

List of cases of resistance to plant protection products detected in France

Background

The management of resistance to PPPs is a major challenge for plant protection because it contributes to limiting ineffective or remedial treatments and therefore to implementing the French “Plan Ecophyto” on the reduction of pesticide use. Optimal resistance management requires the integration of multiple information (*e.g.* resistance dynamics, the mechanisms involved, the frequency of resistant pests in the area concerned, etc.). It must take into account the specificities of each case of resistance to advise relevant and effective management strategies. However, this information is not always readily accessible. It may be included in complex scientific articles, be part of unpublished “private” information, etc... thus not always being available with sufficient precision or speed.

The lists proposed by R4P display our current knowledge on the cases of PPP resistance detected and published in France. They aim at reaching a more sustainable use of the PPPs by stakeholders by allowing to optimise their recommendations. The sensitivity of pests to PPPs should indeed be considered a common good, and managed accordingly.

Methods

Resistance case lists have been compiled from several sources:

- Experimental data produced by INRA and Anses laboratories (see also the compilation of technical reports on this website) or private laboratories.
- French or foreign literature, scientific or extension literature

Each case presented consist of one “tryptic” (pest / PPP mode of action / crop) for which biological sensitivity assays have proven the occurrence of resistance (*i.e.* at least one resistant individual has been demonstrated as resistant using a relevant procedure). **Suspicious of resistance not validated by appropriate sensitivity assays are not included in the lists.**

The resistance cases listed in these documents concern only France, mainly metropolitan France. A few cases detected in the French overseas departments and territories are also mentioned. The lists may not be comprehensive for these cases, due to a lack of reliable documentary sources. **Similar cases detected in countries other than France are not listed.**

A member of R4P serving as a referent expert is associated to each case listed, as well as relevant publications, preferably in French. The complete references of the publications, as well as the royalty-free files, can be consulted on the "Documentation" section of the R4P website.

Last, the lists display the resistance cases towards fungicides, insecticides, acaricides and herbicides, either for active substances currently registered and in use in France (List I) or for active substances formerly registered in France (List II).

Legends

Column	Description
Section "Fungicide/Insecticide/Acaricide/Herbicide"	
<i>Mode of action</i>	Biochemical mode of action of the active substance or group of active substances concerned by resistance, as formulated in R4P classification.
<i>Target site</i>	Biochemical target (target protein) of the active substance or group of active substances concerned by resistance. <i>NB: For more details on targets and modes of action, please refer to the Universal classification of PPPs proposed by R4P on this website.</i>
<i>R4P group</i>	Code corresponding to the active substance or group of active substances concerned by resistance in R4P Universal classification of PPPs.
<i>Group other than R4P</i>	Code corresponding to the active substance or group of active substances concerned by resistance, in the FRAC (http://www.frac.info/), IRAC (http://www.irac-online.org/), HRAC (http://www.hracglobal.com/), WSSA (http://wssa.net/) or according to Fourouzesh et al. (Weed Research 55:334-358).
<i>Group abbreviation</i>	Common abbreviation for chemical class proposed by R4P.
<i>Chemical class (R4P or other)</i>	Name of the chemical class to which the active substance, or group of active substances, concerned by resistance belongs. Detailed chemical classification is available on this website (R4P universal classification).
<i>Active ingredients</i>	Active substance(s) concerned by resistance, in the laboratory or in the field. Unlisted active ingredients might be concerned by the resistance, especially within the same mode of action. Where a large number of substances are involved, additional information may be provided. Positive and negative cross resistance are detailed in the R4P universal pesticide classification on this website.
Section "Pathogen/Insect/Mite/Weed"	
<i>Pest/Disease</i>	The vernacular name of the pest or the disease concerned by the resistance.
<i>Scientific name</i>	The Latin binomial name of the pest concerned by the resistance.
<i>EPPO code</i>	Universal (acronymic) code of the pest assigned by EPPO (https://gd.eppo.int/).
<i>Crop</i>	Crop concerned by the case of resistance. Some crops may be grouped together (e.g. "cereals") for generalist pests. HTV: Herbicide Tolerant Variety.
<i>Status of resistance</i>	"+" indicates that field resistance (partial or total loss of field efficacy of the PPP used under optimal conditions) is possible. It depends in particular on the frequency of resistant individuals in local populations. "("+)" indicates "biological resistance" for which a loss of efficacy has possibly been observed in laboratory assays but not (yet) in the field .
<i>Comments</i>	Comment indicating prevalence (<i>i.e.</i> the proportion of plots affected by resistance) and/or frequency of resistance (<i>i.e.</i> the proportion of resistant individuals in populations), depending on the state of knowledge. Information on the geographical location of the resistance case can be detailed when the distribution is not homogeneous, or when resistance is emerging. ARA: Auvergne-Rhône-Alpes; BFC: Bourgogne-Franche-Comté; BZH: Bretagne; COR: Corse; CVL: Centre-Val de Loire; GES: Grand Est; HDF: Hauts de France; IDF:

	<p>Ile de France; NAQ: Nouvelle Aquitaine; NOR: Normandie; OCC: Occitanie; PAC: Provence-Alpes-Côtes d'Azur; PDL: Pays de Loire.</p> <p>Information on the cost of resistance can be added, for resistance cases accompanied by a lower competitiveness of resistant individuals, which can lead to a reduction in the dynamics of resistance evolution.</p> <p>Finally, various additional information (in particular on cross resistances) can be added.</p>
<i>Resistance intensity</i>	<p>For fungicides lists.</p> <p>Estimation of the resistance factor of the resistant individuals:</p> <p>LR: low intensity resistance MR: medium intensity resistance HR: high intensity resistance.</p>
<i>Resistance mechanism</i>	<p>TSR: Target Site Resistance (+ mutation if known). NTSR: Non Target Site Resistance (+ details if known). <i>For more information on PPP resistance mechanisms, see R4P (2016) Trends in Plant Science.</i></p> <p>Unknown: resistance mechanism non elucidated.</p>
<i>First occurrence in France</i>	Collection date of the oldest sample where the resistance case was detected. May be approximate for "ancient" resistances.
Section "Information"	
<i>Contact</i>	Person who can provide more information on the case of resistance.
<i>References</i>	References describing the case of resistance in France (dynamics, mechanism, phenotype etc...). May include publications about the same resistance case out of France to provide additional information (especially on the resistance mechanism).
<i>Update</i>	Date of update of the information concerning the resistance case.

Acknowledgements

R4P warmly thanks Pierre Leroux, Christian Gauvrit, Robert Delorme and Annie Micoud for their extensive participation in completing these lists, and Evelyne Martin for her valuable assistance in managing the bibliographic database.

Readers are invited to indicate any errors or omissions in these lists at: contact-r4p@inra.fr

Acaricide							Mite								Information		
Mode of action	Target site	R4P group	IRAC group	Group abbreviation	R4P chemical class	Active ingredients	Common name	Scientific name	Eppo code	CROP	Status of resistance	Comments	Resistance mechanism	First occurrence in France	Contact person	Reference	Update
Mitochondrial respiration and energy supply	Mitochondrial complex I electron transport inhibitors	A1b	21A	-	Pyridazinones	pyridabene	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	Old data, unknown distribution	unknown	?	INRAE Sophia - G. Le Goff	-	30/11/17
Mitochondrial respiration and energy supply	Mitochondrial complex I electron transport inhibitors	A1b	21A	-	Pyrazoles	tebufenpyrad	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	Vaucluse, Gard, Tarn and Garonne	unknown	1999	INRAE Sophia - G. Le Goff	Auger et al., 2003	30/11/17
Mitochondrial respiration and energy supply	Mitochondrial complex I electron transport inhibitors	A1b	21A	-	Quinazolines	fenazaquin	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	Vaucluse, Gard, Tarn and Garonne	unknown	1999	INRAE Sophia - G. Le Goff	Auger et al., 2003	30/11/17
Mitochondrial respiration and energy supply	Mitochondrial complex I electron transport inhibitors	A1b	21A	-	Phenoxyypyrazoles	fenpyroximate	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	Old data, unknown distribution	unknown	?	INRAE Sophia - G. Le Goff	-	30/11/17
Carbohydrate metabolism	Mite growth inhibitors - Chitine synthase	C3d	10 B	-	Thiazolidinones	hexythiazox	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	South of France	NTSR (detoxification)?	1991	INRAE Sophia - G. Le Goff	Nauen et al., 2001, Grosscurt et al., 1994	29/06/20
Carbohydrate metabolism	Mite growth inhibitors - Chitine synthase	C3d	10 A	-	Tetrazines	clofentezine	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	South of France	NTSR (detoxification)?	1991	INRAE Sophia - G. Le Goff	Nauen et al., 2001; Chauvel & Jugnet 2005; Grosscurt et al., 1994	29/06/20
Nervous sytem or muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	all	Strawberry spider mite	<i>Eotetranychus turkestani</i>	TETRTK	Small red fruits	(+) or +	Old data, unknown distribution	unknown	?	INRAE Sophia - G. Le Goff	-	30/11/17
Nervous sytem or muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	all	European red mite	<i>Panonychus ulmi</i>	METTUL	Apple	+	Old data, unknown distribution	unknown	?	INRAE Sophia - G. Le Goff	-	30/11/17
Nervous sytem or muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	all	Two spotted mite	<i>Tetranychus urticae</i>	TETRUR	Greenhouse crops, Grapevine	+	Old data, unknown distribution	unknown	?	INRAE Sophia - G. Le Goff	-	30/11/17