FRAC CODE LIST 1:
Fungicides sorted by FRAC Code

INTRODUCTION

The following table lists commercial fungicides according to their mode of action and resistance risk. The most important bactericides are also included.

The Table headings are defined as:

Code
Numbers and letters are used to distinguish the fungicide groups. The numbers were assigned primarily according to the time of product introduction to the market. The letters refer to P = host plant defence inducers, M = multi-site inhibitors, and U = recent molecules with unknown mode of action and unknown resistance risk (transient status, mostly not longer than 8 years, until information about mode of action and mechanism of resistance becomes available).

Target Site of Action
If available the biochemical mode of action is given. In many cases the precise target site is not known. However, a grouping can be made due to cross resistance profiles within a group or in relation to other groups.

Group Name
The Group Names listed are widely accepted in literature. They are based on different sources (mode of action, first important representative, chemical group).

Chemical Group
Sub-grouping due to chemical considerations.

Common name
Accepted (or proposed) common name for an individual active ingredient expected to appear on the product label as definition of the product.

Comments on Resistance
If field resistance is known to one member of the Group, it is most likely but not exclusively valid that cross resistance to other Group members will be present. There is increasing evidence that cross resistance may not be clearly visible between Group members and that the degree of the effect can differ both between group members and fungal species or even within species. For the latest information on resistance and cross resistance status of a particular fungus-fungicide complex, you are advised to contact your

local FRAC representative, product manufacturer's representative or crop protection advisor. The intrinsic risk for resistance evolution to a given fungicide group is estimated to be **low, medium or high** according to the principles described in FRAC Monographs 1, 2 and 3. Resistance management is driven by pathogen risk and agronomic risk (see FRAC pathogen risk list)

Similar classification lists of fungicides have been published by T. Locke on behalf of FRAG–UK (Fungicide Resistance, August 2001), and by P. Leroux (Classification des fongicides agricoles et résistance, Phytoma, La Défense des Végétaux, No. 554, 43-51, November 2002).

Last update: December 2005
Next update: December 2006

CODE	TARGET SITE OF ACTION	GROUP NAME	CHEMICAL GROUP	COMMON NAME	COMMENTS
1	mitosis: ß-tubuline assembly	MBC - fungicides (Methyl Benzimidazole Carbamates)	benzimidazoles	benomyl carbendazim fuberidazole thiabendazole	Resistance common in many fungal species. Several target site mutations, mostly E198A/G/K, F200Y Positive cross resistance between the group members. Negative cross resistance to N-Phenylcarbamates High risk. See FRAC Benzimidazole Guidelines for resistance management.
			thiophanates	thiophanate thiophanate-methyl	
2	NADH cytochrome c reductase in lipid peroxidation (proposed)	dicarboximides		chlozolinate iprodione procymidone vinclozolin	Resistance common in Botrytis cinerea and found in some other fungal species. Several mutations found in OS1 histidine kinase (Daf 1), mostly I365S Cross resistance common between the group members. Medium to high risk. See FRAC Dicarboximide Guidelines for resistance management.
3	C14-demethylation in sterol biosynthesis	DMI-fungicides (DeMethylation Inhibitors) (SBI: Class I)	imidazoles	imazalil oxpoconazole pefurazoate prochloraz triflumizole	There are great differences in the activity spectra of the different DMI fungicides. Resistance is known in various fungal species. Several resistance mechanisms known incl. target site mutation Y136F, ABC transporters and others. Generally wise to accept that cross resistance is present between fungicides active against the same fungus. DMI fungicides are Sterol Biosynthesis Inhibitors (SBI's) but show no cross resistance to other SBI classes. Medium risk. See FRAC SBI Guidelines for resistance management. .
			piperazines	triforine	
			pyridines	pyrifenox	
			pyrimidines	fenarimol nuarimol	
			triazoles	azaconazole bitertanol bromuconazole cyproconazole difenoconazole diniconazole epoxiconazole fenbuconazole fluquinconazole flusilazole flutriafol hexaconazole imibenconazole ipconazole metconazole myclobutanil penconazole propiconazole prothioconazole simeconazole tebuconazole tetraconazole triadimefon triadimenol triticonazole	

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4	RNA polymerase I	PA - fungicides (PhenylAmides)	acylalanines	benalaxyl furalaxyl metalaxyl metalaxyl-M (=mefenoxam)	Resistance and cross resistance well known in various Oomycetes but resistance mechanism unknown. High risk. See FRAC Phenylamide Guidelines
			oxazolidinones	oxadixyl	
			butyrolactones	ofurace	
5	Δ^{14}-reductase and $\Delta^{8}\rightarrow\Delta^{7}$ isomerase in sterol biosynthesis	Amines ("Morpholines") (SBI: Class II)	morpholines	aldimorph dodemorph fenpropimorph tridemorph	Decreased sensitivity described 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.
			piperidines	fenpropidin piperalin	
			spiroketalamines	spiroxamine	
6	phospholipid biosynthesis, methyltransferase	phosphoro-thiolates		edifenphos iprobenfos (IBP) pyrazophos	Resistance known for specific fungi. Low to medium risk. Resistance management required if used for risky pathogens.
		dithiolanes		isoprothiolane	
7	complex II in fungal respiration (succinate-dehydrogenase)	carboxamides		benodanil boscalid carboxin fenfuram flutolanil furametpyr mepronil oxycarboxin penthiopyrad thifluzamide	Resistance known for specific fungi. Target site mutation H257L. Medium risk. Resistance management required if used for risky pathogens.
8	adenosin-deaminase	hydroxy-(2-amino-) pyrimidines		bupirimate dimethirimol ethirimol	Medium risk. Resistance and cross resistance known in powdery mildews. Resistance management required.
9	methionine biosynthesis (proposed)	AP - fungicides (Anilino-Pyrimidines)		cyprodinil mepanipyrim pyrimethanil	Resistance known in Botrytis and sporadically in Venturia, mechanism speculative (CGS). Medium risk. See FRAC Anilinopyrimidine Guidelines for resistance management.
10	mitosis: ß-tubulin assembly	N-phenyl carbamates		diethofencarb	Resistance known. Target site mutation E198K. Negative cross resistance to benzimidazoles. High risk. Resistance management required.

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11	complex III of fungal respiration: ubiquinol oxidase, Qo site	QoI-fungicides (Quinone outside Inhibitors)	methoxyacrylates	azoxystrobin enestrobin picoxystrobin	Resistance known in various fungal species. Target site mutations G143A, F129L and additional mechanisms.
			methoxy-carbamates	pyraclostrobin	
			oximino acetates	kresoxim-methyl trifloxystrobin	Cross resistance shown between all members of the QoI group.
			oximino-acetamides	dimoxystrobin metominostrobin orysastrobin	
			oxazolidine-diones	famoxadone	High risk. See FRAC QoI Guidelines for resistance management.
			dihydro-dioxazines	fluoxastrobin	
			imidazolinones	fenamidone	
12	MAP protein kinase in osmotic signal transduction	PP-fungicides (PhenylPyrroles)		fenpiclonil fludioxonil	Resistance found sporadically, mechanism speculative (OS-2 kinase). Low to medium risk. Resistance management required.
13	G-proteins in early cell signalling (proposed)	quinolines		quinoxyfen	Resistance known. Medium risk. Resistance management required.
14	lipid peroxidation (proposed)	AH-fungicides (Aromatic Hydrocarbons) (chlorophenyls, nitroanilines)		biphenyl chloroneb dicloran quintozene (PCNB) tecnazene (TCNB) tolclofos-methyl	Resistance known to some fungi. Low to medium risk. Cross resistance patterns complex due to different activity spectra.
		heteroaromatics	1,2,4-thiadiazoles	etridiazole	
16.1	reductase in melanin biosynthesis	MBI-R (Melanin Biosynthesis Inhibitors - Reductase	isobenzofuranone	fthalide	Resistance not known
			pyrroloquinolinone	pyroquilon	
			triazolobenzo-thiazole	tricyclazole	
16.2	dehydratase in melanin biosynthesis	MBI-D (Melanin Biosynthesis Inhibitors - Dehydratase	cyclopropane-carboxamide	carpropamid	Resistance known. Medium risk. Resistance management required.
			carboxamide	diclocymet	
			propionamide	fenoxanil	
17	3-keto reductase during C4 demethylation in sterol biosynthesis	hydroxyanilides (SBI: Class III)		fenhexamid	Low to medium risk. Resistance management required.
18	squalene epoxidase in sterol biosynthesis	(SBI: class IV)	thiocarbamates	pyributicarb	Herbicide and fungicide. Resistance not known
			allylamines	naftifine terbinafine	medical fungicide
19	chitin synthase	polyoxins	peptidyl pyrimidine nucleoside	polyoxin	Resistance known. Medium risk. Resistance management required.

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20	cell division (proposed)	phenylureas		pencycuron	Resistance not known
21	complex III of fungal respiration: ubiquinone reductase, Qi site	QiI - fungicides (Quinone inside Inhibitors)	cyanoimidazole	cyazofamid	Resistance risk unknown but assumed to be medium to high (mutations at target site known in model organisms). Resistance management required.
22	mitosis ß-tubulin assembly	benzamides		zoxamide	Low to medium risk. Resistance management required.
23	protein synthesis	enopyranuronic acid antibiotic		blasticidin-S	Low to medium risk. Resistance management required.
24	protein synthesis	hexopyranosyl antibiotic		kasugamycin	Medium risk. Resistance known. Resistance management required.
25	protein synthesis	glucopyranosyl antibiotic		streptomycin	Bactericide. Resistance known. High risk. Resistance management required.
26	trehalase and / or inositol-biosynthesis	glucopyranosyl antibiotic		validamycin	Resistance not known
27	unknown	cyanoacetamide-oximes		cymoxanil	Resistance described. Low to medium risk. Resistance management required.
28	cell membrane permeability, fatty acids (proposed)	carbamates		iodocarb propamocarb prothiocarb	Low to medium risk. Resistance management required.
29	uncoupler of oxidative phosphorylation		dinitrophenyl crotonates	binapacryl dinocap	Resistance not known
			pyrimidinone-hydrazones	ferimzone	Resistance not known
			2,6-dinitro-anilines	fluazinam	Low risk. However, resistant isolates of Botrytis claimed to exist in Japan in 2000
30	inhibitors of oxidative phospho-rylation, ATP synthases	organo tin compounds	tri phenyl tin compounds	fentin acetate fentin chloride fentin hydroxide	Some resistance cases known. Low to medium risk
31	DNA topoisomerase type II (gyrase)	carboxylic acids		oxolinic acid	Bactericide. Resistance known. Risk unknown. Resistance management required.
32	DNA/RNA synthesis (proposed)	heteroaromatics	isoxazoles	hymexazole	Resistance not known
			isothiazolones	octhilinone	
33	unknown	phosphonates	ethyl phosphonates	fosetyl-Al	Few resistance cases reported in few pathogens. Low risk
				phophorous acid and salts	
34	unknown	phthalamic acids		teclofthalam (Bactericide)	Resistance not known

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35	unknown	benzotriazines		triazoxide	Resistance not known
36	unknown	benzene-sulfonamides		flusulfamide	Resistance not known
37	unknown	pyridazinones		diclomezine	Resistance not known
38	ATP production (proposed)		thiophene-carboxamides	silthiofam	Resistance reported. Risk low
39	Complex I of respiration (proposed)		pyrimidinamides	diflumetorim	Resistamce not known
40	phospholipid biosynthesis and cell wall deposition (proposed)	CAA-fungicides (Carboxylic acid amides)	cinnamic acid amides	dimethomorph flumorph	Low to medium risk. Resistance management required.
			valinamide carbamates	benthiavalicarb iprovalicarb	
			mandelic acid amides	mandipropamid	
41	protein synthesis attachment of aminoacyl-tRNA to ribosomal acceptor (A) site	tetracycline antibiotic		oxytetracycline	Bactericide. Resistance known. High risk. Resistance management required.
42	unknown	thiocarbamate		methasulfocarb	Resistance not known
P	host plant defence induction	P1 salicylic acid pathway	benzo-thiadiazole BTH	acibenzolar-S-methyl	Resistance not known
		P2	benzisothiazole	probenazole (also antibacterial and antifungal activity)	
		P3	thiadiazole-carboxamide	tiadinil	

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U	unknown	U5	thiazole-carboxamides	ethaboxam	Resistance not known
	unknown	U6	benzamidoxime	cyflufenamid	Resistance not known
	unknown	U7	quinazolinone	proquinazid	Resistance not known
	unknown	U8	benzophenone	metrafenone	Resistance not known
	unknown	U9	acylpicolide	fluopicolide	Resistance not known
M	multi-site contact activity	M1	inorganic	copper (different salts)	Generally considered as a low risk group without any signs of resistance developing to the fungicides * For dodine, resistance was reported in Venturia inaequalis suggesting that dodine may not be a multi-site inhibitor. Resistance management recommended No cross resistance between group members M1 to M9
		M2	inorganic	sulphur	
		M3	dithiocarbamates and relatives	ferbam mancozeb maneb metiram propineb thiram zineb ziram	
		M4	phthalimides	captan captafol folpet	
		M5	chloronitriles (phthalonitriles)	chlorothalonil	
		M6	sulphamides	dichlofluanid tolylfluanid	
		M7	guanidines	dodine* guazatine iminoctadine	
		M8	triazines	anilazine	
		M9	quinones (anthraquinones)	dithianon	
NC	not classified	NC	diverse	mineral oils, organic oils, potassium bicarbonate	Resistance not known