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2018 North Dakota FIELD CROP PLANT DISEASE MANAGEMENT GUIDE

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NDSU EXTENSION SERVICE

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

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DISCLAIMER

This plant disease management guide is based on the latest information available from the North Dakota Agricultural Experiment Station, U.S. Department of Agriculture, U.S. Environmental Protection Agency (EPA) and the agricultural chemical industry. The information conformed to federal and state regulations at the time of printing. The user should determine that the intended use is consistent with label directions. ***Designation that a product is labeled for control of a crop disease does not imply endorsement by the authors of use of that product or the degree of efficacy of that product for that use.***

Always follow the label directions. See individual fungicide labels for important information on:

- Safety recommendations and worker protection requirements
- Guidelines for ground, irrigation or aerial application
- Mixing procedures and tank mixes allowed
- Rotational and grazing restrictions
- Resistance management statements

LABEL PRECAUTIONS, RESTRICTIONS

Field re-entry, handling and loading precautions

Most fungicide labels state that workers either should not enter a sprayed field until the sprays have dried or should not enter for 24 hours unless they wear appropriate protective clothing. Information on use of protective clothing during mixing and loading also is given on the label. See the label for details.

Replant restrictions

Labels for all formulations of Ridomil have restrictions on what crops can be planted in less than a year following application of the product. These restrictions may vary somewhat depending on the formulation. Check these and all other labels **before** application to determine if replant restrictions will cause problems when determining what crop to plant next season.

Dosages

All dosages given in this guide are stated as the amount of formulated product (lb., oz., fl. oz., quarts) to use.

Restricted-use fungicides are fluids that are not available to the general public and are to be purchased and used by a certified pesticide applicator.

Fungicides containing triphenyltin hydroxide are restricted-use fungicides. These include products such as Super Tin, Agri Tin and Super Tin 4L. These are designated as RUP and Restricted-Use Pesticide in the tables.

Disclaimer

The information given herein is for educational purposes only. North Dakota State University does not endorse commercial products or companies, even though reference may be made to trade names, trademarks or service names. **Omission of labeled products is possible if information about the product was not available at the time of printing or if it had questionable efficacy. Products not normally available in North Dakota are omitted from the guide. Seed treatment chemicals that are primarily insecticides with subminimal amounts of fungicide also are omitted.**

The plant pathology faculty at North Dakota State University assume no responsibility for property damage, personal injury or other loss due to the use of fungicides listed in this publication because they have no control over the use or misuse of these products.

FUNGICIDE FORMULATIONS

Most fungicides are solids that are not soluble in water. To use them, they must be made into a formulation (preparation). Some of the more common formulations are listed below. The common abbreviation for each formulation is given in parentheses following the name.

Wettable powders (WP)

Many fungicides are wettable powders consisting of solid fungicide and a wetting agent. When mixed with water, they form a suspension. Many of these suspensions settle out quickly, so an agitator is needed in the spray tank to keep the particles in suspension.

Water-soluble pouch (WSP)

Some fungicides are available in water-soluble pouch containers. These pouches dissolve in the mixing tank and release the fungicide. This reduces the exposure of mixer and loader personnel to dust from the fungicide.

Dusts (D)

Dusts are powders that are mixed with inert ingredients to form a product with a low percent of active material. These are used around the home garden, and a few formulations are used in commercial applications.

Granules (G)

The active ingredient is incorporated into small granules of inert material such as clay. Granules are incorporated into the soil.

Emulsifiable concentrates (EC)

A fungicide that is insoluble in water is dissolved in an organic solvent. An emulsifying agent is incorporated in the formulation so an emulsion is formed when the product is mixed with water. An emulsion is a suspension of very tiny drops of the solvent/fungicide in the water. It usually has a milky appearance (milk itself is an emulsion of fats in water).

Flowables (F)

Flowables are insoluble fungicides ground into a very fine product, usually by a wet-grinding process. These particles are nearly colloidal and are suspended in water to form a thick liquid. They remain suspended in water for relatively long periods of time but should be agitated before use. They are dust-free, easy to mix, remain in suspension longer than wettable powders and also may resist washing off the plant better than the wettable powders. Examples of flowables include Champ Flowable, Kocide 4.5 LF, Vitavax 200 and Dithane F-45. They need to be protected from freezing.

Dry flowable (DF)

See dispersible granules. (Next page)

Dispersible granules (DG)

Dispersible granules also are called dry flowable formulations. They are small granules that pour from a container like a liquid but do not stick to the sides of the container and do not need to be protected from freezing. They are virtually dust-free and disperse readily in water to form a suspension. Examples include Bravo Ultrex DG, Dithane DF, Rainshield NT, Manzate 75 DF and Penncozeb DF.

Fumigants

Fumigants are liquids that turn into a gas after application. They generally are used for soil fumigation.

MODE OF ACTION OF FUNGICIDES

The action of most fungicides takes place outside the host and is called "*protection*." A fungicide that acts outside the host is called a "protectant fungicide." Most older fungicides sprayed on leaves and fruit are of this type. "*Therapy*" is chemical action inside the host. For example, fungicides are locally systemic and move into the plant at the site of deposition. Several triazole fungicides have several days of therapeutic action against wheat leaf rust and also reduce the production of viable spores; that is, spores capable of growing.

Most protectant fungicides are relatively stable by themselves. Generally, they are relatively insoluble in water and resist removal or chemical change by water, yet must be toxic to fungi. Often a chemical change is brought about by the fungus, the host or the environment before toxicity occurs. Toxicity simply means the ability to damage the fungus cells.

Fungicides may act to produce a toxic reaction in the fungus in several different ways. (1) Some may inhibit (slow down or stop) cell wall formation. (2) Some affect the permeability of the cell wall, causing a leaking of nutrient materials from the cell. (3) Some fungicides may combine with essential metals in a way that they become unavailable for normal cell functions, including the functioning of essential enzymes. (4) Other fungicides may inhibit respiration or nuclear division, or may break dormancy of spores.

Some fungicides also may be toxic to plants if applied at rates too high or if applied under unfavorable environmental conditions. This is called *phytotoxicity*. Formulations of maneb + zinc are less phytotoxic to many vegetables than formulations that contain only maneb. Sometimes the method of formulation may make a fungicide less phytotoxic.

TOXICITY OF FUNGICIDES

Effects of chemicals on humans

Fungicides have various levels of toxicity to humans. Human exposure (skin, eye, internal) to fungicides can result in mild to severe reaction. Due to high levels of toxicity, some fungicides are restricted-use only.

Symptoms associated with chemical poisoning are listed below. All symptoms are not associated with every pesticide. Some of these symptoms are described below, but consulting a physician always is wise. Avoid diagnosing the effects on yourself or others.

Eyes watering excessively
Stomach cramps
Dizziness
Vomiting
Excessive sweating
Pupils of the eye reduced in size
Rapid heart beat
Muscle tremors or convulsions
Extreme nervousness
Mental confusion, lack of coordination
Uncontrolled drooling or watering at the mouth
Severe burns of the skin
Loss of ability to use muscles
Difficulty in breathing
Unconsciousness

First aid

The following list should be considered:
Stop exposure
Call a physician
Remove contaminated and restrictive clothing
Drench contaminated area with water; flush repeatedly
Provide fresh air but prevent chilling and overheating
Avoid giving alcohol
Provide milk for patient to drink
Antidote - to be administered only by a physician

North Dakota Poison Control Center
Toll-free: (800) 732-2200

Toxicity ratings of pesticides

Pesticides generally are categorized according to acute **oral toxicity** (the toxicity when taken by mouth), but because users may absorb a significant quantity of the pesticide through their skin, **dermal toxicity** (toxicity when absorbed through the skin) is of equal or greater practical importance.

LD_{50} values generally show relative toxicities among the chemicals and are not truly representative of effects on humans, especially since they usually are obtained on rats. Actual toxicities do not constitute the only hazards associated with exposure to the chemicals. For instance, a chemical with low toxicity may be hazardous due to concentration, high volatility, careless use or effects of long-term exposure.

LD_{50} depends upon body weight. Thus, a given amount of chemical would have greater effect on a child than on an adult. LD_{50} also is proportional to the percent of active ingredient. A material only 50 percent active requires twice as much to produce a toxic effect as 100 percent pure material.

The lower the LD_{50} value, the greater the toxicity. A common standard for comparison is aspirin, which has an LD_{50} of 1,200 mg/kg and is considered slightly toxic.

The following table illustrates the various toxicity classes:

Oral Toxicity		Dermal (Skin) Toxicity	
LD_{50}-mg/kg	Toxicity Class	LD_{50}-mg/kg	Toxicity Class
1-50	High	1-200	Severe
50-500	Moderate	200-2,000	Moderate
500-5,000	Low	2,000-20,000	Mild
Over 5,000	Very Low	Over 20,000	Very Mild

Information on the LD_{50} of a specific fungicide and other toxicology information are available on the MSDS (Material Safety Data Sheet) for each product. These generally may be found at www.cdms.net.

PROTECTING GROUNDWATER

Pesticides differ in their persistence and mobility in soil. Those that are highly persistent or highly mobile are more liable to contaminate groundwater than those that are not. Areas of the state where groundwater is most at risk are areas with coarse-textured soils, are low in organic matter and have a high water table. Most fungicides are relatively immobile, especially in clay soils with high organic matter, because they are adsorbed on clay particles or on the organic matter.

A few fungicides are somewhat mobile. Take care in the use of these fungicides, particularly the application of these products through a sprinkler irrigation system in high-risk areas. Risks may be reduced by minimizing the amount of water used for application through a sprinkler system, more use of ground or aerial application instead of application through the sprinkler system, and use of a different fungicide that is less mobile.

The persistence and mobility of fungicides commonly used in North Dakota may be found in NDSU Extension Service publication EB-49, “Persistence and Mobility of Pesticides in Soil and Water.”

HANDLING CHEMICALS

Avoid splashing and spilling. Wear a mask especially when handling dusts or powders. Some chemicals, when combined, have increased toxicity (potentiation).

Rinse containers several times after using chemicals. Pour rinsate into the spray tank when using the same chemical. Dispose of containers as indicated in the next section. Keep a record of plant disease control chemicals used and methods of handling.

FUNGICIDE LABELS

Fungicides are named according to their chemical composition or the *chemical name*. An example of a chemical name is a coordination production of zinc ion and manganese ethylene bisdithiocarbamate; the chemical names are required on the label. Since chemical names often are long, *common names* frequently are used; for example, the common name for the above chemical is mancozeb. Manufacturers use *trade names* to identify their specific products. For example, there are various trade names for mancozeb, such as Dithane, Manzate and Penncozeb.

In addition to the names on labels, various other required label information includes precautions in handling, antidotes or telephone contacts to use in case of accidental poisoning, recommendations for use, materials contained in the package and their percentages, the manufacturer's or distributor's name and address, and the EPA registration number.

Some fungicides are made up in various formulations for different uses or methods of application, such as wettable powders, dusts, emulsifiable concentrates, granules, flowables, dispersible granules or solutions. The nature of the chemical sometimes restricts it to one or a few of these formulations.

SEED TREATMENT

Cereals

Fungicidal seed treatment helps protect the seed from rotting and the emerging seedlings from damping off and seedling blight. These are caused by soil-borne pathogens. When seeds germinate under favorable soil conditions, the danger of seed and seedling attack from soil-borne pathogens is lessened unless seed is of poor quality. Treatment of seed with a protectant fungicide may help protect against soil-borne pathogens and thus help stand establishment when seeds are germinating under unfavorable conditions, such as cold, wet weather. Many products are available for protection against seedling blight.

Treating seeds with a fungicide also helps protect them from diseases that are seed-borne. These include the covered smuts, bunt, scab, black point and black semi-loose smut of barley, and loose smuts of wheat, barley and oats. Loose smuts of wheat and barley are internally seed-borne. Loose smut of oats is seed-borne as spores under the hulls. These smuts cannot be controlled by conventional protectant seed treatment fungicides, but are controlled by systemic seed treatment products. The embryo test can be used by the North Dakota State Seed

Department to determine if loose smut is present in barley seed. This test cannot be used for the loose smuts of oats or wheat or black semiloose smut of barley. All current barley varieties are susceptible to loose smut. An embryo test is recommended for barley seed; if infection is 2 percent or greater, seed treatment of barley with an effective fungicide seed treatment is advised.

Common (*Bipolaris, Helminthosporium* or *Cochliobolus*) root rot of wheat and barley is a chronic problem in North Dakota, causing average yield losses of 5 to 11 percent, with much greater losses in some fields in certain years. Several seed treatment products are labeled for suppression of common root rot. Some seed treatments are also labeled for suppression of *Fusarium* root rot and take all root rot.

Chickpeas

Treating chickpea seed to protect against *Pythium* is essential for good emergence. A seed treatment to protect against seed-borne *Ascochyta* is important because this is a common and serious disease.

Dry beans and soybeans

Treating seed may reduce seedling blight during weather that is unfavorable for emergence. Do not use streptomycin with Rhizobium inoculant. If using captan seed treatments, in-furrow inoculant is preferable because inoculant does not survive well on captan-treated seed. Several products can be used to reduce the root rot potential, and many newer products have a broad spectrum of activity.

Flax

Treating flax seed with a fungicide helps protect against seed rot, damping off and seedling blight. Seed treatment is especially important in cases where the seed coats are broken, allowing entry of pathogens. Seed from fields heavily infected with Pasmo (*Septoria linicola*) may be susceptible to seedling blight and should be seed treated.

Potatoes

Treatment of cut-seed pieces helps protect the cut surface against seed-piece decay. Most seed treatments are fungicides that will protect against fungi such as *Pythium, Rhizoctonia*, *Helminthosporium* and *Fusarium*. Fungicides do not protect against bacteria such as *Erwinia* or *Clavibacter*. However, control of fungi indirectly helps control *Erwinia* bacteria because seed decay is greater in seed infected with fungi. The addition of streptomycin to fungicide has limited value because it will control only bacteria contaminating cut surfaces and may inhibit wound healing. Seed treatment will reduce or help control new infections but will not cure existing decay, prevent lenticel infection or prevent infection of roots and stolons away from the seed piece due to soil or environmental inoculum. Seed treatment is no substitute for using good, sound, healthy seed. Seed should be stored at less than 40 F during the winter. In the spring, warm the seed to 50 to 60 F for 1 1/2 to two weeks before planting or until it just begins to sprout. Do not handle the seed until it is warm. Plant the cut seed in warm (50 to 58 F at planting depth), moist soil. If cut seed must be held, store in a well-ventilated area for suberization at 50 to 60 F with a relative humidity of 85 percent. Hold for one week, then lower the temperature to 50 to 60 F. Ideally, plant when seed and soil are the same temperature; the optimum is 50 F.

Safflower

Safflower rust is both seed-borne and soil-borne. The most devastating phase of the disease is a seedling blight, and root and foot rot. Typical rust pustules develop later on the leaves. Seed-borne safflower rust is controlled by seed treatment.

Sunflower

Soil-borne downy mildew infections were controlled with metalaxyl or mefenoxam seed treatment in the past. The downy mildew fungus, however, has developed insensitivity to metalaxyl and mefenoxam in much of North Dakota, South Dakota and Minnesota, so these fungicides are not effective. Several fungicides or fungicide-insecticide combinations have received state or federal labels for seed treatment of sunflower for seed rot and seedling blights.

APPLICATION OF SEED TREATMENT

Seed may be treated commercially or it may be treated on the farm. Commercial seed treatment may use a slurry treater or various automatic seed treaters. The various automatic seed treaters differ considerably, so they cannot be discussed here. Commercial seed treatment has become more common in recent years for many crops.

On-farm treatment may use various home-type or slurry mixers. Drill-box seed treatment is popular because no extra steps are required; the seed is treated in the drill-box at planting time. Good disease control depends on uniform fungicide coverage of the seed, but this is more difficult to accomplish in drill-box treatment because the means of mixing the seed and fungicide is inadequate. For effective drill-box treatment, fill the box with one-third the quantity of seed and fungicide and mix carefully with a paddle; repeat with the next third and then the final third. The paddle should not be used for any other purpose and should be stored in a safe place, out of reach of children and animals.

On-farm auger seed treatment methods are common. The fungicide is metered into the base of the auger used to fill the drill box. This method assures fairly good mixing and coverage.

All seed treatments have certain basic precautions. Use care in handling seed treatment products; many are irritating to the eyes, nose and skin. Treated seed usually is identified by the dye used in the chemical, and treated seed should not be fed to livestock or used for human food. Pesticide containers should be disposed of properly in a landfill or buried in an area with no surface drainage to nearby waterways. If seed treatment cannot be done

outdoors, it should be done in a well-ventilated room. Commercial seed treaters should have an adequate air exhaust system for treatment rooms. Workers exposed to seed treatment chemicals for long periods of time should have an approved chemical mask. The filter should be changed frequently. Recommended rates of application should be followed carefully because higher rates may injure the seed and lower rates may not give satisfactory disease control.

Forage legume seed should be treated well in advance of planting and inoculated with nitrogen-fixing *Rhizobia* at planting time. If dry beans have been treated with streptomycin for control of externally borne blight bacteria, inoculating with *Rhizobia* is not available.

FIELD CROP FOLIAR SPRAYS

Foliar fungicides are used to control fungal disease organisms that attack the above-ground portions of plants. Fungicides are used to protect the potential yield and quality of a crop. Many fungicides protect foliage from infection; therefore, these fungicides must be on the foliage before the fungus spores germinate.

Several foliar fungicides act differently from the protectants described above. For example, benzimidazole fungicides thiabendazole and thiophanate methyl are absorbed by the plant and translocated up the plant by the conducting tissues. They are called systemic fungicides. They only move up the plant; they do not move down. Thus, to control white mold on dry beans, complete coverage of stems, lower leaves and blossoms is required. Spraying only the upper leaves is not satisfactory because the fungicide will not move down to the location where it is needed. Strobilurin and triazole fungicides are locally systemic; they have some upward mobility and translaminar movement and some limited therapeutic action. Metalaxyl will move down from potato foliage into tubers in limited amounts to provide tuber protection against metalaxyl-sensitive strains of the late blight fungus and pink rot infection.

Spray control programs to prevent disease have been developed from data through years of research. Because each disease develops in a distinct manner, the decision to use a disease prevention program is based on weather conditions, disease development, potential yield of the crop and the dollars returned to management with use of the fungicides.

Many fungicides are registered for application through a sprinkler irrigation system, as well as by a spray. If a fungicide can be applied through a sprinkler system (fungigation), this is noted under application.

Most fungicide labels contain information on field re-entry, handling and loading precautions. Most labels state that workers either should not enter a sprayed field until the sprays have dried or should not enter for 24 hours unless they wear appropriate protective clothing. Information on the use of protective clothing during mixing and loading also is given on the label.
See the label for details.

Spraying

Spraying can be done with many different types of ground and air equipment. Getting good coverage is important: At least 5 gallons per acre (gal/A) should be used for aerial application and higher gallon amounts are required for ground equipment.

Droplet size for aerial application should be 200 to 400 microns (l/64 to 1/128 inch) in diameter. Generally, if nozzles are pointed back, appropriate nozzles are used and pressures do not exceed 30 or 35 pounds per square inch (psi), the correct droplet size will result. Application should be made with the boom 8 to 10 feet above the crop.

Some plant surfaces have a waxy or hairy coating, making good coverage difficult. The spray will collect in large, erect droplets, which then run off. Wheat and cabbage leaves are good examples. Frequently, using a wetting agent improves coverage. Usually this is a spreader-sticker. Certain fungicides may work better with certain spreader-stickers than others. This type of information usually can be found on the label or in supplemental brochures. Spreader-stickers may be incorporated into some flowable formulations, so adding a spreader-sticker to the spray tank is not necessary. However, the label must be checked on each product for this use.

RESISTANCE TO FUNGICIDES

Fungi may develop tolerance or resistance to certain fungicides. Several examples where this occurs in North Dakota are described below.

The sugar beet leafspot fungus (*Cercospora*) has developed resistance to the systemic benzimidazole fungicides (benomyl, thiabendazole and thiophanate methyl) in the Red River Valley and southern Minnesota. These fungicides should be not used at all in the southern Red River Valley and no more than once a season in a tank mix with an unrelated fungicide in the northern Red River Valley.

Resistance to the benzimidazole fungicides thiabendazole (TBZ or Mertect) and thiophanate methyl (Topsin M) has developed recently in the potato *Fusarium* dry rot pathogen *Fusarium sambucinum* and the potato silver scurf pathogen *Helminthosporium solani*. This resistance is common throughout the United States and Canada.

Resistance to iprodione has been reported from other parts of the country. Cross-resistance to the chemically related product vinclozolin is common when resistance to iprodione develops.

The A2 mating type of the late blight fungus, which is common in North Dakota and Minnesota, is resistant to metalaxyl and mefenoxam.

In North Dakota, reduced sensitivity to strobilurin fungicides have been observed in populations of the earlyblight fungus *Alternaria* sp. on potato and to the aschochyta blight pathogen (*Aschochyta rabiei*) on chickpeas (this does not cause aschochyta blight on lentils or field peas). Greater than 90% of the early blight fungus, *Alternaria solani*, are resistant to the QoI fungicides pyraclostrobin, fluoxastrobin, and azoxystrobin. Additionally, a very high proportion of the *Aschochyta rabiei* population affecting chickpea is resistant to pyraclostrobin. The *A. solani* population has also developed resistance to SDHI fungicides such as boscalid and penthiopyrad. Five mutations have been detected that convey resistance to this class of fungicide. Fluopyram, which is also a SDHI fungicide, is not affected by these mutations.

Tolerance of the leafspot fungus to triphenyltin hydroxide was widespread in southern Minnesota and the southern Red River Valley in 1999 and common in the Northern Red River Valley. However, tin-tolerant isolates do not survive as well as sensitive isolates when alternative fungicides are used. With appropriate FRAC (Fungicide Resistance Action Committee) rotations, tin-tolerant isolates have largely disappeared.

In contrast, benzimidazole-resistant strains survive well when alternative fungicides are used and persist for a long time. The best way to combat resistance is to prevent or delay it by alternating the different classes of fungicides and by avoiding constant use of fungicides known to trigger development of resistant fungi. Using tank mixes of unrelated fungicides also is reported to retard the development of resistance.

FUNGICIDE RESISTANCE MANAGEMENT STATEMENTS

The following statements are recommendations for commonly used fungicides. Information from the FRAC is available at www.frac.info/.

1. Methyl benzimidazole carbamates (MBC; Group 1) – High risk. Both mixtures and alternations with non-Group 1 fungicides are acceptable methods of preventing/managing resistance to Group 1 fungicides. For high-risk pathogens, mixtures are preferred to alternations.

2. Dicarboximides (Group 2) – Medium to high risk. Minimize the selection pressure by minimizing the number of applications. As a guide, do not apply more than two to three per crop per season. Maintain regular, prolonged times without exposure to Group 2 fungicides. When applying for *Botrytis* control, restrict applications to those times when *Botrytis* infection pressure is high. Where *Botrytis* resistance is well-established, use combinations to stabilize *Botrytis* control, but their application must follow the same rules as for Group 2 fungicides alone.

3. Sterol biosynthesis inhibitors (SBI; Groups 3, 5, 17 and 18) – Low to medium risk. Repeated applications of SBI fungicides alone should not be used on the same crop in one season against a high-risk pathogen in areas of high disease pressure for that particular pathogen. For crop/pathogen situations where repeated spray applications are made during the season, alternation or mixtures with an effective noncross-resistant fungicide are recommended. Where alternation or the use of mixtures is not feasible because of a lack of effective or compatible noncross-resistant partner fungicides, then input of SBIs should be reserved for critical parts of the season or crop growth stage. If SBI performance should decline and sensitivity testing has confirmed the presence of less sensitive forms, SBIs should be used only in mixture or alternation with effective noncross-resistant partner fungicides. The introduction of the new classes of chemistry offers new opportunities for more effective resistance management. The use of different modes of action should be maximized for the most effective resistance management strategies. Users must adhere to the manufacturers' recommendations. In many cases, reports of "resistance" have, on investigation, been attributed to cutting recommended rates of use, or to poor or mistimed application. Fungicide input is only one aspect of crop management. Fungicide use does not replace the need for resistant crop varieties, good agronomic practice, plant hygiene/sanitation, etc.

4. Phenylamides (PA; Group 4) – High risk. The Group 4 fungicides should be used on a preventative and not curative or eradicative basis. For foliar applications, Group 4 fungicides should be used in prepacked mixtures with an unrelated effective partner and used in a sound management program. Where using residual partners, use between three-fourths and full recommended rates. The Group 4 fungicide dosage in the mixture depends on its intrinsic activity and is defined by the respective company. The Group 4 fungicides should not be used as soil treatments against airborne diseases. When solo formulations are made available for soil use, strategies that prevent any possibilities for foliar applications must be implemented. For seed treatment, mixtures rather than straight Group 4 fungicides should be used whenever possible. The number of Group 4 fungicide applications should be limited (two to four consecutive applications per crop and year). The application intervals should not exceed 14 days and may be shorter in cases of high disease pressure. If rates and application intervals are reduced, the total amount of the Group 4 fungicide used per season should not exceed that of the full rate, and the total exposure time should remain the same. The rate of the mixing partners should remain the same for both intervals. Group 4 fungicide sprays are recommended early season during the period of active vegetative growth of the crop. The grower should switch to non-Group 4 products not later than the normal standard application interval of the non-Group 4 product.

5. Quinone outside inhibitors (Qol; Group 11) – High risk. When using a Group 11 fungicide as a solo product, the number of applications should be no more than one-third of the total number of fungicide applications per season. In programs with tank mixes or pre-mixes of a Group 11 fungicide, applications should be no more than one-half of the total number of fungicide applications per season. In programs in which applications of Group 11 fungicides are made with both solo products and mixtures, the number of Group 11 fungicide-containing applications should be no more than half of the total number of fungicide applications per season.

6. **Succinate dehydrogenase inhibitor (SDHI): (group 7)** Medium to high risk. This group includes fungicides such as boscalid, benodamil, flutolanil, mepronil, fluopyram, florfuran, carboxin, oxycarboxin, thifluzamide, bixafen, fluxapyroxad, furametpyr, isopyrazam, penflufen, penthiopyrad, sedaxane and boscalid. Laboratory and field studies have confirmed target site mutations to SDHI. Limit use of SDHI and rotate with other chemistries of different modes of action.

Recent research has indicated that >90% of the *Alternaria solani* (cause of early blight of potato) are resistant to the SDHI fungicide, boscalid. Currently, there are five known mutations in the early blight pathogen which convey resistance to boscalid that have been identified in ND isolates. However, these mutations may or may not affect other SDHI fungicides, such as fluopyram, fluxapyroxad and penthiopyrad. When selecting SDHI fungicides for management of early blight of potato, consult comments in the 'Remarks' column for more information on resistance.

FUNGICIDE GROUPS

The soil application and foliar sprays tables in this guide have a numerical or letter designation (in parentheses) for each chemical component of the listed commercial Fungicides. This number or letter code indicates the Code is developed by the Resistance Action Committee = (FRAC). The purpose of FRAC is to prolong the effectiveness of fungicides liable to encounter resistance problems and to limit crop losses should resistance appear. If field resistance is known to one member of the fungicide group, cross-resistance to other chemicals within that group may be present. This Fungicide Guide is providing information on fungicide groups so that users are aware of potential resistance problems with continued use of chemicals in the same fungicide group. The intrinsic risk for resistance to develop to a given fungicide group varies among chemistries; for example, resistance development among the strobilurins, Group 11, is much more likely than resistance development among the mancozebs or manebs, Group Y. For more information about fungicide resistance and the FRAC fungicide list, see the following Web site:
www.frac.info

The following tables (pages 9-18) are derived directly from the FRAC code, and they describe modes of action, chemical group names, common names, and FRAC Code number.

FRAC Code List© 2017 (Pages 9-18)

FRAC Code List© 2017

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
A: nucleic acids synthesis	**A1** RNA polymerase **I**	**PA** – fungicides (**P**henyl**A**mides)	acylalanines	benalaxyl benalaxyl-M (=kiralaxyl) furalaxyl metalaxyl metalaxyl-M (=mefenoxam)	Resistance and cross resistance well known in various Oomycetes but mechanism unknown. **High risk.** **See FRAC Phenylamide Guidelines for resistance management**	**4**
			oxazolidinones	oxadixyl		
			butyrolactones	ofurace		
	A2 adenosin-deaminase	hydroxy- (2-amino-) pyrimidines	hydroxy- (2-amino-) pyrimidines	bupirimate dimethirimol ethirimol	Medium risk. Resistance and cross resistance known in powdery mildews. Resistance management required.	**8**
	A3 DNA/RNA synthesis (proposed)	heteroaromatics	isoxazoles	hymexazole	Resistance not known.	**32**
			isothiazolones	octhilinone		
	A4 DNA topoisomerase type II (gyrase)	carboxylic acids	carboxylic acids	oxolinic acid	Bactericide. Resistance known. Risk in fungi unknown. Resistance management required.	**31**
B: Cytoskeleton and motor proteins	**B1** ß-tubulin assembly in mitosis	**MBC** - fungicides (**M**ethyl **B**enzimidazole **C**arbamates)	benzimidazoles	benomyl carbendazim fuberidazole thiabendazole	Resistance common in many fungal species. Several target site mutations, mostly E198A/G/K, F200Y in β-tubulin gene. Positive cross resistance between the group members. Negative cross resistance to N-Phenylcarbamates. **High risk. See FRAC Benzimidazole Guidelines for resistance management.**	**1**
			thiophanates	thiophanate thiophanate-methyl		
	B2 ß-tubulin assembly in mitosis	N-phenyl carbamates	N-phenyl carbamates	diethofencarb	Resistance known. Target site mutation E198K. Negative cross resistance to benzimidazoles. High risk. Resistance management required.	**10**
	B3 ß-tubulin assembly in mitosis	benzamides	toluamides	zoxamide	Low to medium risk. Resistance management required.	**22**
		thiazole carboxamide	ethylamino-thiazole-carboxamide	ethaboxam		
	B4 cell division (proposed)	phenylureas	phenylureas	pencycuron	Resistance not known.	**20**
	B5 delocalisation of spectrin-like proteins	benzamides	pyridinylmethyl-benzamides	fluopicolide	Resistance not known.	**43**
	B6 actin/myosin/fimbrin function	cyanoacrylates	aminocyanoacrylates	phenamacril	Resistance known in Fusarium graminearum. Target site mutations in the gene coding for myosin-5 found in lab studies. Medium to high risk. Resistance management required.	**47**

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
C. respiration	**C1** complex I NADH Oxido-reductase	pyrimidinamines	Pyrimidinamines	diflumetorim	Resistance not known.	**39**
		pyrazole-MET1	pyrazole-5-carboxamides	tolfenpyrad		
	C2 complex II: succinate-dehydro-genase	SDHI (**S**uccinate-**deh**ydrogenase **i**nhibitors)	phenyl-benzamides	benodanil flutolanil mepronil	Resistance known for several fungal species in field populations and lab mutants. Target site mutations in sdh gene, e.g. H/Y (or H/L) at 257, 267, 272 or P225L, dependent on fungal species. Resistance management required. **Medium to high risk.** **See FRAC SDHI Guidelines for resistance management.**	**7**
			phenyl-oxo-ethyl thiophene amide	isofetamid		
			pyridinyl-ethyl-benzamides	fluopyram		
			furan- carboxamides	fenfuram		
			oxathiin-carboxamides	carboxin oxycarboxin		
			thiazole-carboxamides	thifluzamide		
			pyrazole-4-carboxamides	benzovindiflupyr bixafen fluxapyroxad furametpyr isopyrazam penflufen penthiopyrad sedaxane		
			N-methoxy-(phenyl-ethyl)-pyrazole-carboxamides	pydiflumetofen		
			pyridine-carboxamides	boscalid		
			pyrazine-carboxamides	pyraziflumid		
	C3 complex III: cytochrome bc1 (ubiquinol oxidase) at Qo site *(cyt b gene)*	**QoI**-fungicides (**Q**uinone **o**utside **I**nhibitors)	methoxy-acrylates	azoxystrobin coumoxystrobin enoxastrobin flufenoxystrobin picoxystrobin pyraoxystrobin	Resistance known in various fungal species. Target site mutations in cyt b gene (G143A, F129L) and additional mechanisms. Cross resistance shown between all members of the QoI group. **High risk.** **See FRAC QoI Guidelines for resistance management.**	**11**
			methoxy-acetamide	mandestrobin		
			methoxy-carbamates	pyraclostrobin pyrametostrobin triclopyricarb		
			oximino-acetates	kresoxim-methyl trifloxystrobin		
			oximino-acetamides	dimoxystrobin fenaminstrobin metominostrobin orysastrobin		
			oxazolidine-diones	famoxadone		
			dihydro-dioxazines	fluoxastrobin		
			Imidazolinones	fenamidone		
			benzyl-carbamates	pyribencarb		
	C4 complex III: cytochrome bc1(ubiquinone reductase) at Qi site	**QiI** - fungicides (**Q**uinone **i**nside **I**nhibitors)	cyano-imidazole	cyazofamid	Resistance risk unknown but assumed to be medium to high (mutations at target site known in model organisms). Resistance management required.	**21**
			sulfamoyl-triazole	amisulbrom		

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
C: respiration (continued)	**C5** uncouplers of oxidative phos-phorylation		dinitrophenyl crotonates	binapacryl meptyldinocap dinocap	Resistance not known. Also acaricidal activity.	**29**
			2,6-dinitro-anilines	fluazinam	Low risk. However, resistance claimed in *Botrytis* in Japan.	
			(pyr.-hydrazones)	(ferimzone)	Reclassified to U 14 in 2012.	
	C6 inhibitors of oxidative phos-phorylation, ATP synthase	organo tin compounds	tri-phenyl tin compounds	fentin acetate fentin chloride fentin hydroxide	Some resistance cases known. Low to medium risk.	**30**
	C7 ATP production (proposed)	thiophene-carboxamides	thiophene-carboxamides	silthiofam	Resistance reported. Risk low.	**38**
	C8 complex III: cytochrome bc1 (ubiquinone reductase) at Qo site, stigmatellin binding sub-site	QoSI fungicides (Quinone outside Inhibitor, stigmatellin binding type)	triazolo-pyrimidylamine	ametoctradin	Not cross resistant to QoI fungicides. Resistance risk assumed to be medium to high (single site inhibitor). Resistance management required.	**45**
D: amino acids and protein synthesis	**D1** methionine biosynthesis (proposed) *(cgs gene)*	**AP -** fungicides (**A**nilino-**P**yrimidines)	anilino-pyrimidines	cyprodinil mepanipyrim pyrimethanil	Resistance known in *Botrytis* and *Venturia*, sporadically in *Oculimacula*. **Medium risk. See FRAC Anilinopyrimidine Guidelines for resistance management.**	**9**
	D2 protein synthesis	enopyranuronic acid antibiotic	enopyranuronic acid antibiotic	blasticidin-S	Low to medium risk. Resistance management required.	**23**
	D3 protein synthesis	hexopyranosyl antibiotic	hexopyranosyl antibiotic	kasugamycin	Resistance known in fungal and bacterial (*P. glumae*) pathogens. Medium risk. Resistance management required.	**24**
	D4 protein synthesis	glucopyranosyl antibiotic	glucopyranosyl antibiotic	streptomycin	Bactericide. Resistance known. High risk. Resistance management required.	**25**
	D5 protein synthesis	tetracycline antibiotic	tetracycline antibiotic	oxytetracycline	Bactericide. Resistance known. High risk. Resistance management required.	**41**

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
E: signal transduction	**E1** signal transduction (mechanism unknown)	aza-naphthalenes	aryloxyquinoline	quinoxyfen	Resistance to quinoxyfen known. Medium risk. Resistance management required. Cross resistance found in *Erysiphe (Uncinula) necator* but not in *Blumeria graminis*.	**13**
			quinazolinone	proquinazid		
	E2 MAP/Histidine-Kinase in osmotic signal transduction *(os-2, HOG1)*	**PP**-fungicides (**P**henyl**P**yrroles)	phenylpyrroles	fenpiclonil fludioxonil	Resistance found sporadically, mechanism speculative. Low to medium risk. Resistance management required.	**12**
	E3 MAP/Histidine-Kinase in osmotic signal transduction *(os-1, Daf1)*	dicarboximides	dicarboximides	chlozolinate dimethachlone iprodione procymidone vinclozolin	Resistance common in *Botrytis* and some other pathogens. Several mutations in OS-1, mostly I365S. Cross resistance common between the group members. **Medium to high risk. See FRAC Dicarboximide Guidelines for resistance management.**	**2**

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
F: lipid synthesis or transport / membrane integrity or function	**F1**	formerly dicarboximides				
	F2 phospholipid biosynthesis, methyltransferase	phosphoro-thiolates	phosphoro-thiolates	edifenphos iprobenfos (IBP) pyrazophos	Resistance known in specific fungi. Low to medium risk. Resistance management required if used for risky pathogens.	**6**
		dithiolanes	Dithiolanes	isoprothiolane		
	F3 lipid peroxidation (proposed)	**AH**-fungicides (**A**romatic **H**ydrocarbons) (chlorophenyls, nitroanilines)	aromatic hydrocarbons	biphenyl chloroneb dicloran quintozene (PCNB) tecnazene (TCNB) tolclofos-methyl	Resistance known in some fungi. Low to medium risk. Cross resistance patterns complex due to different activity spectra.	**14**
		heteroaromatics	1,2,4-thiadiazoles	etridiazole		
	F4 cell membrane permeability, fatty acids (proposed)	carbamates	carbamates	iodocarb propamocarb prothiocarb	Low to medium risk. Resistance management required.	**28**
	F5	formerly CAA-fungicides				
	F6 microbial disrupters of pathogen cell membranes	microbial (*Bacillus* sp.)	*Bacillus* sp. and the fungicidal lipopeptides produced	*Bacillus subtilis* syn. *B.amyloliquefaciens** strain QST 713	*synonyms for *Bacillus amyloliquefaciens* are *Bacillus subtilis* and *B. subtilis* var. *amyloliquefaciens* (previous taxonomic classification). Resistance not known. Induction of host plant defence described as additional mode of action for strain FZB24.	**44**
				Bacillus amyloliquefaciens strain FZB24		
				Bacillus amyloliquefaciens strain MBI600		
				Bacillus amyloliquefaciens strain D747		
	F7 cell membrane disruption (proposed)	plant extract	terpene hydrocarbons, terpene alcohols and terpene phenols	extract from *Melaleuca alternifolia* (tea tree)	Resistance not known.	**46**
				Plant oils (mixtures): eugenol, geraniol, thymol		
	F8 ergosterol binding	polyene	amphoteric macrolide antifungal antibiotic from *Streptomyces natalensis* or *S. chattanoogensis*	natamycin (pimaricin)	Resistance not known agricultural, food and topical medical uses.	**48**
	F9 lipid homeostasis and transfer/storage	OSBPI oxysterol binding protein homologue inhibition	piperidinyl-thiazole-isoxazolines	oxathiapiprolin	Resistance risk assumed to be medium to high (single site inhibitor). Resistance management required. (Previously U15).	**49**

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
G: sterol biosynthesis in membranes	**G1** C14- demethylase in sterol biosynthesis *(erg11/cyp51)*	**DMI**-fungicides (**De****M**ethylation **I**nhibitors) (SBI: Class I)	piperazines	triforine	There are big differences in the activity spectra of DMI fungicides. Resistance is known in various fungal species. Several resistance mechanisms are known incl. target site mutations in cyp51 (erg 11) gene, e.g. V136A, Y137F, A379G, I381V; cyp51 promotor; ABC transporters and others. Generally wise to accept that cross resistance is present between DMI fungicides active against the same fungus. DMI fungicides are Sterol Biosynthesis Inhibitors (SBIs), but show no cross resistance to other SBI classes. **Medium risk.** **See FRAC SBI Guidelines for resistance management.**	**3**
			pyridines	pyrifenox pyrisoxazole		
			pyrimidines	fenarimol nuarimol		
			imidazoles	imazalil oxpoconazole pefurazoate prochloraz triflumizole		
			triazoles	azaconazole bitertanol bromuconazole cyproconazole difenoconazole diniconazole epoxiconazole etaconazole fenbuconazole fluquinconazole flusilazole flutriafol hexaconazole imibenconazole ipconazole metconazole myclobutanil penconazole propiconazole simeconazole tebuconazole tetraconazole triadimefon triadimenol triticonazole		
			triazolinthiones	prothioconazole		
	G2 Δ^{14}-reductase and $\Delta^{8}\rightarrow\Delta^{7}$-isomerase in sterol biosynthesis *(erg24, erg2)*	amines (“morpholines”) (SBI: Class II)	morpholines	aldimorph dodemorph fenpropimorph tridemorph	Decreased sensitivity for powdery mildews. Cross resistance within the group generally found but not to other SBI classes. **Low to medium risk. See FRAC SBI Guidelines for resistance management.**	**5**
			piperidines	fenpropidin piperalin		
			spiroketal-amines	spiroxamine		
	G3 3-keto reduc-tase, C4- de-methylation *(erg27)*	(SBI: Class III)	hydroxyanilides	fenhexamid	Low to medium risk. Resistance management required.	**17**
			amino-pyrazolinone	fenpyrazamine		
	G4 squalene-epoxidase in sterol biosynthesis *(erg1)*	(SBI class IV)	thiocarbamates	pyributicarb	Resistance not known, fungicidal and herbicidal activity.	**18**
			allylamines	naftifine terbinafine	Medical fungicides only.	

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
H: cell wall biosynthesis	**H3**	Formerly glucopyranosyl antibiotic (validamycin)			reclassified to U18	**26**
	H4 chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	polyoxin	Resistance known. Medium risk. Resistance management required.	**19**
	H5 cellulose synthase	**CAA**-fungicides (**C**arboxylic **A**cid **A**mides)	cinnamic acid amides	dimethomorph flumorph pyrimorph	Resistance known in *Plasmopara viticola* but not in *Phytophthora infestans*. Cross resistance between all members of the CAA group. **Low to medium risk. See FRAC CAA Guidelines for resistance management.**	**40**
			valinamide carbamates	benthiavalicarb iprovalicarb valifenalate		
			mandelic acid amides	mandipropamid		
I: melanin synthesis in cell wall	**I1** reductase in melanin biosynthesis	**MBI-R** (**M**elanin **B**iosynthesis **I**nhibitors – **R**eductase)	isobenzo-furanone	fthalide	Resistance not known.	**16.1**
			pyrrolo-quinolinone	pyroquilon		
			triazolobenzo-thiazole	tricyclazole		
	I2 dehydratase in melanin biosynthesis	**MBI-D** (**M**elanin **B**iosynthesis **I**nhibitors – **D**ehydratase)	cyclopropane-carboxamide	carpropamid	Resistance known. Medium risk. Resistance management required.	**16.2**
			carboxamide	diclocymet		
			propionamide	fenoxanil		
	I3 polyketide synthase in melanin biosynthesis	**MBI-P** (**M**elanin **B**iosynthesis **I**nhibitors – **P**olyketide synthase)	trifluoroethyl-carbamate	tolprocarb	Resistance not known.	**16.3**
P: host plant defence induction	**P1** salicylic acid pathway	benzo-thiadiazole (BTH)	benzo-thiadiazole (BTH)	acibenzolar-S-methyl	Resistance not known.	**P 01**
	P2	benzisothiazole	benzisothiazole	probenazole (also antibacterial and antifungal activity)	Resistance not known.	**P 02**
	P3	thiadiazole-carboxamide	thiadiazole-carboxamide	tiadinil isotianil	Resistance not known.	**P 03**
	P4	natural compound	polysaccharides	laminarin	Resistance not known.	**P 04**
	P5	plant extract	complex mixture, ethanol extract	extract from *Reynoutria sachalinensis* (giant knotweed)	Resistance not known.	**P 05**
	P6	microbial	*Bacillus cereus* group	*Bacillus mycoides* isolate J	Resistance not known.	**P 06**

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
U: Unknown mode of action (U numbers not appearing in the list derive from reclassified fungicides)	unknown	cyanoacetamide-oxime	cyanoacetamide-oxime	cymoxanil	Resistance claims described. Low to medium risk. Resistance management required.	**27**
	unknown	phosphonates	ethyl phosphonates	fosetyl-Al	Few resistance cases reported in few pathogens. Low risk.	**33**
				phosphorous acid and salts		
	unknown	phthalamic acids	phthalamic acids	teclofthalam (Bactericide)	Resistance not known.	**34**
	unknown	benzotriazines	benzotriazines	triazoxide	Resistance not known.	**35**
	unknown	benzene-sulfonamides	benzene-sulphonamides	flusulfamide	Resistance not known.	**36**
	unknown	pyridazinones	pyridazinones	diclomezine	Resistance not known.	**37**
	unknown	thiocarbamate	thiocarbamate	methasulfocarb	Resistance not known.	**42**
	unknown	phenyl-acetamide	phenyl-acetamide	cyflufenamid	Resistance in *Sphaerotheca*. Resistance management required	**U 06**
	actin disruption (proposed)	aryl-phenyl-ketone	benzophenone	metrafenone	Less sensitive isolates detected in wheat powdery mildew. Medium risk. Resistance management required.	**U 08**
			benzoylpyridine	pyriofenone		
	cell membrane disruption (proposed)	guanidines	guanidines	dodine	Resistance known in *Venturia inaequalis.* Low to medium risk. Resistance management recommended.	**U 12**
	unknown	thiazolidine	cyano-methylene-thiazolidines	flutianil	Resistance not known.	**U 13**
	unknown	pyrimidinone-hydrazones	pyrimidinone-hydrazones	ferimzone	Resistance not known (previously C5).	**U 14**
	complex III: cytochrome bc1, unknown binding site (proposed)	4-quinolyl-acetate	4-quinolyl-acetates	tebufloquin	Not cross resistant to QoI. Resistance risk unknown but assumed to be medium. Resistance management required.	**U 16**
	Unknown	tetrazolyloxime	tetrazolyloximes	picarbutrazox	Resistance not known. Not cross resistant to PA, QoI, CAA.	**U 17**
	Unknown (Inhibition of trehalase)	glucopyranosyl antibiotic	glucopyranosyl antibiotics	validamycin	Resistance not known. Induction of host plant defense by trehalose proposed (previously H3).	**U 18**

MOA	TARGET SITE AND CODE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
NC: not clas-si-fied	unknown	diverse	diverse	mineral oils, organic oils, potassium bicarbonate, material of biological origin	Resistance not known.	**NC**
M: Chemicals with multi-site activity	multi-site contact activity	inorganic	inorganic	copper (different salts)	Generally considered as a low risk group without any signs of resistance developing to the fungicides.	**M 01**
		inorganic	inorganic	sulphur		**M 02**
		dithiocarbamates and relatives	dithio-carbamates and relatives	ferbam mancozeb maneb metiram propineb thiram zinc thiazole zineb ziram		**M 03**
		phthalimides	phthalimides	captan captafol folpet		**M 04**
		chloronitriles (phthalonitriles)	chloronitriles (phthalonitriles)	chlorothalonil		**M 05**
		sulfamides	sulfamides	dichlofluanid tolylfluanid		**M 06**
		bis-guanidines	bis-guanidines	guazatine iminoctadine		**M 07**
		triazines	triazines	anilazine		**M 08**
		quinones (anthraquinones)	quinones (anthra-quinones)	dithianon		**M 09**
		quinoxalines	quinoxalines	chinomethionat / quinomethionate		**M 10**
		maleimide	maleimide	fluoroimide		**M 11**
		Formerly polypeptides from plant extracts (“BLAD”)			reclassified to BM1	**M12**

MOA	TARGET SITE	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS	FRAC CODE
BM: Biologicals with multiple modes of action	multiple effects on cell wall, ion membrane transporters; chelating effects	polypeptide (from plant extract)	polypeptide (lectin)	extract from the cotyledons of lupine plantlets ("BLAD")	Resistance not known (previously M12).	**BM 01**
	competition, mycoparasitism, antibiosis, lytic enzymes and induced resistance	microbial (*Trichoderma* spp.)	*Trichoderma* spp. and the fungicidal metabolites produced	*Trichoderma atroviride* strain SC1	Resistance not known	**BM 02**