PATHOGEN RISK LIST

(December 2005)

Purpose

Information is provided about the risk of pathogens to develop resistance to fungicides under specific agronomic conditions.

Introduction

Because no scientific criteria are available to accurately determine the risk of a pathogen to develop resistance, our classification is based on experience and reported resistance claims over the last 40 years. Generally, the risk increases when a pathogen undergoes many and short disease cycles per season, the dispersal through spores over time and space is high, sexual recombination is mandatory in the disease cycle and the competitive ability of resistant individual is at least as high as that of the wild type (in the absence of selection pressure). Furthermore, the risk is considered as high when resistance evolved already after few years of product use.

Examples to illustrate pathogen risk

It is quite easy to detect single isolates of a pathogen with reduced sensitivity to a given fungicide but only their frequency over time and space will decide whether product performance will be affected significantly. Therefore, we consider the pathogen risk as medium to high only if resistance was reported in commercial situations for more than one fungicide class.

Wheat powdery mildew is considered as high risk pathogen because resistance evolved to six different chemical classes within 2 to 5 years, whereas wheat brown rust is a low risk pathogen because no resistance evolved to the major fungicide classes (DMIs, QoIs, morpholines) used against this pathogen, even not after 25 year (DMIs). Eyespot in wheat bears a medium risk, resistance evolved to MBCs and prochloraz (DMIs) only after 10 to 15 years.

An interesting case is *Phytophthora infestans* that developed resistance quite rapidly to the phenylamide fungicides but not at all to dimethomorph, iprovalicarb, fluazinam, cymoxanil, azoxystrobin and fenamidone (QoI fungicides), cyazofamid (QiI fungicide), propamocarb, and organotins. Therefore, we re-classified P. infestans as high risk pathogen for the RNA polymerase target only and as a medium risk pathogen for all other modes of action (see Table 1 and 2).

Pathogen risk classes

The following plant pathogens (Table 1) from major world markets have evolved resistance to fungicides in a time span sufficiently short to be a serious threat to the commercial success of more than one fungicide class.

Table 1: Plant pathogens accepted as showing a high risk of development of resistance to fungicides (adapted from EPPO 2002, FRAC Monograph No. 3, Russell, 2003)

Pathogen	**Crop**	**Disease**
Botryotinia fuckeliana (Botrytis cinerea)	various, especially grapevine	grey mould
Erysiphe (=Blumeria) graminis	wheat/barley	powdery mildew
Mycosphaerella fijiensis	banana	black sigatoka
Penicillium spp.	citrus, various	post harvest rot
Phytophthora infestans (RNA polymerase)	potato/tomato	late blight
Plasmopara viticola	grapevine	downy mildew
Pseudoperonospora cubensis and related spp.	cucurbits, various	downy mildews
Pyricularia spp.	rice, turf	rice blast, leaf spot
Sphaerotheca fuliginea and related spp.	cucurbits, various	powdery mildews
Venturia spp.	apple, pear	scab

The following pathogens (Table 2) are regarded as posing a much lower risk because resistance is not a major problem or has been slow to develop. In some cases this due to the pattern of product use. Cases of specific isolates being classed as resistant may be known in some instances, but in commercial practice resistance has not created major disease control problems. The EPPO Guideline does not list these and decisions on baseline production must be made on individual case reviews.

Table 2: Plant pathogens accepted as showing a medium risk of development of resistance to fungicides

Pathogen	Crop	Disease
Bremia lactucae	lettuce	downy mildew
Cercospora spp.	sugar beet, peanuts, various	leaf spots
*Gibberella fujikuori**	rice	bakanae
Monilinia spp.	various	Monilia rot
Mycosphaerella graminicola (Septoria tritici)	wheat	leaf spot
Mycosphaerella musicola	banana	yellow sigatoka
Peronospora spp.	various	downy mildews
Phytophthora infestans (target outside RNA polymerase)	potato/tomato	late blight
Pyrenophora teres	barley	net blotch
Rhynchosporium secalis	barley	leaf blotch/scald
Sclerotinia spp. (especially *homoeocarpa, sclerotiorum*)	various (turf, oil seed rape)	Sclerotinia diseases, dollar spot
Tapesia spp.	wheat/barley	eyespot
*Uncinula (= Erysiphe) necator**	grapevine	powdery mildew
** The EPPO Guideline lists these pathogens as high risk pathogens of which baseline sensitivity is normally requested*		

In some cases the financial outlay in establishing baselines will not be justified by the small markets involved irrespective of their risk of resistance development. Typical pathogens and diseases are given in Table 3. Pathogens in this group are of local importance, but in commercial market terms are considered as minor pathogens. Decisions on baseline production must be made on a case by case basis. For certain pathogens (e.g. *Phytophthora infestans*), resistance occurred only to one chemical class (phenylamides) but not to others and therefore, the pathogen is considered as low risk pathogen.

Table 3: Plant pathogens with low risk of development of resistance to fungicides or of minor commercial importance

Pathogen	Crop	Disease
Alternaria spp.	various	leaf spots
Colletotrichum spp.	various	anthracnose
Fusarium and related spp.	various	Fusarioses
Hemileia vastatrix	coffee	rust
Leptosphaera (=Stagonospora) nodorum	wheat	leaf spot
Phytophthora spp. (soil borne)	various	damping off
Podosphaera leucotricha	apple	powdery mildew
Puccinia and related rust spp.	wheat/barley, various	rusts
Pythium spp.	various	damping off
Rhizoctonia spp.	various	foot and root rot
Sclerotium spp.	various	blight
Tilletia spp.	cereals	bunts
Ustilago spp.	cereals	smuts

When the pathogen risk is plotted against the inherent resistance risk of the fungicide class, the combined resistance risk for each pathogen/fungicide combination can be estimated (Figure 1).

Figure 1: Combined resistance risk diagram based on inherent fungicide risk and inherent pathogen risk (* only most important classes and groups mentioned) (according to FRAC Monograph No. 2, by K.J. Brent and D.W. Hollomon, 1998, ** QoI fungicides have been moved from medium to high risk)

Fungicide Classes *	**Fungicide Risk**	**Combined Risk**		
benzimidazoles dicarboximides phenylamides QoI fungicides **	high = 3	**3**	**6**	**9**
carboxamides SBI fungicides anilinopyrimidines phenylpyrroles phosphorothiolates	medium = 2	**2**	**4**	**6**
multi site fungicides (e.g.dithiocarbamates Copper, Sulphur) MBI-R inhibitors SAR inducers	low = 1	**1**	**2**	**3**
	Pathogen risk	low = 1	medium = 2	high = 3
	Pathogen groups *	seed borne pathogens (e.g. *Pyrenophora* spp. *Ustilago* spp.) soil-borne pathogens (e.g. *Phytophthora* spp.) rust fungi *Rhizoctonia* spp. *Tapesia* spp.	*Rhynchosporium secalis* *Septoria tritici*	*Erysiphe graminis* *Botrytis cinerea* *Penicillium* spp. *Magnaporthe grisea* *Venturia inaequalis* *Mycosphaerella fijiensis* *Phytophthora infestans*

The pathogen risk should be estimated also in regard to the local intensity of disease development that is based on weather conditions, fertilization, irrigation, cultural practices and degree of resistance of cultivars. Therefore, we propose to modify the risk diagram in the following manner (Figure 2). Detail can be found in the article written by KH Kuck, “Fungicide Resistance Management in a New Regulatory Environment”, in the Proceedings of the Reinhardsbrunn Symposium 2004 (Modern fungicides and antifungal agents, Dehne, Gisi, Kuck, Russell, eds., BCPC 2005).

Figure 2: Combined resistance risk diagram based on inherent fungicide risk, inherent pathogen risk, and agronomic risk (* only most important classes and groups mentioned) (according to Kuck, 2005)

↓ **Fungicide Classes ***	↓ **Fungicide Risk**	**Combined Risk**			↓ **Agronomic Risk**
benzimidazoles dicarboximides phenylamides QoI fungicides	high = 6	**6** **3** **1,5**	**12** **6** **3**	**18** **9** **4,5**	high = 1 medium = 0.5 low = 0.25
carboxamides SBI fungicides anilinopyrimidines phenylpyrroles	medium = 4	**4** **2** **1**	**8** **4** **2**	**12** **6** **3**	high = 1 medium = 0.5 low = 0.25
multi site fungicides (e.g.dithiocarbamates) MBI-R inhibitors SAR inducers	low = 1	**1** **0,5** **0,25**	**2** **1** **0,5**	**3** **1,5** **0,75**	high = 1 medium = 0.5 low = 0.25
Pathogen risk →		low = 1	medium = 2	high = 3	
Pathogen groups * →		seed borne pathogens (e.g. *Pyrenophora* sp. *Ustilago* sp.) soil-borne pathogens (e.g. *Phytophthora* sp.) rust fungi *Rhizoctonia sp.* *Fusarium* sp.	*Uncinula necator* *Gibberella fujikuori* *Tapesia* sp. *Rhynchosporium secalis* *Pyrenophora teres* *Septoria tritici* *Sclerotinia* sp. *Monilinia* sp. *Cercospora* sp. *Phytophthora infestans*/other modes of action	*Erysiphe graminis* *Botrytis cinerea* *Plasmopara viticola* *Magnaporthe grisea* *Venturia inaequalis* *Mycosphaerella fijiensis* *Phytophthora infestans*/RNA polymerase	