

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 It may be included in complex scientific articles, be part of unpublished “private” information, etc...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

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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 intensity	Resistance mechanism	First occurrence in France	Contact person	References	Update
Carbohydrate metabolism	Chitin biosynthesis	C4a	15	-	Benzoylureas	all, except flufenoxuron	Codling moth	<i>Cydia pomonella</i>	CARPO	Apple	+	Generalized, all regions (old data)		NTSR (detoxification)	1990s	Anses Lyon - B. Barrès, C. Mottet	Brazier et al, 2008	30/11/17
Carbohydrate metabolism	Chitin biosynthesis	C4a	15	-	Benzoylureas	all	Pear leaf miner	<i>Leucophaea malifoliella</i>	LEUCSC	Apple	(+) ou + ?	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Carbohydrate metabolism	Chitin biosynthesis	C4b	16	-	Thiadiazinones	buprofezine	Whiteflies	<i>Trialeurodes vaporariorum</i>	TRIAVA	Greenhouse crops		Old data, South-Eastern			1999	Anses Lyon - C. Plantamp	Rufingier et al., 1999	10/07/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	cyfluthrin	Cotton and melon aphid	<i>Aphis gossypii</i>	APHIGO	Cucurbits, Solanaceae	+	One population in Southern France			2001	Anses Lyon - C. Plantamp	Nauen and Elbert 2003	20/07/20
Nervous system or muscle	Sodium canal of axons: modulation or closure	N2b	3A	-	Pyrethroids	cyfluthrin	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Peach, Potato, Sugarbeet, Rapeseed	+	Four populations in South-Western and Southern France		TSR and NTSR (detoxification)	2001	Anses Lyon - C. Plantamp	Devonshire and Moores, 1982; Nauen and Elbert 2003	20/07/20
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	aldrin, dieldrin	Wireworm	<i>Agriotes lineatus</i>	AGRILI	Maize?	+	Old data, little information				Anses Lyon - C. Plantamp	Coulon, J. (1965). In: FAO 1967.	30/11/17
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	aldrin, dieldrin	Wireworm	<i>Agriotes obscurus</i>	AGRIOB	Maize?	+	Old data, little information				Anses Lyon - C. Plantamp	Coulon, J. (1965). In: FAO 1967.	30/11/17
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	γ-BHC	Cotton and melon aphid	<i>Aphis gossypii</i>	APHIGO	Cucurbits, Solanaceae	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	aldrin/dieldrin, chlordane, heptachlor, isobenzan	Onion maggot	<i>Delia antiqua</i>	HYLEAN	Onion	+	Old data, little information				Anses Lyon - C. Plantamp	Missonnier et al., 1964; Hennequin and La Croix 1966	10/07/20
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	aldrin, dieldrin, chlordane, heptachlor, isobenzan, lindane	Cabbage maggot	<i>Delia brassicae</i>	HYLERA	Cabbage	+	Old data, little information				Anses Lyon - C. Plantamp	Missonnier et al., 1964; Missonnier 1974 FAO	30/11/17
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	aldrin, dieldrin, heptachlor, lindane	Seedcorn maggot	<i>Delia platura</i>	HYLECI	Vegetable seedling		Old data, little information				Anses Lyon - C. Plantamp	Hennequin 1973	10/07/20
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	γ-BHC	Potato beetle	<i>Leptinotarsa decemlineata</i>	LPTDNE	Potato	+	Old data, little information				Anses Lyon - C. Plantamp	Lhoste, 1960	30/11/17
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	DDT, endosulfan, lindane	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Peach, Potato, Sugarbeet, Rapeseed	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	endosulfan, dieldrin	Currant-lettuce aphid	<i>Nasonovia ribisnigri</i>	NASORN	Salads, Currant	+	Old data, little information				Anses Lyon - C. Plantamp	Rufingier et al., 1999	10/07/20
Nervous system and muscle	GABA-dependant chlorine canal - blocking or closure	N3a	2A	-	Organochlorides	aldrin/dieldrin, cyclodienes, chlordane, heptachlor, γ-BHC	Carrot fly	<i>Psila rosae</i>	PSILRO	Carrot	+	Old data, little information				Anses Lyon - C. Plantamp	Missonnier et al., 1964; Missonnier 1974 FAO	30/11/17
Nervous system and muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	triazamate, methomyl	Cotton and melon aphid	<i>Aphis gossypii</i>	APHIGO	Cucurbits, Solanaceae	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	triazamate, methomyl	Rosy apple aphid	<i>Dysaphis plantaginea</i>	DYSAPL	Apple	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	isolan, methomyl	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Peach, Potato, Sugarbeet, Rapeseed	+	Detoxication by esterase and point mutation on AchE		TSR and NTSR (detoxification)	1999	Anses Lyon - C. Plantamp	Needham and Sawicki, 1971; Devonshire and Moores, 1982; Field et al., 1999; Fontaine et al., 2011a	20/07/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	methomyl, propoxur	Currant-lettuce aphid	<i>Nasonovia ribisnigri</i>	NASORN	Salads, Currant		Old data, little information				Anses Lyon - C. Plantamp	Rufingier, 1997; Rufingier et al., 1999	10/07/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	methomyl	Whiteflies	<i>Trialeurodes vaporariorum</i>	TRIAVA	Greenhouse crops		Old data, South-Eastern population, RF around 100	HR		1999	Anses Lyon - C. Plantamp	Rufingier et al., 1999	10/07/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5a	1A	ACHEI	Carbamates	methomyl	Beet armyworm	<i>Spodoptera exigua</i>	LAPHEG	Cotton, Tomato, Celery, Lettuce, Cabbage and Alfalfa	(+)	locally		NTSR (detoxification)	2005	Anses Lyon - C. Plantamp	Bues et al., 2006	26/06/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	dimethoate, oxydemeton-methyl	Cotton and melon aphid	<i>Aphis gossypii</i>	APHIGO	Cucurbits, Solanaceae	+	One population in Southern France for oxydemeton-methyl. No data on dimethoate			2001	Anses Lyon - C. Plantamp	Nauen and Elbert 2003	20/07/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	azinphos-methyl, monocrotophos, chlorpyrifos, mevinphos	Pear psylla	<i>Cacopsylla pyri</i>	PSYLPY	Pear	(+) ou +	Old data, described in South-East of France			1994	Anses Lyon - C. Plantamp	Bues et al., 1999	26/06/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	vamidothion, dimethoate, omethoate, oxydemeton-methyl	Rosy apple aphid	<i>Dysaphis plantaginea</i>	DYSAPL	Apple	+	Old data, locally described in South-East and South-West of France		TSR and NTSR (detoxification)	1996	Anses Lyon - C. Plantamp	Delorme et al., 1997; Delorme et al., 1999; Decoin 2000	26/06/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	dimethoate, amidothion	Woolly apple aphid	<i>Eriosoma lanigerum</i>	ERISLA	Apple	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	azinphos-ethyl, demeton-S-methyl, endothon, formotion, malathion, menazon, methamidophos, methylparathion, mevinphos, oxydemeton-methyl, parathion	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Peach, Potato, Sugarbeet, Rapeseed	+	Detoxication by esterase and point mutation on AchE		TSR and NTSR (detoxification)	1999	Anses Lyon - C. Plantamp	Needham and Sawicki, 1971; Devonshire and Moores, 1982; Field et al., 1999; Nauen and Elbert 2003; Fontaine et al., 2011a	20/07/20

Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	dimethoate	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Peach, Potato, Sugarbeet, Rapeseed	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	acephate	Currant-lettuce aphid	<i>Nasonovia ribisnigri</i>	PHODHU	Salads, Currant	+	Old data, little information				Anses Lyon - C. Plantamp	Rufingier et al., 1997	10/07/20
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	all	Hop aphid	<i>Phorodon humili</i>	PHODHU	Hop	+	Old data, little information				Anses Lyon - C. Plantamp		30/11/17
Nervous system and muscle	Acetylcholine esterase inhibition	N5b	1 B	ACHEI	Organophosphates	acephate	Beet armyworm	<i>Spodoptera exigua</i>	LAPHEG	Cotton, Tomato, Celery, Lettuce, Cabbage and Alfalfa	(+)	locally		NTSR (detoxification)	2005	Anses Lyon - C. Plantamp	Bues et al., 2006	26/06/20
Nervous system or muscle	Acetylcholine esterase inhibition	N5b	1B	ACHEI	Organophosphates	all	Codling moth	<i>Cydia pomonella</i>	CARPPO	Apples, Pears	+	Present in all regions, high frequencies of resistant insects in some plots, known resistance east		NTSR	2003- 2004	INRAE Avignon - M. Siegwart Anses Lyon - B. Barrès, C. Mottet	Reyes et al., 2007	30/11/17
Nervous system or muscle	Nicotinic receptor of acetylcholine - competitive modulation	N6b	4A	-	Neonicotinoids	all	Whiteflies	<i>Bemisia tabaci</i>	BEMIAR	Greenhouse crops	+	Old data without monitoring of resistance at national level		Unknown	2007	Anses Lyon - B. Barrès, C. Mottet	Gorman et al., 2010	30/11/17
Nervous system or muscle	Nicotinic receptor of acetylcholine - competitive modulation	N6b	4A	-	Neonicotinoids	thiacloprid	Codling moth	<i>Cydia pomonella</i>	CARPPO	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 receptor of acetylcholine - competitive modulation	N6b	4A	-	Neonicotinoids	all	Green peach aphid	<i>Myzus persicae</i>	MYZUPE	Peach	+	Resistance present in northern and eastern France, cross-resistance		TSR and NTSR (detoxification)	2010	Anses Lyon - B. Barrès, C. Mottet	Bass et al., 2011; Slater et al., 2012; Mottet et al., 2016	26/06/20
Nervous system or muscle	Nicotinic receptor of acetylcholine - competitive modulation	N6b	4A	-	Neonicotinoids	all	Whiteflies	<i>Trialeurodes vaporariorum</i>	TRIAVA	Greenhouse crops	+	Old data		Unknown	2007	Anses Lyon - B. Barrès, C. Mottet	Gorman et al., 2007	30/11/17
Nervous system and muscle	Octopamine receptor - Agonist	N9	19	-	Formamidines	amitraz	Pear psylla	<i>Cacopsylla pyri</i>	PSYLPI	Pear	(+) ou +	Old data, described in South-East of France			1995	Anses Lyon - C. Plantamp	Bues et al., 1999	26/06/20