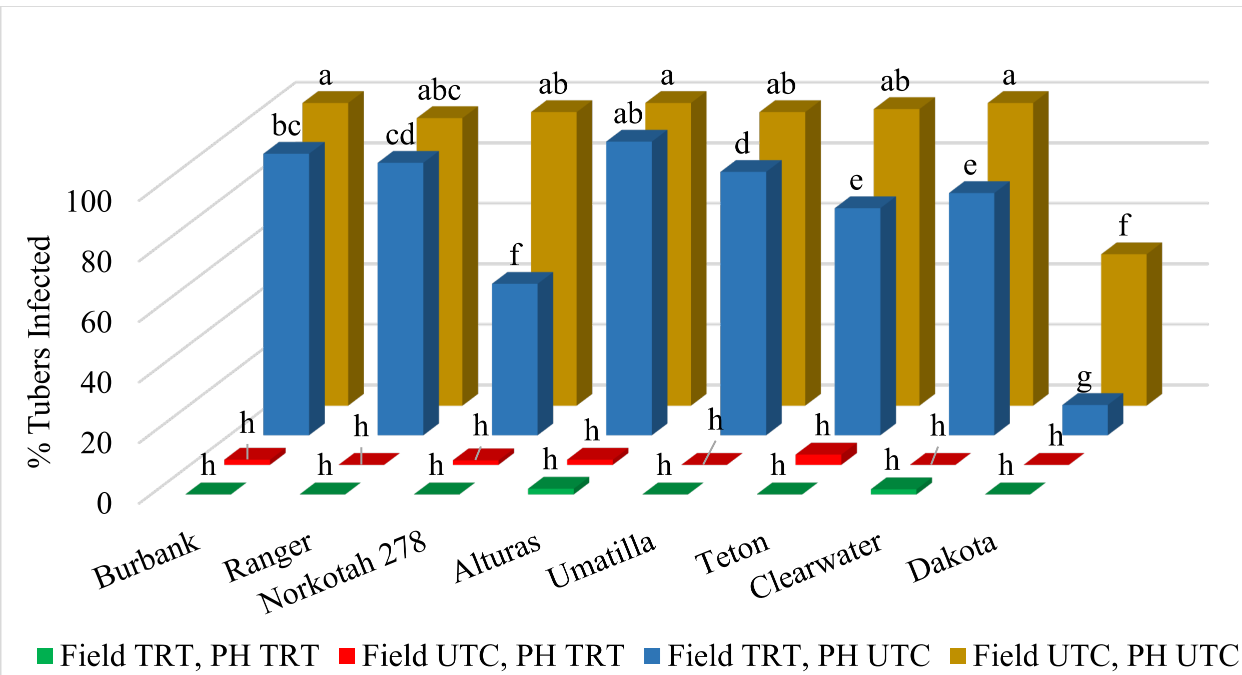


Figure 2. Effect of field treatment of a phosphorous acid program, a post-harvest treatment with phosphorous acid, and a combination of both programs on pink rot development in eight russet-skinned varieties.

The recent success some have experienced with foliar applications of phosphorous acid and the difficulties associated with the post-harvest application have led some to believe that a post-harvest application of phosphorous acid is not necessary if a field program is in place. Under the right conditions this may be true. However, the foliar phosphorous acid program may not always provide complete control. If pink rot develops in the field in spite of a foliar fungicide program, a post-harvest application may still be warranted. Dakota Russet did show a low infection rate with the field program only but adding the post-harvest treatment further reduced pink rot.

**Pythium Leak**

Many of the practices recommended for pink rot are also effective for leak, yet from our experience leak is more difficult to control. Recommendations for leak control include:

1. Soil fumigation with metam sodium or metam sodium + 1,3-dichloropropene (Hamm et al., 2003a)
2. Plant less susceptible varieties
3. Use appropriate fungicides
4. Avoid "disease-favorable" conditions at harvest
5. Apply post-harvest fungicides
6. Grade out infected tubers going into storage
7. Reduce tuber pulp temperatures to 55 F or lower as quickly as possible

As above, this discussion will focus on field and post-harvest fungicides

Mefenoxam-based fungicides are labeled for the management of leak. As with pink rot, mefenoxam-based fungicides are effective since they are systemic and the active ingredient can be distributed throughout the plant. However, foliar applications of mefenoxam have not always been effective (Taylor et al., 2004). Some control has been shown when mefenoxam was applied in furrow at planting, or in furrow in combination with a second application followed three weeks after planting (Taylor et al., 2004).

Mefenoxam resistance has been observed in isolates recovered from some areas of North America (Taylor et al., 2002) and has caused significant problems in some areas of the PNW (Hamm et al., 2003b; Porter et al., 2009). Unlike the case of pink rot, foliar applications of phosphorous acid have not been effective in reducing leak (Johnson et al., 2005). As resistance to mefenoxam becomes more prevalent, it is crucial to research other active ingredients that could manage Pythium leak.

In the literature cited in the above paragraphs, protection against leak was determined through the use of rigorous post-harvest wound inoculations. These inoculations are thought to be representative of how the pathogen enters the tuber via wounds (Taylor et al., 2004). But, we have observed infected tubers prior to harvest with the absence of any visible wounding (see example of the infected tuber in Figure 1).

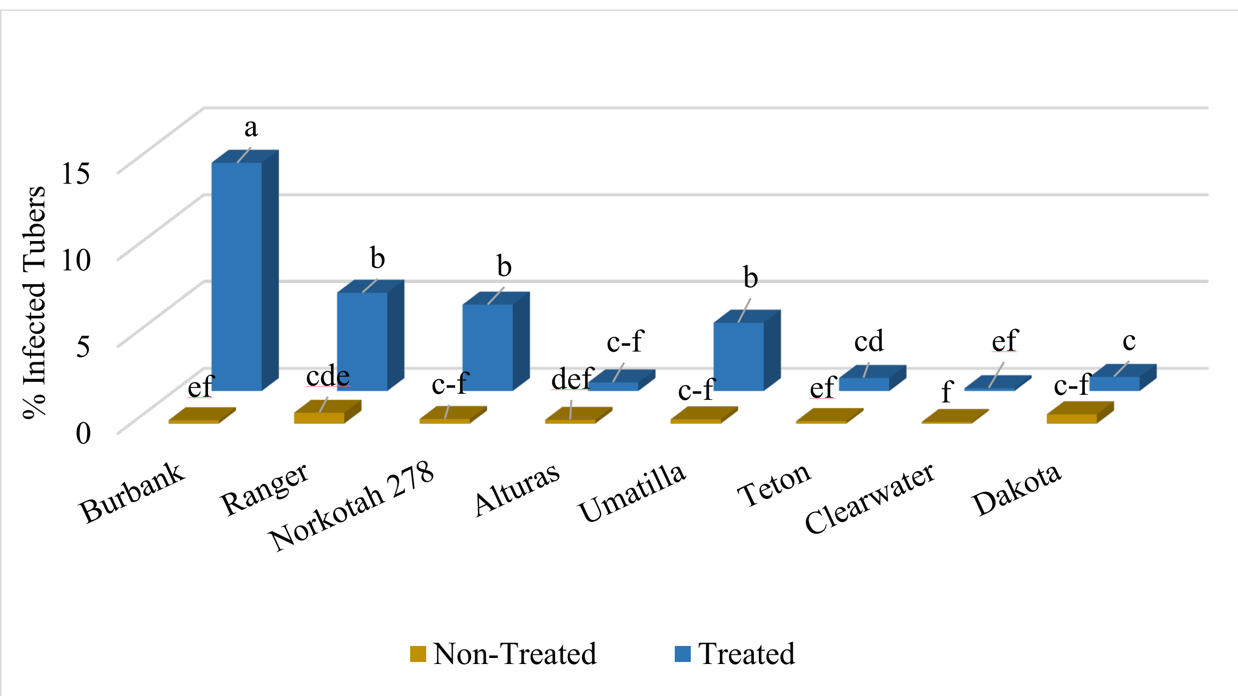


Figure 3. Incidence of Pythium leak in the field at harvest. Non-treated plots did not receive any fungicide treatments during the season. Treated plots received three applications of phosphorous acid (Resist 57) and four applications of fungicides not effective against pink rot for early and late blight management.

In the 2019 variety trial, significantly more Pythium leak was observed with Burbank, Ranger, Norkotah, Umatilla, and Teton when they were treated with fungicide than without (Figure 3). These five varieties also showed the greatest difference in early blight severity and late-season vigor. The difference between the untreated and treated plots for these five varieties was greater than for Alturas, Clearwater, and Dakota. We hypothesize reduced infection occurred in the untreated tubers of the aforementioned five varieties due to the fact that the foliage in the untreated plots died earlier, and thus the tubers matured sooner in the season than those that were treated with foliar fungicides. These more mature tubers may have been more resistant to Pythium leak.

These data (Figure 4) also do not support the use of foliar phosphorous acid applications for managing leak. Similar to the pink rot experiments, healthy tubers were taken from the field at harvest and challenged with the leak pathogen. After inoculation, tubers were either sprayed with water or treated with Stadium (0.05 fl oz/cwt). Post-harvest application of Stadium significantly reduced the incidence of leak on Burbank, Clearwater, and Dakota, but not Alturas. (Due to experimental difficulties, we were not able to inoculate all varieties.) Stadium was chosen based on previous experimental results indicating some management of Pythium leak. Stadium is currently not labeled for the use against Pythium leak.

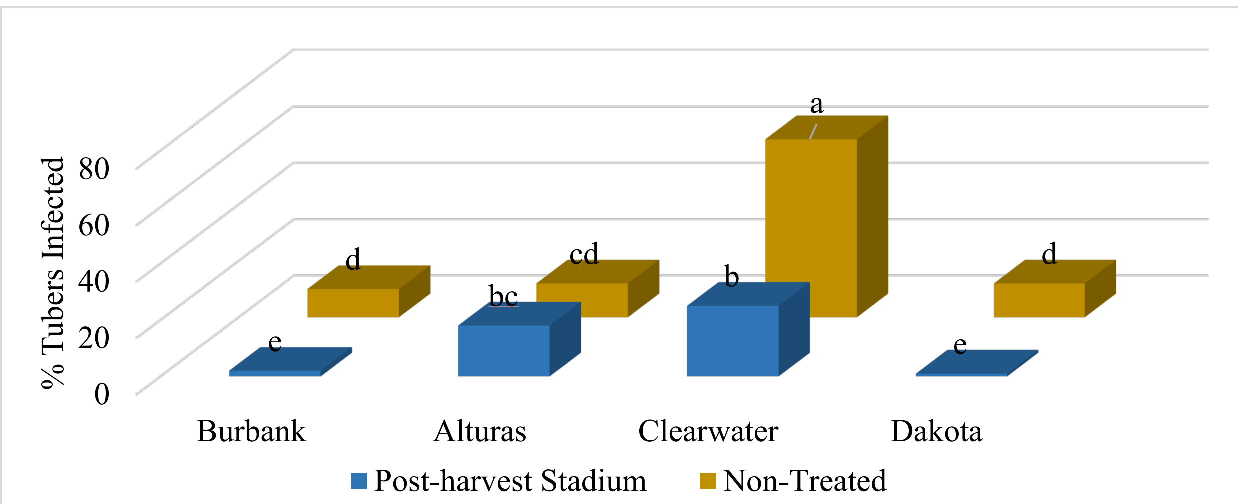


Figure 4. Effect of post-harvest Stadium treatment on Pythium leak as determined by a post-harvest inoculation/treatment test.

**Summary**

Phosphorous acid fungicides are effective in reducing pink rot development in the field, but the field treatment may not be effective for infections that can occur at harvest. Post-harvest phosphorous acid applications may be needed if pink rot is present prior to harvest. The effect of the post-harvest application was not dependent upon variety. Foliar phosphorous acid treatments are not effective against leak, but post-harvest Stadium applications can reduce disease, depending on the variety. Unfortunately, Stadium is not available to use for many growers due to export issues.

Foliar fungicide applications may increase the threat of Pythium leak by providing a longer potential infection period. Additionally, post-harvest fungicides are not as effective for leak as with pink rot. It is best when fungicides are used in combination with all other management practices. Relying on fungicides alone will not be effective if other efforts are not made to minimize disease development.

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