

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 It may be included in complex scientific articles, be part of unpublished “private” information, etc...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

et de Recherches sur
les Résistances
aux Pesticides

Insecticide							Insect							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
Carbohydrate metabolism	Chitin biosynthesis	C4a	15	-	Benzoylurées	diflubenzuron	Codling moth	<i>Cydia pomonella</i>	CARPPO	Apples, Pears	+	Old data detected locally in south-eastern France, cross-resistance with tebufenozide	NTSR (detoxification)	1994	INRAE Avignon - M. Siegwart	Sauphanor and Bouvier 1995	30/11/17
Hormonal regulation	Juvenile hormone mimics - Unknown target site	L6b	7	-	Alkylcarbamates	fenoxycarb	Codling moth	<i>Cydia pomonella</i>	CARPPO	Apples, Pears	+	Old data detected locally in south-eastern France, cross-resistance with others growth regulators	NTSR	2003	INRAE Avignon - M. Siegwart	Reyes et al., 2007	30/11/17
Hormonal regulation	Moulting acceleration ecdysone receptor	L7	18	-	Diacylhydrazines	tebufenozide	Codling moth	<i>Cydia pomonella</i>	CARPPO	Apple	+	Old data detected locally in south-eastern France, cross-resistance with diflubenzuron	NTSR (detoxification)	1994	INRAE Avignon - M. Siegwart	Sauphanor and Bouvier 1995	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Pear psylla	<i>Cacopsylla pyri</i>	PSYLP1	Pear	+	Old data without monitoring of resistance at national level	Unknown	1999	INRAE Avignon - M. Siegwart	Bues et al., 1999; Bues et al., 2003	26/06/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Rape winter stem weevil	<i>Ceutorhynchus piciparsis</i>	CEUTPI	Oilseedrape	+	Mainly found in eastern France but expanding in other regions at very high frequencies of resistant insects in some plots.	TSR and NTSR (detoxification)	2010	Terrinovia - Céline Robert	Robert et al. 2017	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Codling moth	<i>Cydia pomonella</i>	CARPPO	Apple	+	First detected in the South of France and then spread throughout the territory, low frequency presence in plots without treatment, but quickly awakened by pyrethroids treatment.	NTSR (detoxification)	1990s	INRAE Avignon - M. Siegwart Anses Lyon - B. Barrés, C. Mottet	Bouvier et al. 1997 ; Sauphanor et al., 1997; Sauphanor et al., 2000; Bouvier et al., 2001	26/06/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Codling moth	<i>Cydia pomonella</i>	CARPPO	Apple	+	Present in all regions, high frequencies of resistant insects in some plots, low resistance cost.	TSR	2003- 2004	INRAE Avignon - M. Siegwart Anses Lyon - B. Barrés, C. Mottet	Brun-Barale et al., 2005 ; Brazier et al. 2008	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Oriental fruit moth	<i>Grapholita molesta</i>	LASPMO	Peach, Quince	+	Locally detected in the South East of France	NTSR (detoxification)	2007	INRAE Avignon - M. Siegwart Anses Lyon - B. Barrés, C. Mottet	Siegwart et al. 2011	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Cotton bollworm	<i>Helicoverpa armigera</i>	HELIAR	Vegetables	+	Old data detected locally in the South East of France	NTSR (detoxification)	2004	INRAE Avignon - M. Siegwart	Buès et Boudinhon, 2003; Bues et al., 2005	26/06/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	more or less, all	Pollen beetles	<i>Meligethes aeneus</i>	MELIAE	Oilseedrape	+	Generalized resistance throughout France, locally high frequencies of resistant insects in certain plots.	Unknown	1999	Terrinovia - Céline Robert	Détourné et al. 2008, Slater et al., 2011; Zimmer et Nauen 2011; Zimmer et al., 2014	26/06/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	deltamethrin, fenvalerate, fluvalinate, lambda-cyhalothrine	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Beetroot, Peach, Rapeseed	+	Resistance present in northern and eastern France and widespread on rapeseed, very high frequencies of resistant insects in certain plots, high frequencies of resistant insects on beetroot	TSR and NTSR (detoxification)	2009	Anses Lyon - B. Barrés, C. Mottet	Fontaine et al., 2011a ; Fontaine et al., 2011b, on beetroot: Report Anses 2018; 2019; Devonshire and Moores, 1982	25/06/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	deltamethrin	Currant-lettuce aphid	<i>Nasonovia ribisnigri</i>	NASORN	Salads, Currant	+	Old data detected locally in the South of France	NTSR (detoxification)	1997	Anses Lyon - B. Barrés, C. Mottet	Rufingier, 1997	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	Lambda-cyhalothrine, deltamethrin	European corn borer	<i>Ostrinia nubilalis</i>	PYRUNU	Maize	+	Resistance present in central France, Very high frequency of resistant insects in certain plots with a high history of pyrethroid treatments.	TSR and NTSR (detoxification)	2009	INRAE Avignon - M. Siegwart	Siegwart et al. 2017	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	tau-fluvalinate, lambda-cyhalotrin	Hop aphid	<i>Phorodon humuli</i>	PHODHU	Hop	+	Old data	Unknown	1967	Anses Lyon - B. Barrés, C. Mottet	Lewis et al., 1984	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Cabbage stem flea beetle	<i>Psylliodes chrysocephala</i>	PSYICH	Oilseedrape	+	Mainly found in eastern France but expanding in other regions at very high frequencies of resistant insects in some plots.	TSR and NTSR (detoxification)	2010	Terrinovia - Céline Robert	Robert et al. 2017	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Beet armyworm	<i>Spodoptera exigua</i>	LAPHEG	Cotton, Tomato, Celery, Lettuce, Cabbage and Alfalfa	(+)	locally present in West of France	NTSR	2005	INRAE Avignon - M. Siegwart	Bues et al., 2006	30/11/17
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	all	Whiteflies	<i>Trialeurodes vaporariorum</i>	BEMAR	Greenhouse crops	+	Old data, some cases locally in the South of France	Unknown	1999	INRAE Avignon - M. Siegwart	Rufingier et al., 1999	30/11/17
Nervous system or muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	pirimicarb	Cotton and melon aphid	<i>Aphis gossypii</i>	APHIGO	Cucurbits, Solanaceae	+	Old data, with a description in Southeast France	TSR	1996	Anses Lyon - B. Barrés, C. Mottet	Delorme et al., 1997; Villatte et al., 1997; Nauen and Elbert 2003	26/06/20

Insecticide							Insect							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
Nervous system or muscle	Acetylcholine esterase inhibition	N5a	1 A	ACHEI	Carbamates	pirimicarb	Rosy apple aphid	<i>Dysaphis plantaginea</i>	DYSAPL	Apple	+	Old data detected locally in South-Western and South-Eastern France	TSR and NTSR (detoxification)	1996	INRAE Avignon - M. Siegwart Anses Lyon - B. Barrès, C. Mottet	Delorme et al., 1997; Delorme et al., 1999; Decoin 2000	26/06/20
Nervous system or muscle	Acetylcholine esterase inhibition	N5a	1 A	ACHEI	Carbamates	pirimicarb	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Beetroot, Peach, Rapeseed	+	Resistance present in northern and eastern France and widespread on rapeseed, very high frequencies of resistant insects in certain plots, high frequencies of resistant insects on beetroot	TSR and NTSR (detoxification)	2001	Anses Lyon - B. Barrès, C. Mottet	Fontaine et al., 2011a ; Fontaine et al., 2011b, sur la betterave; Report Anses 2018; 2019; Nauen and Elbert 2003	25/06/20
Nervous system or muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	pirimicarb	Currant-lettuce aphid	<i>Nasonovia ribisnigri</i>	NASORN	Salads, Currant	+	Old data detected locally in the South East of France	NTSR (detoxification)	1996	Anses Lyon - B. Barrès, C. Mottet	Rufingier, 1997; Rufingier et al., 1999	26/06/20
Nervous system or muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	phosmet	Pear psylla	<i>Cacopsylla pyri</i>	PSYLPI	Pear	+	Old data, with a description in Southeast France	NTSR (detoxification)	1992	INRAE Avignon - M. Siegwart	Bues et al., 1994; Bues et al., 1999	26/06/20
Nervous system or muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	all	Codling moth	<i>Cydia pomonella</i>	CARPP0	Apples, Pears	+	Present in all regions, high frequencies of resistant insects in some plots, known resistance cost	NTSR	2003- 2004	INRAE Avignon - M. Siegwart Anses Lyon - B. Barrès, C. Mottet	Reyes et al., 2007	30/11/17
Nervous system or muscle	chordonatal organ inhibitor	N13	29	-	Carboxamids	Fonicamid	Rosy apple aphid	<i>Dysaphis plantaginea</i>	DYSAPL	Apple	+	New data, high frequencies of resistant insects in some plots	Unknown	2017	Anses Lyon - B. Barrès, C. Mottet	in prep. Report Anses 2017	25/06/20
Nervous system or muscle	Nicotinic recepteur of acetylcholine - competitive modulation	N7	5	-	Spinosyns	spinosad	Codling moth	<i>Cydia pomonella</i>	CARPP0	Apples, Pears	+	Old data detected locally in south-eastern France, cross-resistance	NTSR	2003	INRAE Avignon - M. Siegwart	Reyes et al., 2007	30/11/17
Nervous system or muscle	Nicotinic acetylcholine receptor - allosteric modulators	N7	5	-	Spinosyns	spinosad	Californian thrips	<i>Frankliniella occidentalis</i>	FRANOC	Greenhouse crops	+	Target mutation detected in numerous	TSR	2018	INRAE Avignon - M. Siegwart	Siegwart et al. In prep	23/09/2019
Nervous system or muscle	Ryanodin receptor	N10	28	-	Pyridylpyrazoles	chlorantraniliprole	tomato leafminer	<i>Tuta absoluta</i>	GNORAB	Tomato	+	Emerging resistance, under study	Unknown	2017	INRAE Avignon - M. Siegwart	Pas encore publié	30/11/17
Interference with cellular membranes	Interaction with membrane receptors of gut epithelium	O1b	11a	-	<i>Bacillus thuringiensis</i>	cry toxin	Beet armyworm	<i>Spodoptera exigua</i>	LAPHEG	Cotton, Tomato, Celery, Lettuce, Cabbage and Alfalfa	(+)	Emerging resistance, under study	Unknown	2009	INRAE Sophia-antipolis - G. LeGoff	Hernandez-Martinez et al., 2009	30/11/17
Microbial biopesticides	Virus preparation	YV1b	NC	-	Baculovirus	Isolat M	Codling moth	<i>Cydia pomonella</i>	CARPP0	Apple / Pear	+	Present in all regions, high frequency of resistant insects in some plots, very low resistance cost.	Unknown	2007	INRAE Avignon - M. Siegwart	Sauphanor et al., 2006 ; Bering et al., 2009	30/11/17