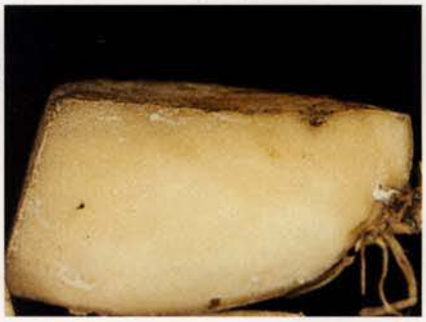
Managing Benzimidazole Resistance in the Potato Dry Rot Fungus

P. Nolte



Dry rot is one of the most destructive potato tuber diseases in the world, causing serious losses both in stored potatoes and in cut seed. Benzimidazole resistance in *Fusarium sambucinum*, one of the species of *Fusarium* that causes dry rot, has been investigated for several years in Idaho and in other potato-producing states. The benzimidazoles are a common and important group of agricultural fungicides that include thiabendazole (marketed as TBZ or Mertect) and thiophanate-methyl, (marketed as Tops or Topsin), which are labeled for use on potatoes. The presence of benzimidazole resistance means that you may not obtain control or suppression of *Fusarium* dry rot when benzimidazoles are employed.

How widespread is the resistance problem? To address this question, a procedure called the "modified bag test," described below, has been developed to examine seed lots for both dry rot potential and for the presence of benzimidazole resistance in the pathogens that cause it. Results from 68 modified bag tests performed during the winter of 1992-93 show that 53 of the samples (78 percent) were benzimidazole resistant and only 15 (22 percent) were sensitive.

The percentage of resistant isolates found in this series of tests is similar to the results from the other major potato-producing areas of the United States. Benzimidazole resistance could adversely affect both seed and commercial potato growers because a lack of dry rot control may result when benzimidazole fungicides are used, both in stored potatoes and on cut seed. A fungicide resistance management program has been initiated to inform Idaho growers about the potential for dry rot problems and to provide them with guidelines for resistance management.

As yet, there have not been any cases of seed piece treatment failures in the field. However, growers who regularly pre-cut and store seed for more than 2 weeks before planting could be taking a serious risk if they use a benzimidazole fungicide seed piece treatment and the strains of dry rot fungus in their farming operation are resistant. The risk in cut and stored seed is much greater than that for seed that is cut, treated, and planted immediately. This is because the environmental conditions in a large pile of cut potatoes are apparently much more favor-

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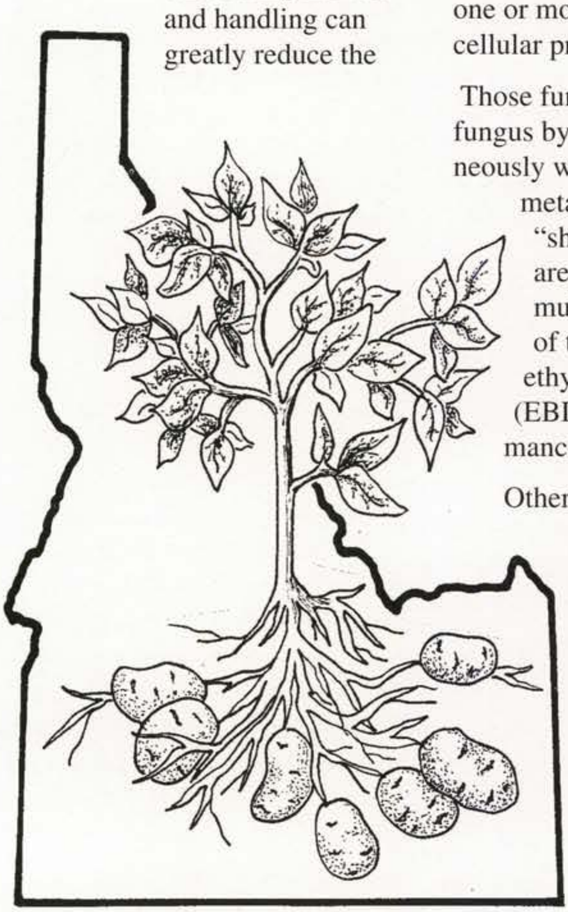
able for dry rot development than the conditions encountered in the soil.

The Dry Rot Fungi

Dry rot is caused by fungi of the genus *Fusarium*. These fungi can cause seed piece decay as well as rotting in whole potatoes during storage. There are two species that are important in Idaho: *Fusarium sambucinum* and *F. coeruleum*. Either of the two species can cause dry rot but there are distinct differences in symptoms and in rotting patterns. With both species, early stages of the disease appear as small brown areas around and beneath wounds. As they get older, lesions caused by *F. coeruleum* turn yellow to brown in color and the lesions start from the site of infection and progress in a fairly uniform manner through the tuber tissues. Lesions caused by *F. sambucinum*, on the other hand, tend to be very dark in color, from dark brown to almost black, and often progress through the tuber tissue in a very nonuniform manner, a pattern that has been described as "tunneling." Figure 1 compares the two species of *Fusarium*. In both species, the lesions eventually become dry and spongy in texture and may be accompanied by hollow cavities. As the infection progresses, the skin over the lesion collapses and wrinkles. Severely rotted tubers shrivel and become mummified.

At low storage temperatures and in older lesions, the affected tissues are usually dry and firm, and may have a papery texture. At high temperatures and in the early stages of infection, however, the lesions are often wet and pliable. This condition is sometimes referred to as "wet phase" *Fusarium*. This latter trait can cause confusion during diagnosis because it resembles the symptoms of other disorders, such as black-heart or blackleg. Older infections are characterized by tuber tissues that are brown and collapsed, often with a white fungal growth; other colors, including areas of yellow, orange, or even pink are often found in these older lesions. So far, benzimidazole resistance has been identified only in *F. sambucinum*.

Dry rot pathogens enter potatoes only through cuts and openings in the tuber skin caused by bruising during harvest and transport. Extra care during harvest and handling can greatly reduce the amount of decay that may show up later. Dry rot does not spread from tuber to tuber during storage; yet it is, by far, the most common storage disease in Idaho.



Development of Fungicide Resistance

How does fungicide resistance develop fungi? The answer lies partly in the type of and how the fungicide is used. To understand how the type of fungicide affects the development of resistance, we must first consider how fungicides work. Even the lowly dry rot fungi are very complex organisms that must conduct a great many chemical and physical processes in order to survive and reproduce. Fungicides, and other pesticides, kill the target organism by interfering with one or more of these important cellular processes.

Those fungicides that kill the fungus by interfering simultaneously with several of these vital metabolic processes, a sort of "shotgun" mode of action, are referred to as having multi-site action. Examples of this type are the ethylene-bisdithiocarbamate (EBDC) fungicides, such as mancozeb or polyram.

Other fungicides use a more specific "silver bullet" approach and only target one of the many fungal metabolic processes. Such fungicides are referred to as having single site action. The benzimidazoles belong to this group.

This point is very important. A single

mode of action in the fungicide means that a single mutation in the fungus can enable it to circumvent the activity of this type of fungicide. Resistance to multi-site action fungicides is much less likely to occur because several mutations of exactly the right combinations would be necessary. For example, there are no known cases of EBDC resistance among plant disease-causing fungi.

Although a mutation to resistance can occur at any time, research has shown that most populations of fungi contain some strains that already possess a fungicide resistance trait. Interestingly, possession of this resistant trait will often, but not always, make that strain of fungus less able to compete with wild type strains. In the absence of any particular selection pressure, the wild types dominate and the resistant types remain merely a tiny fraction of the population.

The situation changes when a single-site action chemical (or a related chemical with the same mode of action), is applied frequently or exclusively. Under these conditions, the resistant strain is able to grow and reproduce while the sensitive or susceptible wild types are killed by the fungicide. Even though the fraction of resistant types in the original population is very small, selection for resistant strains can occur very rapidly under the right kind of selection pressure.

In summary, fungicide resistance develops because a certain type of fungicide (single site mode of action) is used frequently or exclusively to control a particular fungus. Over time, strains of the fungus resistant to this fungicide become the predominant type and the fungicide loses its effectiveness against the disease.

Fungicide Resistance Management Procedures

The basics of fungicide resistance management will require some changes in how growers use fungicides to control dry rot.

1. Use Integrated Pest Management (IPM) practices.
2. Alternate fungicides.
3. Use fungicide combinations (when possible).

1. **Use IPM practices**. A very important point of resistance management procedures is that relying on only one form of disease control, i.e., using a fungicide, is risky. Resistance is more likely to develop and become a problem when fungal populations are high. Growers should reduce the potential for dry rot by employing integrated pest management (IPM) procedures for dry rot control whenever possible. IPM practices combine cultural control measures with chemical controls, which eases the selection pressure on the dry rot pathogen. (For further information, see PNW 257 *Potatoes, Storage, and Quality Maintenance in the Pacific Northwest*, and CIS 725 *Bruise-free Potatoes, Our Goal* or the following videos: 586 *Potato Bruise Prevention* (also available in Spanish, 586 B), 275 *Potato Bruise Prevention: The Harvester*, and 471 *Potato Bruise Prevention: Harvester Chain Adjustment)*. Remember only precut and store seed with extreme caution because of the very favorable conditions for dry rot development present under precutting conditions.

2. **Alternate fungicides**. Starting now, for potato dry rot control, using fungicides with modes of action different from the benzimidazoles is necessary. Under this strategy, you can still use benzimidazole fungicides (Mertect /TBZ is the only treatment registered for post-harvest application on potatoes) but fungicides with different modes of action, such as EBDC's would be employed as seed piece treatments.

3. **Use fungicide combinations**. Using combinations of fungicide is another option. Under this strategy, a benzimidazole fungicide can still be used for dry rot control on cut seed but it is combined with another fungicide that has a different mode of action and the two are applied together, in combination. The combination fungicide can have either multi-site or single-site action. Under these conditions, the fungus must overcome more than one type of chemical in order to become resistant. In Idaho, two fungicide combinations currently are registered for use on cut seed, and others are under development.

Recent research at the University of Idaho indicates that in the absence of resistant strains of dry rot fungus, the benzimidazole fungicides are still very effective for controlling sensitive strains of *F. sambucinum* and for controlling all known strains of *F. coeruleum*.

Fig. 1. Typical dry rot symptom associated with *F. coeruleum* (left) and *F. sambucinum* (right).

Growers are encouraged to perform the modified bag test to determine whether or not benzimidazole resistance is present in their seed before deciding which seed piece treatment to use. Those who do not know or who are unsure about benzimidazole resistance in their seed lots are encouraged to use either non-benzimidazole or combination fungicides as seed treatments.

The Modified Bag Test

The bag test was developed to enable growers to determine if there is a potential for dry rot problems in their seed potatoes. The modified bag test employs the same methods but has some simple added features for fungicide resistance determination. The traditional bag test will be described first, followed by the modified test.

The Bag Test

To perform the bag test, you will need a knife, a large paper shopping bag, a large plastic trash bag (large lawn bags are ideal), and at least 25 6 to 10 ounce seed tubers from the storage or seed lot that you wish to test. Pick the tubers at random, but don't include any tubers that you would grade out before cutting because of obvious decay problems.

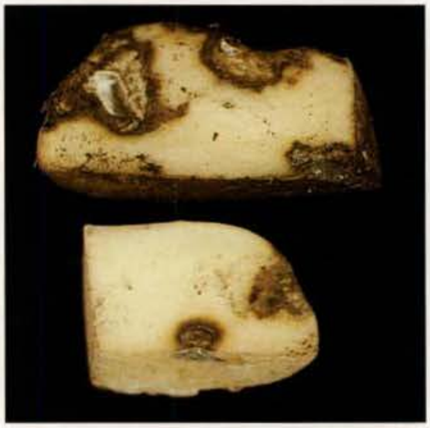
Once you have gathered all these items, performing the test is simple. First, cut all of the tubers into seed pieces with the knife (put the single drops in whole) and place them in the large paper shopping bag. Cutting the tubers into quarters with a longitudinal cut followed by a cross section cut exposes a lot of wounded tissue. Seed pieces made this way are ideal for the test.

Next, roll the top down on the paper bag and gently shake the bag for at least 30 seconds. You may wish to invert the bag several times during this process. The shaking will serve to inoculate the freshly-cut surfaces with any *Fusarium* spores that might be present. Don't worry if the top of the bag unrolls when you are finished.

Then put the paper bag (with the cut seed still inside) into the large plastic trash bag. DO NOT SEAL THE PLASTIC BAG! Instead, allow the top of the bag to droop over just so that the seed in the

A

B



C

Fig. 2. Results of a traditional bag test showing:
A. Low dry rot potential,
B. High dry rot potential, and
C. Severe dry rot lesions starting from dry rot infection already established in the tuber. Note that dry rot lesions have also started on the newly cut surface as well.

A

B

C

Fig. 3. Results of a modified bag test showing benzimidazole resistance in the dry rot fungus.
A. Untreated check.
B. Benzimidazole-treated.
C. Mancozeb or combination-treated. Non-resistant dry rot would have shown very low to no dry rot in both benzimidazole and mancozeb or combination treatments.

paper bag is not subjected to direct air currents. The aim here is to trap most of the humidity from the cut seed in the plastic bag while still allowing for some oxygen exchange. Without some humidity, the seed pieces will simply dry out and without oxygen (if the trash bag were sealed) they will probably decay due to soft rot.

Now, store the bag test in a place where you can leave it undisturbed for 3 to 4 weeks at a reasonably warm temperature. Room temperature (72°F) is about the upper limit but the temperature should be at least 60°F. A corner of your office or under a bench in a heated shop is an ideal location.

Examine the cut seed after 3 to 4 weeks for decay. If the seed pieces are whole and there is little or no dry rot present, you should have no problems with your seed (fig. 2A). If there is a lot of dry rot, however, your seed lot may have a high dry rot potential (fig. 2B). One indication of high dry rot potential may be a high incidence decay that does not come in from the newly cut surface. This indicates that the rot started from an already established *Fusarium* lesion (fig. 2C). Seed piece fungicides applied after cutting will not protect the cut seed from dry rot that has already established an infection in the tuber. A high dry rot potential is a factor you will have to take into account when planting or selling the seed next season.

The bag test is easy to perform and provides growers with important information about their seed. Growers should perform this simple test on their seed lots every year.

Determining Benzimidazole Resistance

One minor modification to the traditional bag test turns it into a tool for determining benzimidazole fungicide resistance. Gather the materials for doing a bag test, only this time triple the number of tubers and shopping bags. This means three shopping bags and at least 75 tubers. Divide the 75 tubers into three equal groups. Do the bag test exactly as described previously for one of the three groups of tubers. Consider this to be the untreated check. This untreated check will give you an indication of the dry rot potential of your seed if you don't use any seed piece treatment.

With the other two groups we will do almost the same thing but we'll make one modification: After the cut seed has been shaken in the paper bag to inoculate it, open the bag and add a seed treatment. Use a benzimidazole product, such as TBZ or Topsin in one bag, and either a combination or an EBDC such as Mancozeb in the other. It would be best if you used a small scale to weigh the cut seed to determine the proper amount of fungicide. Here's a simple formula you can use with a hand calculator to determine the amount of seed treatment fungicide you will need:

16 x (the weight of your seed in lb /100) = __ oz of seed treat for the test.

If you don't have a small scale, you can still get close enough to the right amount to do a valid test. The following values are very close to the proper amount: 25 tubers x 8 oz (avg.) = 12.5 lb. of cut seed. Most seed treatments go on at the rate of 1 lb (16 oz) per cwt, so 16 x (12.5 / 100) = 2.0 oz of seed treat. To make things even easier, we have determined that 1 ounce of seed treat is just about 3 level tablespoons. If you use an actual tablespoon, be sure that no one uses it for preparing food afterwards.

After you add the seed treatment, tightly roll the top of the bag down and shake it gently for at least 30 seconds to coat the seed pieces with the treatment. You may wish to turn the bag upside down several times during this procedure to ensure good coverage. Let the roll at the top of the bag relax.

Now place your control and your bags of treated seed in the plastic trash bag and store as described above. At the end of 3 or 4 weeks, examine both treated and untreated seed for decay. If the benzimidazole treated seed has as much or more decay than the control, and the combination or EBDC treatment has little or no decay, you probably have a resistant strain of *Fusarium* in your seed lot (fig. 3A-C). Call your Extension agricultural agent if you find this problem. Once the problem has been identified, it is relatively easy to control.

Other Possibilities

A number of modifications of the above technique are possible. Perhaps you only want to know if the seed treatment you are planning to use will be effective. If so, simply substitute your seed treatment choice for the benzimidazole treatment described above.

Another option is to test several different seed treatments. To do this, just add another bag and another 25 tubers for each seed treatment you wish to test. You can store up to four paper bags in one trash bag without any problems.

For More Information

Iritani, W. M., and W. C. Sparks. 1985. Potatoes, Storage, and Quality Maintainance in the Pacific Northwest. PNW 257. Moscow, ID: University of Idaho.

Kleinschmidt, G., and M. K. Thornton. 1991. Bruise-free Potatoes, Our Goal. Bulletin 725. Moscow, ID: University of Idaho.

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