

Group Code	Primary Target Site of Action	Chemical Group	Common Name	Product Name	Resistance Risk
1	Mitosis: α -tubulin assembly	benzimidazoles	thiabendazole	Mertect	High
		thiophanates	thiophanate, thiophanate-methyl	Tops, Topsin M	High
2	NADH cytochrome c reductase in lipid peroxidation (proposed)	dicarboximides	iprodione	Rovral	Medium to High
4	RNA polymerase I	phenylamides	metalaxyl mefenoxam	Ridomil Ridomil Gold, Ultra Flourish	High
7	Complex II of fungal respiration	carboxamides	boscalid flutolanil	Endura Moncut, Moncoat	Medium
9	Methionine biosynthesis (proposed)	anilino-pyrimidines	pyrimethanil	Scala	Medium
11	Complex III of fungal respiration; QoI site	<u>strobilurins</u> <ul style="list-style-type: none"> ▪ methoxyacrylate ▪ methoxycarbamate ▪ oximinoacetate ▪ ozazolidinedione ▪ imidazolinone 	azoxystrobin pyraclostrobin trifloxystrobin famoxadone fenamidone	Quadris, Amistar, Quadris Opti Headline Gem Tanos (contains cymoxanil) Reason	High
12	MAP protein kinase in osmotic signal transduction	phenylpyrroles	fludioxonil	Maxim	Low to Medium
14	Lipid peroxidation (proposed)	aromatic hydrocarbons	quintozene (PCNB)	Blocker	Low to Medium
15	Cell wall synthesis	cinnamic acids	dimethomorph	Acrobat, Forum	Low to Medium
21	Complex III of fungal respiration; Qil site	cyanoimidazole	cyazofamid	Ranman	Medium to High
22	Mitosis β -tubulin assembly	benzamides	zoxamide	Gavel (also contains mancozeb)	Low to Medium
27	Unknown	cyanoacetamide	cymoxanil	Curzate	Low to Medium
28	Cell membrane permeability, fatty acids (proposed)	carbamates	propamocarb hydrochloride	Previcur Flex	Low to Medium
29	Uncoupler of oxidative phosphorylation	2,6-dinitro-anilines	fluazinam	Omega	Low
30	Inhibitors of oxidative phosphorylation	organotin compounds	triphenyltin hydroxide	SuperTin	Low to Medium
M	Multi-site contact	M1 – copper	copper hydroxide	Kocide, Champ	Low
M	Multi-site contact	M3–ethylenebis dithiocarbamates (EBDC's)	mancozeb maneb metiram	Dithane, Manzate, Penncozeb Maneb Polyram	Low
M	Multi-site contact	M4 – phthalimides	captan	Captan	Low
M	Multi-site contact	M5 – phthalonitriles	chlorothalonil	Bravo, Echo, Equus	Low



Fungicides

A Practical Approach to Resistance Management for Potato Diseases



This resistance management brochure is one of three developed by NPC through grower input (also available: Insecticides and Herbicides). Production costs were supported through a grant from:



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What is resistance?

Resistance is an inherited change in a plant pathogen's susceptibility to a fungicide. Intensive use, overuse or misuse of certain fungicides select strains of pathogens with reduced sensitivity to fungicides resulting in complete or partial loss of fungicide efficacy. This reduces the utility of the affected fungicide in a crop, and also compromises future efforts to manage fungicide resistance.

Fungicide resistance.

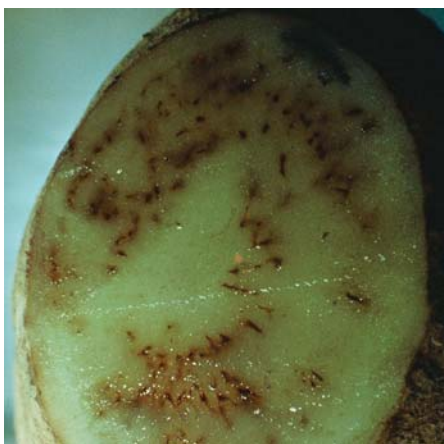
Since the introduction of systemic fungicides in the early 1970s, several instances of resistance have occurred including loss of efficacy to (TBZ) thiabendazole (Fusarium dry rot, silver scurf), metalaxyl (late blight, pink rot, pythium leak). More recently, the early blight fungus has become less sensitive to members of the QoI-group of fungicides. These fungicides affect single well-defined biochemical processes of specific pathogens. Loss of product efficacy has led to increased production risks and sometimes to control failures.

Recognition of resistance

Resistance is first recognized when expectations of disease control in the crop are not met with application of the labeled and recommended dose of fungicide. Loss of product efficacy may gradually increase over time resulting in partial loss of control or resistance may appear suddenly with significant loss of control (e.g. metalaxyl, thiabendazole).

Factors that affect resistance

Resistance to some fungicide groups has occurred more frequently than to others. Likewise, some pathogens are more prone to resistance. Factors that affect the development of fungicide resistance and spread from one area of production to another include the type(s) of fungicide used, frequency of use, whether applied alone, tank-mixed or alternated within a program; the genetic diversity of the target pathogen; the ability of fungicide resistant biotypes to survive; crop rotational practices; climatic variables such as local and long-distance weather phenomena affecting the spread of inoculum in air currents and physical transmission of inoculum on seed tubers or soil.



Fungicide Mode of Action and Cross-resistance

Pathogens resistant to different fungicides, especially within the same mode of action group are termed cross-resistant. The QoI fungicide group includes strobilurin fungicides such as azoxystrobin, pyraclostrobin and trifloxystrobin and similar materials such as famoxadone and fenamidone. All members of this group affect the Qo site of the cytochrome bc3 complex in mitochondria and inhibit respiration. Pathogens exhibiting resistance to one member of this group have varying levels of cross resistance to other members of this group. Residual contact fungicides such as chlorothalonil and the EBDCs, affect general biochemical processes such as protein synthesis and are less prone to selection of resistance.

Effective strategies for management of fungicide resistant pathogens

Most fungicides remain effective against the target organisms for which they were developed; however it is clear that some fungicides are no longer effective against resistant populations of pathogens. Recently, efficacy of the QoI fungicide group has declined sharply in control of the early blight pathogen *Alternaria solani* in many regions of the U.S. Proactive resistance management is critical for the retention of QoI product efficacy and those fungicide chemistries with specific modes of activity where the risk of resistance is medium to high. Use of an integrated crop and pest management strategy will help to reduce the risk of selecting for pathogen resistance to fungicides with site specific modes of activity including the QoI chemistries.

Avoid resistance by.....

- Make use of disease predictive models to effectively time applications of fungicides.
- Scout fields frequently to monitor for appearance of lesions of early blight and late blight especially when conditions are conducive for infection.
- Practice good crop hygiene by elimination of sources of primary inoculum, e.g. volunteer management, proper cull disposal and management of alternate hosts.
- Use varieties less susceptible to foliar and soilborne diseases.
- Monitor and maintain agronomic factors such as soil moisture and crop nutrition to avoid crop stress throughout the season.
- Where possible, extend crop rotation intervals to avoid increasing inoculum of soil-borne pathogens.
- Follow label guidelines for application of all fungicides. Labels of newly registered fungicide products include detailed information on resistance management along with the Fungicide Group Code (carboxamide fungicides (boscalid) belong to **Group 7**, QoI fungicides belong to **Group 11**, mancozeb belongs to **Group M3**, chlorothalonil belongs to **Group M5**).

Avoid resistance by.....

- Group 11 products should be used in 1/3 or fewer of the total number of sprays for the season up to a seasonal limit of six times. Fungicides belonging to other mode of action groups also have product specific use statements on the labels that need to be incorporated into effective disease and resistance management plans.
- Apply fungicides prior to plant infection by the fungus and avoid curative treatments with QoI and other site-specific fungicide groups.
- Never apply back-to-back treatments with site-specific fungicides or fungicides with a medium to high risk of resistance.
- When disease pressure is high, avoid using site-specific fungicides such as Group 11 materials.
- Rotate fungicide applications between different mode of action groups. For effective resistance management, the rotation partners must be active against the target pathogen.
- Use formulated mixtures or tank-mixes of effective fungicides having different modes of action. For effective resistance management, both mixing partners must be active against the target pathogen.
- Use effective multi-site fungicides, less prone to fungicide resistance, as mixing partners and especially in later parts of the growing season when disease pressure is often greatest.
- Be alert for control failures and report control difficulties so that the possibility of resistance can be monitored and evaluated.
- Local and regional cooperation in resistance management is essential.

How can I tell what group a fungicide belongs to?

In 2001, the EPA proposed a pesticide labeling scheme that added the FRAC Mode of Action Classifications to fungicide labels. In this scheme, all registered pesticides are classified by mode of action and each mode of action is assigned a group symbol (number or letter). There are currently over 40 groups and more are added as new modes of action are discovered or identified. Letters are assigned when the mode of action is unknown (U) or multisite (M). For potatoes, 15 groups plus several multisite contacts are registered in the U.S. and currently available for use in disease management programs.

