Managing Fusarium Dry Rot

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Fusarium dry rot is a disease of potato tubers. Some of the fungi involved can also cause a wilt of potato plants during the season (Secor and Salas 2001). The pathogens can overwinter in infected tubers in storage, or as spores in the soil. During the seed cutting process, Fusarium spores from infected tubers can contaminate healthy seed pieces. Dry rot can then begin to develop in the newly cut seed pieces. After planting, dry rot may decay the seed piece weakening developing plants, or preventing emergence thus reducing stand. During the growing season daughter tubers can become contaminated from Fusarium spores in the soil or from the mother seed. At harvest, dry rot develops primarily at wound sites. Once tubers have been cooled to storage temperatures, decay will be slowed. Some contaminated tubers can survive the storage season, thus perpetuating the disease cycle.

In southern Idaho, the primary species known to cause Fusarium dry rot are *Fusarium sambucinum* and *Fusarium coeruleum*. Survey work done in the 1990s showed that *F. sambucinum* was more prevalent than *F. coeruleum* in storage. The symptoms of these two species can differ significantly (Figure 1). More recent work from 1999-2001 (Ocamb et al 2007) and a current survey underway indicates that additional species of *Fusarium* associated with potato dry rot are present in the Pacific Northwest, including *F. oxysporum*, *F. solani, F. equiseti, F. culmorum, F. avenaceum* (Ocamb et al 2007), but *F. sambucinum* appears to be the most prevalent, comprising ~35-50% of isolates collected in these surveys.

F. sambucinum does not uniformly grow through the potato, but instead it appears to develop in channels. Fungicide resistance of *F. sambucinum* to the benzimidazole fungicides was documented in southern Idaho in the 1990s. As a result, seed treatments like Tops 2.5 and Topsin (thiophanate methyl), TBZ (thiabendazole) and the post-harvest fungicide Mertect (thiophanate methyl) became ineffective in managing seed piece decay caused by *F. sambucinum*. Recently, resistance to fludioxonil has been reported for this species in Michigan and Canada (Gachango et al 2012;Peters et al 2012). *F. sambucinum* grows faster than *F. coeruleum* in storage and is more problematic in precut seed that is stored without appropriate ventilation, humidity, and temperature.

F. coeruleum on the other hand can grow uniformly throughout the entire tuber (Figure 1). *F. coeruleum* can be more destructive in the field because it damages the seed piece more severely and grows faster in soil. When dry rot is a problem in fresh cut seed (cut and planted directly without storage), *F. coeruleum* may be more problematic than *F. sambucinum*, but a laboratory test is required to confirm which species are present. In studies conducted in 1994 where tubers were separately inoculated with both species and placed in moist sand at 65-70°F, incidence of infection by *F. coeruleum* was 100% while incidence of infection by *F. sambucinum* was 42%. Fungicide resistance has not been observed with *F. coeruleum*, and it is not as common in storage as *F. sambucinum*. More than one species can infect the same tuber and a combination infection can be more damaging than one species alone.

Figure 1. Symptoms of *Fusarium sambucinum* infection on the left and *Fusarium coeruleum* infection on the right.

Fusarium dry rot is best managed by using multiple management practices:

1. Use clean seed with minimal dry rot
2. Disinfect seed cutting equipment regularly – between seed lots and periodically within a seed lot
3. Sharpen seed cutting knives
4. Avoid holding pre-cut seed in conditions that lack airflow and contribute to condensation events on cut surface
5. Treat with an effective seed treatment
6. Minimize wounding at harvest
7. Promote wound healing with proper ventilation, temperatures, and humidity during the early part of storage
8. Utilize post-harvest treatments

1. Use Clean Seed

Research sponsored by the Idaho Potato Commission in the 1990s showed a relationship between the level of Fusarium dry rot in seed and the level of dry rot which developed in daughter tubers in storage. Seed tubers were inoculated with *F. coeruleum* and left untreated (no fungicide seed piece treatment) or treated with three different fungicide seed treatments (Table 1). While the differences were not statistically significant, the trend was for higher levels of dry rot in the daughter tubers as the level of dry rot in the mother tubers (seed pieces) increased. The conclusion of this research was that using seed with less dry rot will result in a lower potential for dry rot in storage. Of course, this risk can be mitigated by implementing practices that minimize wounding and bruising during harvest time, allow healing before storage, and promote optimal storage conditions.

Table 1. Incidence of Fusarium dry rot in potato seed and in resulting daughter tubers. Seed tubers were inoculated with *F. sambucinum*. Means followed by the same letter are not statistically different ($P<0.10$).

	% Fusarium Dry Rot Incidence	
	Pre-Cut Seed	Storage Decay
Untreated check	89 a	8 a
MZ dust (1 lb)	44 c	4 a
Tops 2.5 (1 lb)	73 b	8 a
Polyram (1 lb)	100 a	12 a

2. Disinfect Seed Cutting Equipment

Fungal spores and bacterial cells can be spread on seed cutting equipment. Early research on Fusarium dry rot showed that cutting knives could spread inoculum (Small 1944). A diseased tuber was cut with a knife and then that knife was used to cut eight tubers. The test was conducted six times so that the researcher had a total of 96 half-cut tubers. A total of 42 (44%) of these half-cut tubers developed dry rot. This was compared with a knife that was disinfected after cutting an infected tuber. All 96 half-cut tubers from the disinfected knife remained healthy.

It is good practice to thoroughly clean and disinfect seed cutting equipment daily (Bohl et al 2003). At a minimum, cutting equipment should be cleaned when changing from one seed lot to another. Proper sanitation practices involve at minimum a two-step process: 1. washing with hot water and detergent followed by 2. application of a disinfectant (Olsen and Nolte 2011). The first step, washing with a detergent, removes any debris that might reduce the effectiveness of the disinfectant; the second step, the disinfectant, reduces pathogen populations.

3. Sharpen Seed Cutting Knives

Sharp cutter blades can reduce Fusarium seed decay because they provide a clean cut that heals more quickly than a ragged cut. A trial using natural inoculum (not inoculated) was conducted in 1994 where tubers were cut with freshly sharpened cutter blades or blades which had been dulled with a file. Seed tubers cut with sharpened blades did not develop dry rot, while seed tubers cut with dull blades exhibited 10% Fusarium dry rot.

4. Avoid holding pre-cut seed in conditions that lack airflow and contribute to condensation events on the cut surface

Pre-cutting and storing seed improves the logistics of potato planting (Bohl et al 2003) and has been shown to result in increased vigor and stand in some circumstances (Chase et al 1989). Growers can cut the seed when the weather is not conducive for planting. More attention and care can be given to the cutting operation. If potato seed is stored properly, cut surfaces can heal which will prevent bacterial soft rot from affecting the seed. However, pre-cutting seed can increase the risk of infection by *Fusarium sambucinum*. If fungicide seed piece treatments are applied to cut seed and then the treated seed must be held for a period of time before planting, be sure to follow labeled instructions regarding limits on height of pile and number of days to hold before planting.

The data presented in Table 2 are indicative of several tests which were conducted in the 1990s. In this specific trial potato seed tubers were cut and inoculated with either *F. sambucinum* or *F. coeruleum*, and then either left non-treated or treated with one of three fungicide seed treatments. Pre-cut seed inoculated with *F. sambucinum* led to significantly more dry rot regardless of the seed treatment. When seed inoculated with *F. sambucinum* was cut and directly planted, significantly less dry rot was observed. In fact, no dry rot developed in the untreated check.

The data were different for *F. coeruleum*. Substantial dry rot developed in both pre-cut and direct planted seed which were not treated. Applying a seed treatment regardless of the seed treatment type significantly reduced dry rot. For pre-cut seed the reduction was greatest for Mancozeb dust and Tops 2.5.

Table 2. Effect of pre-cut and direct planting potato seed inoculated with *F. sambucinum*. Means followed by the same letter are not statistically different (*P*<0.10).

	% Fusarium Dry Rot Incidence			
	Fusarium sambucinum		*Fusarium coeruleum*	
	Pre-Cut	Direct Planted	Pre-Cut	Direct Planted
Untreated check	89 a	0 b	85 a	80 a
MZ dust (1 lb)	44 c	0 b	2 c	30 b
Tops 2.5 (1 lb)	73 b	18 a	6 c	16 b
Polyram (1 lb)	100 a	16 a	70 b	28 b

Applying the liquid fungicide Polyram did not provide adequate protection. The active ingredient in Polyram is metiram which is in the same fungicide class as mancozeb. There is great interest in moving away from dust treatments (such as Mancozeb dust or bark dust) due to worker exposure and health issues. While the human safety issue associated with dust has not been studied specifically in potatoes, research in other crops has shown exposure to dust can increase health problems of workers who handle treated seeds (Smit et al 2006;White and Hoppin 2004). These data show that switching from a dust to liquid formulation of a dithiocarbamate fungicide (i.e. from Mancozeb dust to Polyram) may not be simple. Research conducted at the Aberdeen REC in 2018 demonstrated that a slurry formulation of mancozeb may be effective for dry rot management when followed by an alder bark dust treatment. Additional research is needed to see if liquid dithiocarbamate fungicides can consistently perform as well as Mancozeb dust.

5. Treat with an Effective Seed Treatment

Mancozeb dust has been highly effective in reducing Fusarium dry rot in seed. Miller Research conducted many tests in the early 1990s showing a failure of benzimidazole-type seed treatments (e.g. Tops, TBZ) to control dry rot. However, when mancozeb dust was added to the seed treatments (e.g. Tops MZ), disease control was obtained. Resistance to benzimidazoles in *F. sambucinum* was found to be common then and is still common today as far as we know (Gachango et al 2012). Mancozeb is an effective choice as a seed piece treatment because pathogens are not as likely to develop fungicide resistance to it, and it also is one of the few seed piece treatments that prevent spread of the late blight pathogen which can occur during the cutting process.

In addition to mancozeb, which is available in dust and slurry formulations, other fungicide seed piece treatments that are effective against dry rot are now available as dust, slurry, or liquid formulations and are summarized in Table 3. Research conducted at the University of Idaho at the Aberdeen REC has demonstrated that the liquid formulations work as well or better than the dust formulations in some cases, but all of the commercially available products can be effective. In some cases, following the liquid fungicide treatment with an alder or fir bark may be beneficial.

Table 3. Fungicide seed piece treatments labeled for use in Idaho that effectively manage Fusarium dry rot

<table>
<tr><th>Active ingredient</th><th>Commercial products (partial list) labeled for use as seed piece treatments on potato</th><th>Comments</th></tr>
<tr><td>Mancozeb alone</td><td>StartUP MANZB, Koverall, Manzate Max, Manzate ProStick, Penncozeb, Penncozeb 80 WP, Roper DF Rainshield</td><td>Mancozeb is the only fungicide listed in this table that also has activity against late blight</td></tr>
<tr><td>Mancozeb + Flutolanil</td><td>Moncoat MZ</td><td>The mancozeb component is for dry rot.

The flutolanil component is mainly for Rhizoctonia diseases</td></tr>
<tr><td>Mancozeb + Fludioxonil</td><td>Maxim MZ</td><td rowspan="5">Fludioxonil is an effective fungicide for dry rot, but resistance in F. sambucinum to fludioxonil in other regions outside the PNW has been reported.

Difenoconazole is effective against dry rot and helps with fungicide resistance management.

Sedaxane is effective for Rhizoctonia and silver scurf, but is not considered effective for dry rot.

Thiamethoxam provides insect control for some insects.</td></tr>
<tr><td>Fludioxonil alone</td><td>Maxim 0.5%, Maxim PSP, Maxim 4FS, Spirato, Dyna-Shield</td></tr>
<tr><td>Fludioxonil + Thiamethoxam (insecticide)</td><td>CruiserMaxx Potato</td></tr>
<tr><td>Fludioxonil + Difenoconazole + Thiamethoxam (insecticide)</td><td>CruiserMaxx Potato Extreme</td></tr>
<tr><td>Fludioxonil + Difenoconazole + Sedaxane + Thiamethoxam (insecticide)</td><td>CruiserMaxx Vibrance Potato</td></tr>
<tr><td>Difenoconazole alone</td><td>Salient 372 FS</td><td>Difenoconazole is effective for dry rot.</td></tr>
<tr><td>Prothioconazole + Penflufen</td><td>Emesto Silver</td><td>Prothioconazole is effective for dry rot.

Adding a mancozeb product formulated for seed potatoes may add dry rot efficacy.</td></tr>
</table>

		Penflufen is effective for Rhizoctonia diseases and silver scurf, but not dry rot.
Benzimidazoles: thiophanate-methyl Thiabendazoles (TBZ)	ST-Methyl 540 FS	No longer recommended in our region due to high proportion of fungicide-resistant *F. sambucinum*. Other species of *Fusarium* may be susceptible to this fungicide group

Whole seed versus cut seed – and are there advantages to treating whole seed?
Previous research from the University of Idaho has demonstrated that cut seed, when treated with a protectant fungicide seed piece treatment, can perform as well or better than single drop whole seed that has not been treated with a fungicide. More recently, they found that a seed piece treatment (Maxim MZ in this case, which is a combination of fludioxonil and mancozeb) consistently reduced the incidence and severity of Fusarium seed piece decay, compared to the non-treated control, regardless of whether the treatment was applied to whole seed tubers or cut seed. Overall, fungicide seed piece treatments can have value whether seed is cut or used whole.

Liquid versus dust formulations of fungicide seed piece treatments
How well a seed piece treatment performs depends on several factors, such as how seed pieces are handled before and after treatment, soil temperature and moisture at planting time, disease pressure, and coverage of the product on the seed pieces. Liquids lend themselves to more uniform and precise application, they can potentially provide better coverage on whole seed tubers, they can be easier to apply, and they offer the added benefit of improved worker safety. Some liquid formulations allow the option to use a follow-up treatment with bark or other carrier dust depending on seed handling conditions. Proper calibration of liquid application is critical.

6. Minimize Wounding at Harvest

Fusarium species require a wound to enter tubers, so any reduction in wounding will help manage dry rot. Some of the earliest research on dry rot looked at wounded and non-wounded potatoes at harvest (Small 1944). Very little dry rot was observed in non-bruised tubers and numerous bruised tubers developed dry rot. One encouraging finding from this early research was that dry rot did not appear to spread in storage.

Air blowers on harvesters did not increase dry rot. In a field study conducted in southern Idaho in 1992, tubers were collected from the secondary chain just before tubers were dropped through the blower air stream and just after the drop onto the side elevator. A total of five replicate samples (18 lb each) were collected from five different areas in the field to obtain 25 total samples. These were obtained from three different harvesters. Tubers were placed in the commercial storage where the potatoes from that field were being stored. Samples collected before and after the blower had similar degree of dry rot, indicating that the blowers were not increasing dry rot potential.

Passing tubers through sand separators significantly increased dry rot in storage. Sand machines use sand and air to separate rocks and clods from potato tubers. A trial was conducted where tubers harvested from a commercial field were sliced in half longitudinally and one half was sent through the sand separator and the other was not. Two separate sand machines were tested. Dry rot was increased by 8-19% by passing tubers through a sand separator.

Tubers with knobs or malformations are at a higher risk to developing dry rot because these tubers are more easily damaged at harvest.

7. Promote healing of wounds resulting from handling at harvest

Conditions that promote healing when seed potatoes are first received in the spring are similar to what is required for tubers that are harvested in the fall, except the total time recommended for healing should include the number of days required to remove field heat from the tubers, to avoid holding tubers too warm for too long. Favorable wound healing conditions are high humidity, no free moisture, good airflow, and temperatures above 50°F. Warmer temperatures above 50 to 55°F may be beneficial in the formation of the wound periderm, but greater disease development and weight loss can be a negative consequence. It is ideal to cure potatoes at temperatures just long enough to allow for rapid wound healing, but not too long as to have an impact on weight loss, disease development, and/or other quality characteristics. Temperatures below 50°F require a longer wound healing period that may allow diseases the chance to invade the wound.

8. Utilize Post-Harvest Treatments

Post-harvest treatment with benzimidazole fungicides (i.e. Mertect) used to effectively prevent dry rot development in storage. However, the onset of resistance of *F. sambucinum* to this group of fungicides has rendered it ineffective. The authors have personally observed some cases where using Mertect or Tops made dry rot development more severe. The common disinfectant chlorine dioxide has been shown to be ineffective in controlling Fusarium dry rot (Olsen et al 2003). Biological control trials with *Pseudomonas* bacteria have shown variable results (Al-Mughrabi 2010; Al-Mughrabi et al 2013; Schisler et al 2000).

Recently, the post-harvest fungicide Stadium (produced by Syngenta Crop Protection) has shown reliable efficacy against dry rot (N. Olsen, unpublished data). Prior to using Stadium, growers must consult with their customer (i.e. processor), as export restrictions may exist. Growers raising potatoes for seed can use Stadium keeping in mind export restrictions may affect the sale of any potatoes not sold as seed.

Summary

Fusarium dry rot can be managed with an integrated approach which uses all the tools listed here. Although cultural practices can go a long way to manage this disease, a fungicide seed piece treatment can be considered insurance particularly if cut and treated seed will be planted in non-optimal soil conditions. Newer varieties such as Clearwater Russet may require more intensive management due to its relatively high susceptibility to dry rot (Novy et al 2010). More research is needed to determine how well these measures will work for varieties which are more susceptible than Russet Burbank.

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