Industry´s approach to resistance management: Incidence and characterization of neonicotinoid resistance

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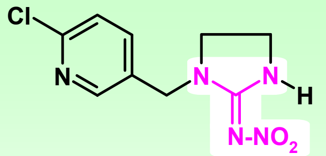
**Rothamsted Research, Harpenden, UK*

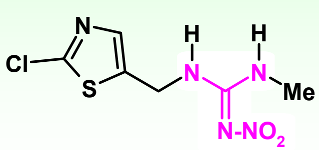
Neonicotinoid classification based on the pharmacophor

Neonicotinoid insecticides

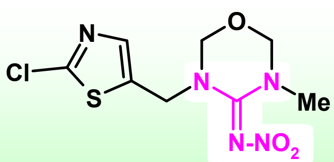
N-Nitroguanidines



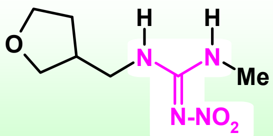
Imidacloprid



Clothianidin

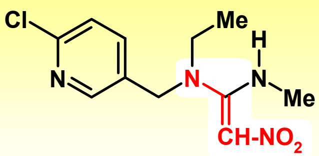


Thiamethoxam



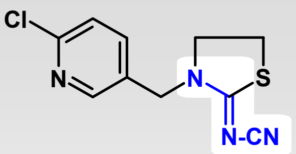
Dinotefuran

Nitromethylens (Nitroenamines)

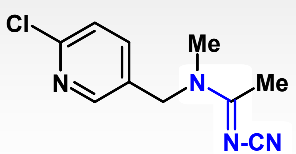


Nitenpyram

N-Cyanoamidines



Thiacloprid



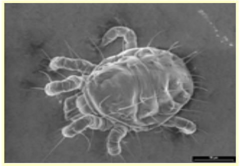
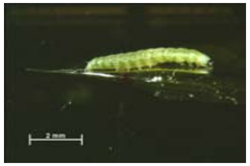
Acetamiprid

IRAC

Insecticide Resistance Action Committee

www.irac-online.org

Resistance in arthropod pest species marks a genetic change in response to selection by pesticides that may impair control in the field at recommended application rates.


EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION (EPPO)

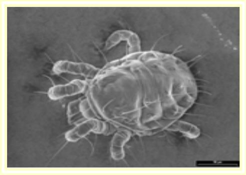
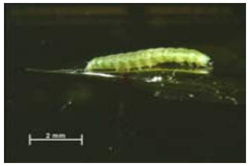
EPPO standard on Resistance Risk Analysis (PP 1/213)

1. *Bemisia tabaci*
2. *Trialeurodes vaporariorum*
3. *Aphis gossypii*
4. *Myzus persicae*
5. *Leptinotarsa decemlineta*
6. *Spodoptera exigua*
7. *Frankliniella occidentalis*
8. *Tetranychus urticae*
9. *Panonychus ulmi*
10. *Cydia pomonella*
11. *Phorodon humuli*

Examples of species in the EPPO region which have developed resistance and for which sensitivity data should normally be provided

Specific scope

This standard describes how the risk of resistance to plant protection products can be assessed and, if appropriate, systems for risk management can be proposed, in the context of official registration of plant protection products.

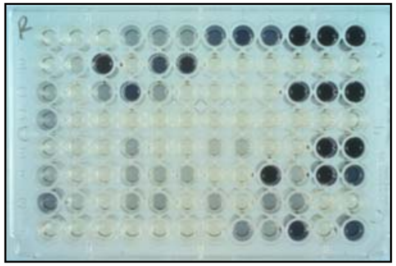





Resistance monitoring

Example 1: *Myzus persicae* (Green peach aphid)

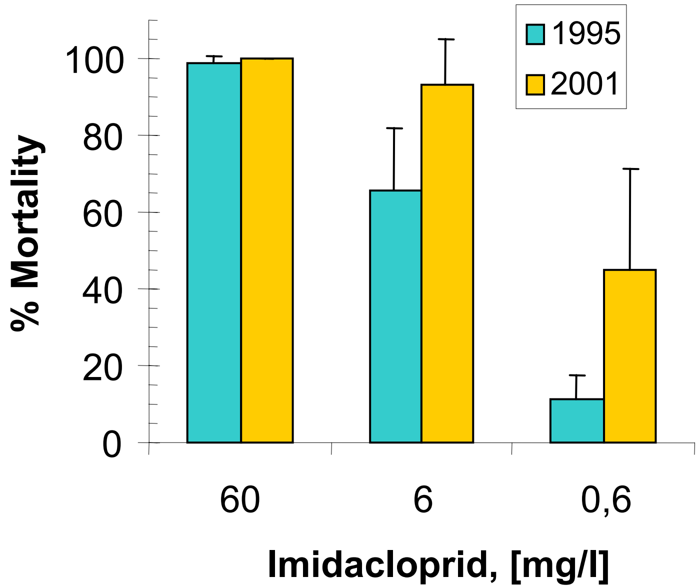
Established resistance mechanisms in *M. persicae*

- Elevated carboxylesterase
  - OPs, carbamates, pyethroids
- Modified acetylcholinesterase (MACE)
  - pirimicarb/triazamate
- Knockdown resistance (kdr)
  - pyrethroids

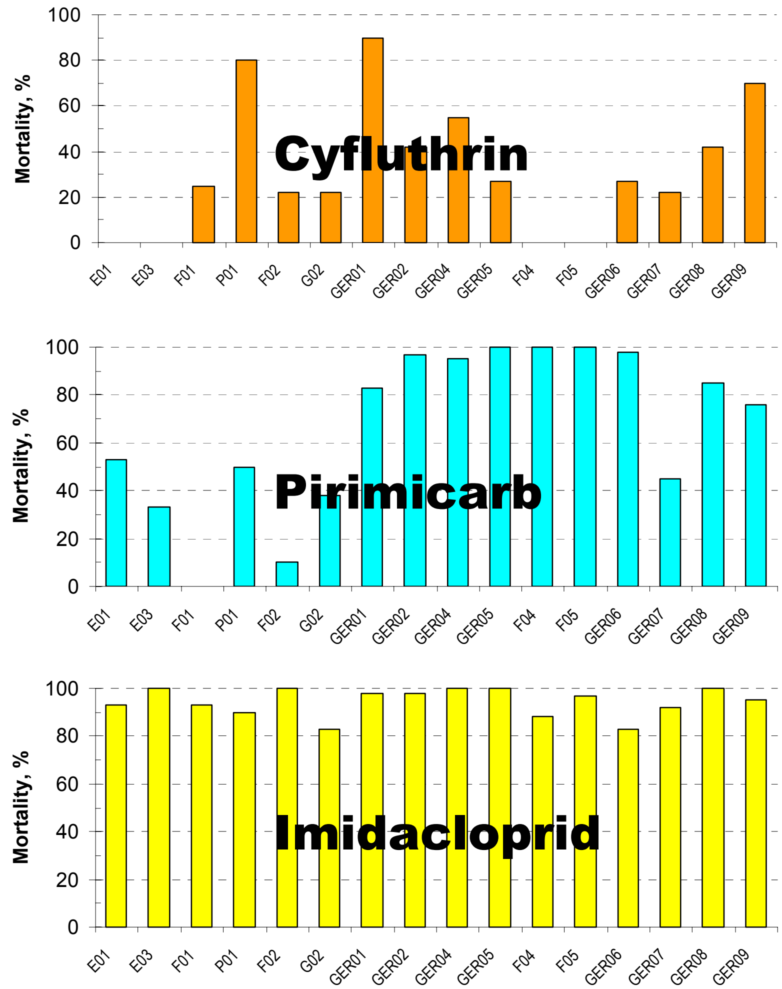


Resistance monitoring

FAO-dip test results; 1995 (21 strains) and 2001 (16 strains).



Nauen & Elbert (2003) Bull. Entomol. Res. 93



A variation in response in tobacco-associated strains of *Myzus persicae,* but no mechanisms could be identified

Pestic. Sci. 1998, **53**, 133–140

Antifeedant Effect, Biological Efficacy and High Affinity Binding of Imidacloprid to Acetylcholine Receptors in *Myzus persicae* and *Myzus nicotianae*

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(Received 1 May 1997; revised version received 6 November 1997; accepted 26 January 1998)

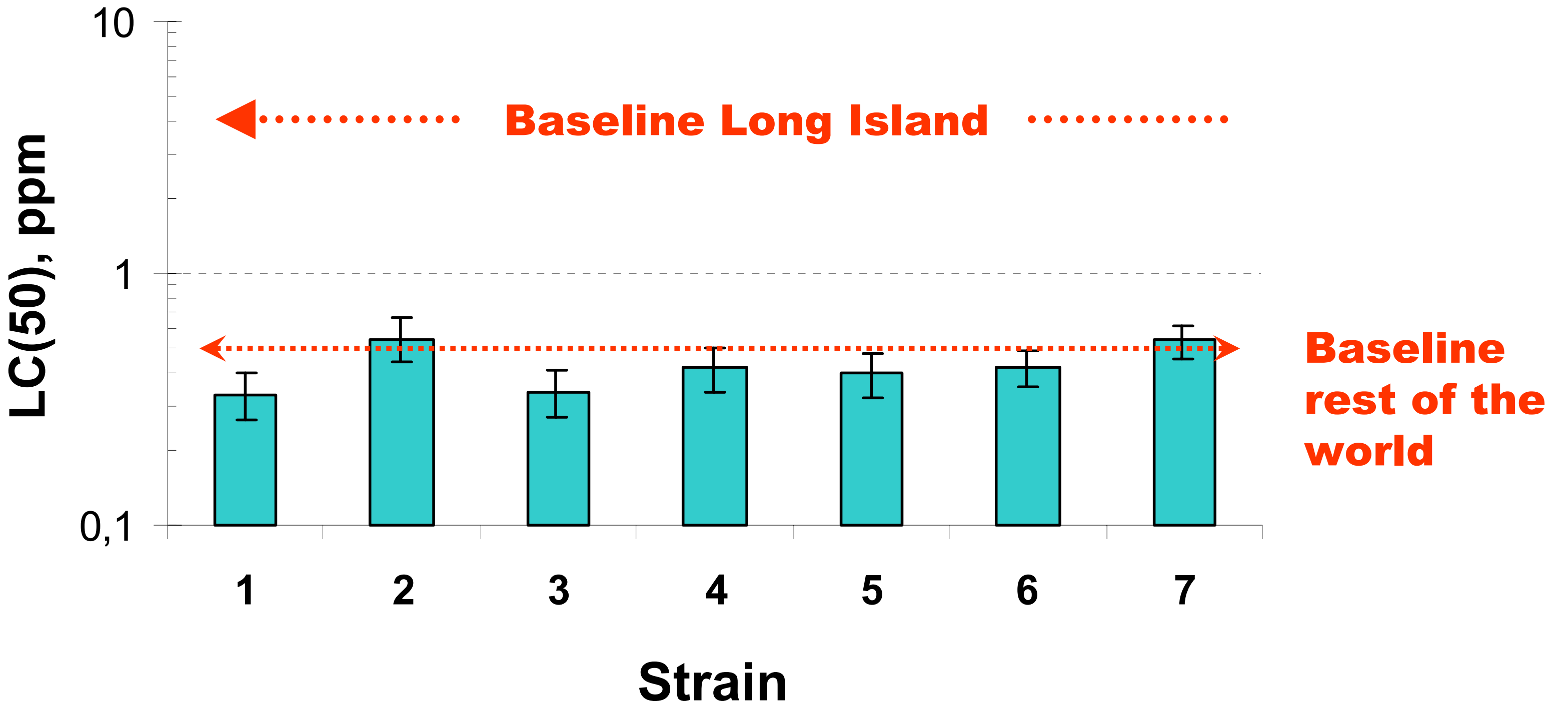
Abstract: It is known from laboratory studies that tobacco-associated forms of *Myzus persicae* (Sulzer) and the closely related tobacco aphid *Myzus nicotianae* (Blackman) are often somewhat less susceptible to imidacloprid than non-tobacco strains of *M. persicae*. Choice tests (floating leaf technique) showed that tobacco aphids were also less susceptible to the antifeedant potential of imidacloprid in contact bioassays. Synergists like piperonyl butoxide or DEF did not enhance the susceptibility of tobacco-associated morphs of *Myzus* ssp. to imid-

- Synergists negative
- Enzyme systems negative
- nAChR binding negative
- Aposymbiotic aphids negative

Resistance monitoring

Example 2: *Leptinotarsa decemlineata* (CPB*)

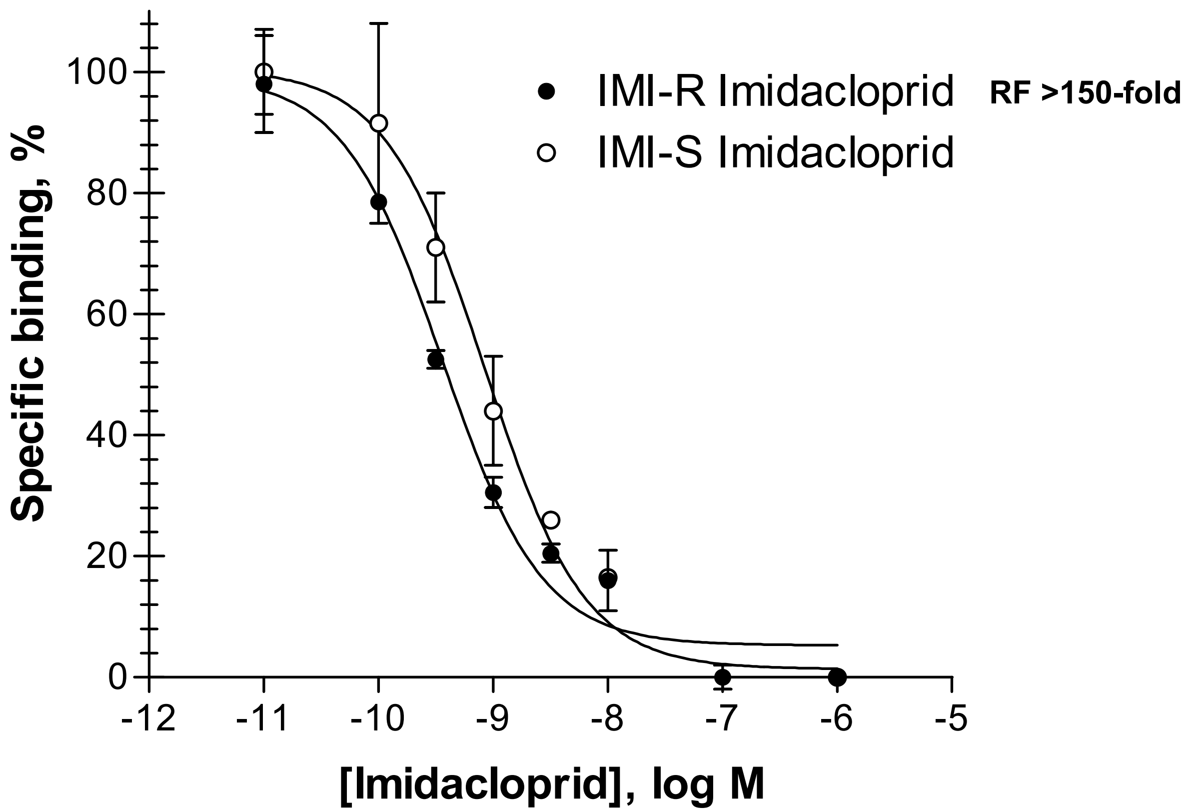
(1996)



* Colorado potato beetle

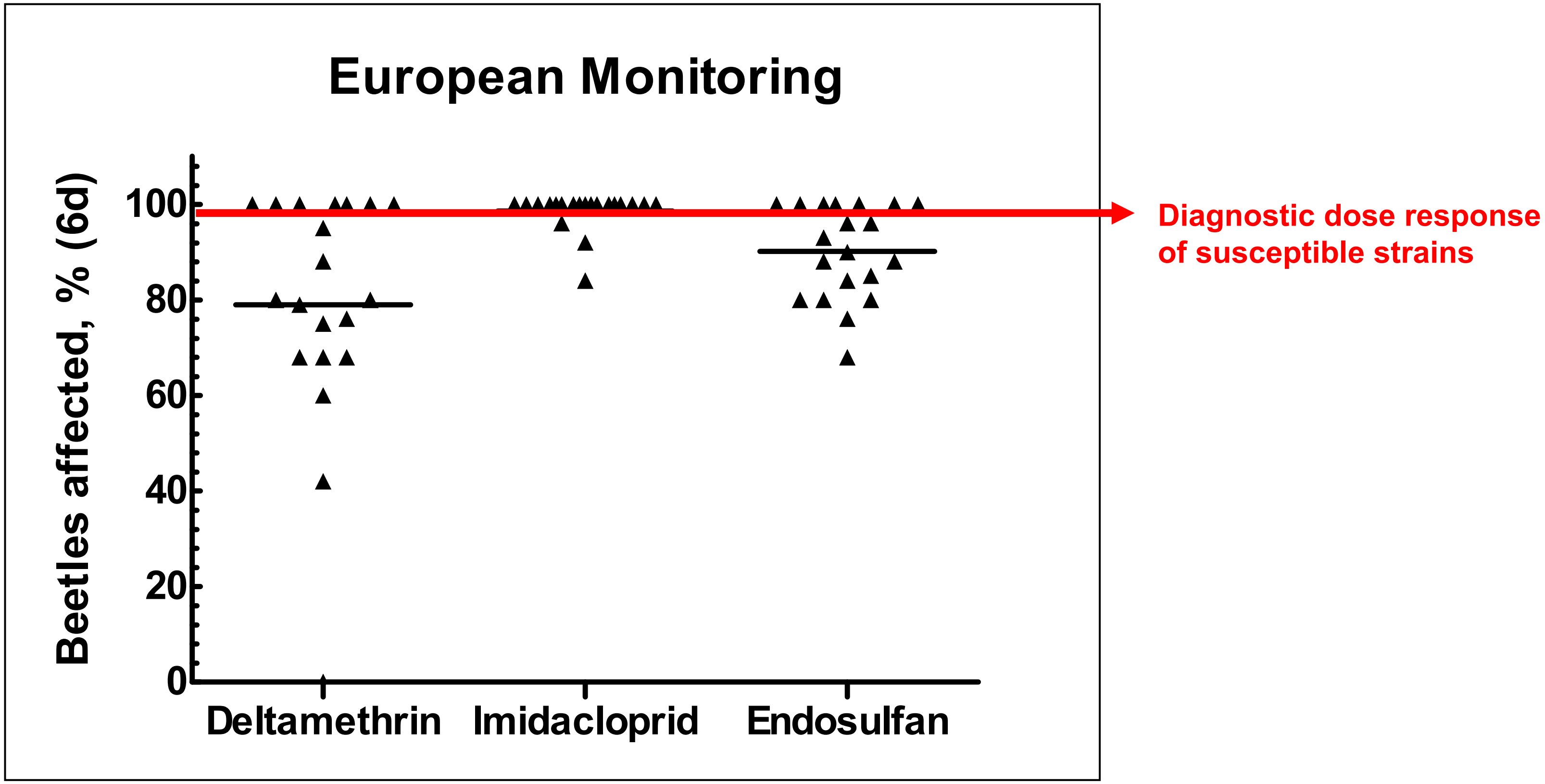
Olsen et al. (2000) J. Econ. Entomol. 93

No reduced binding of imidacloprid to nAChR´s in CPB head membrane preparations



Nauen et al., unpublished

European monitoring in 2003 and 2004 did not reveal imidacloprid Resistance in CPB´s

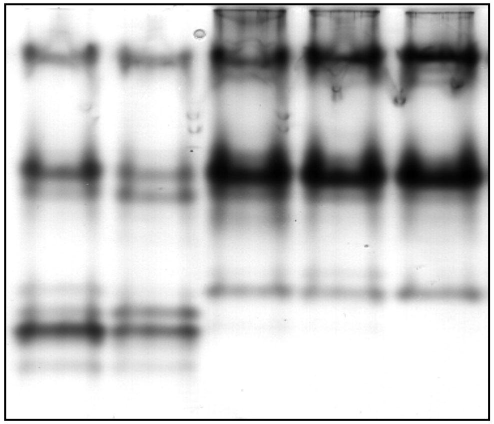


* Colorado potato beetle

Resistance monitoring

Example 3: *Bemisia tabaci*

Q-type B-type



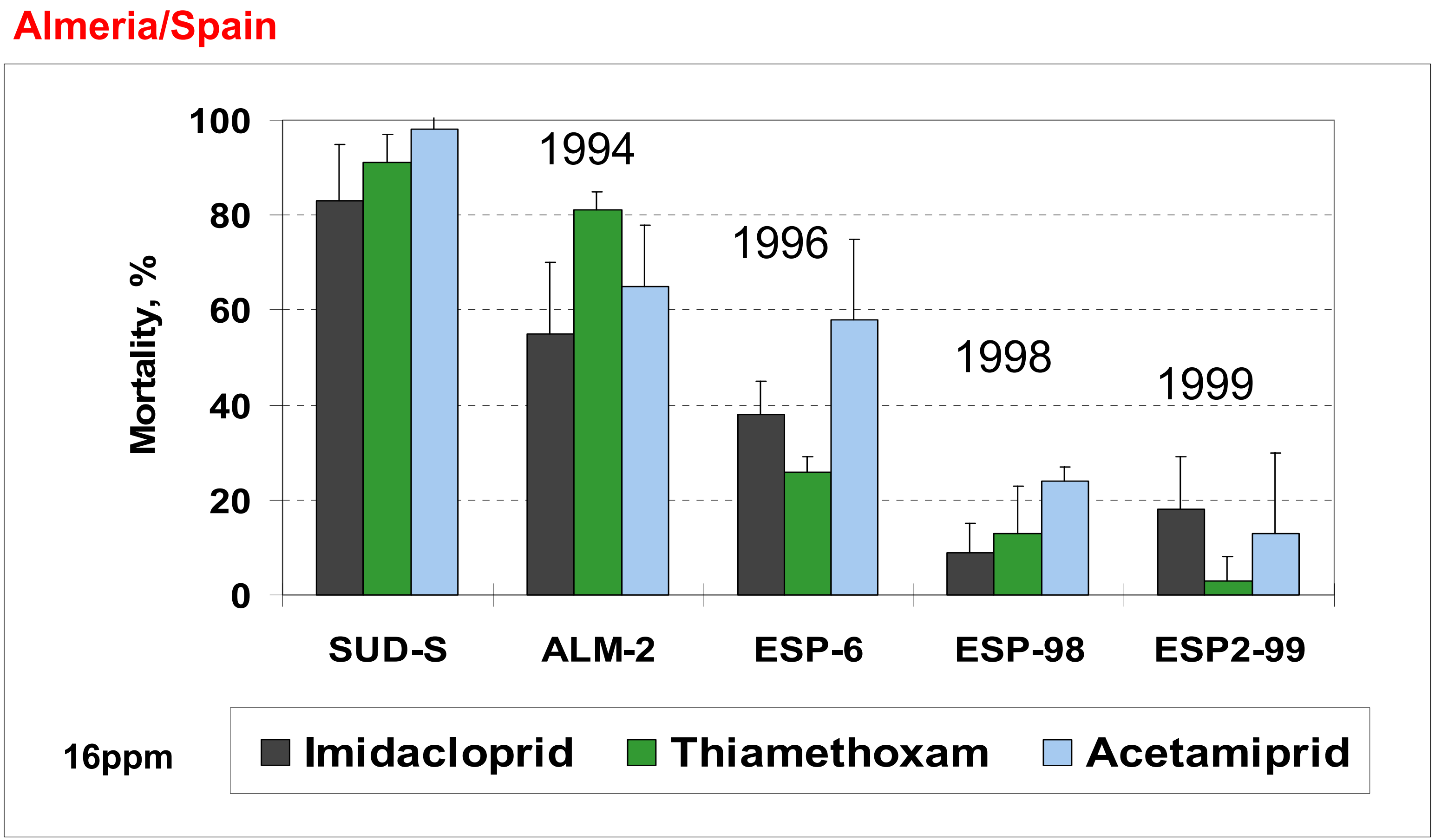
Esterase banding pattern to differentiate biotypes

Bemisia tabaci

(sweetpotato whitefly)

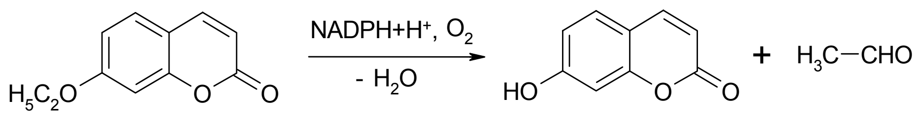
Two important biotypes are B- and Q-types. The most dominant biotype world-wide is B, whereas Q is to a greater or lesser extent restricted to the Mediterranean basin (e.g. Almeria/Spain).

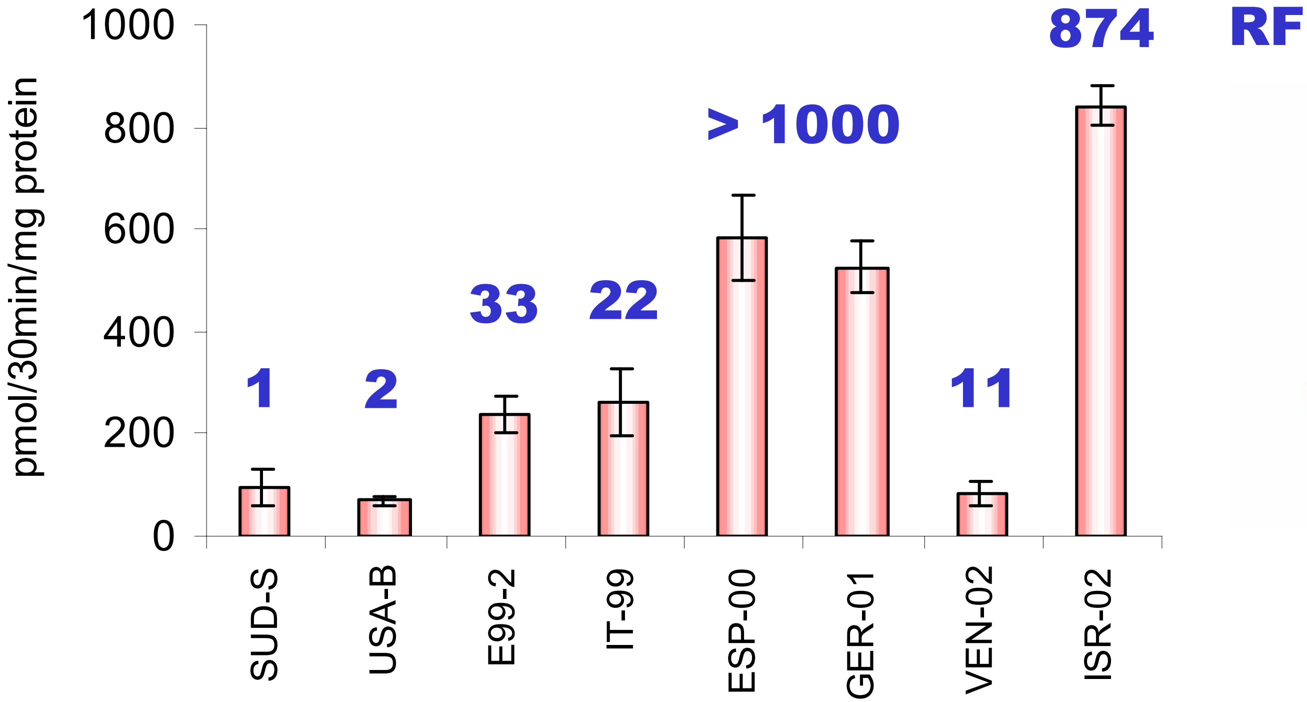
Resistance monitoring in
Almeria, Spain

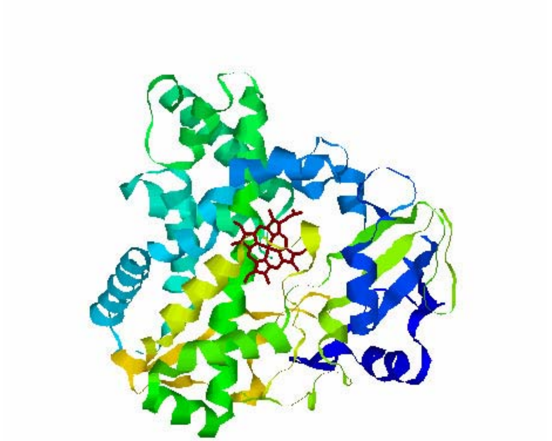


Nauen et al. (2002) Pest. Manag. Sci. 58

Monooxygenases confer neonicotinoid resistance in sweetpotato whiteflies, *Bemisia tabaci*





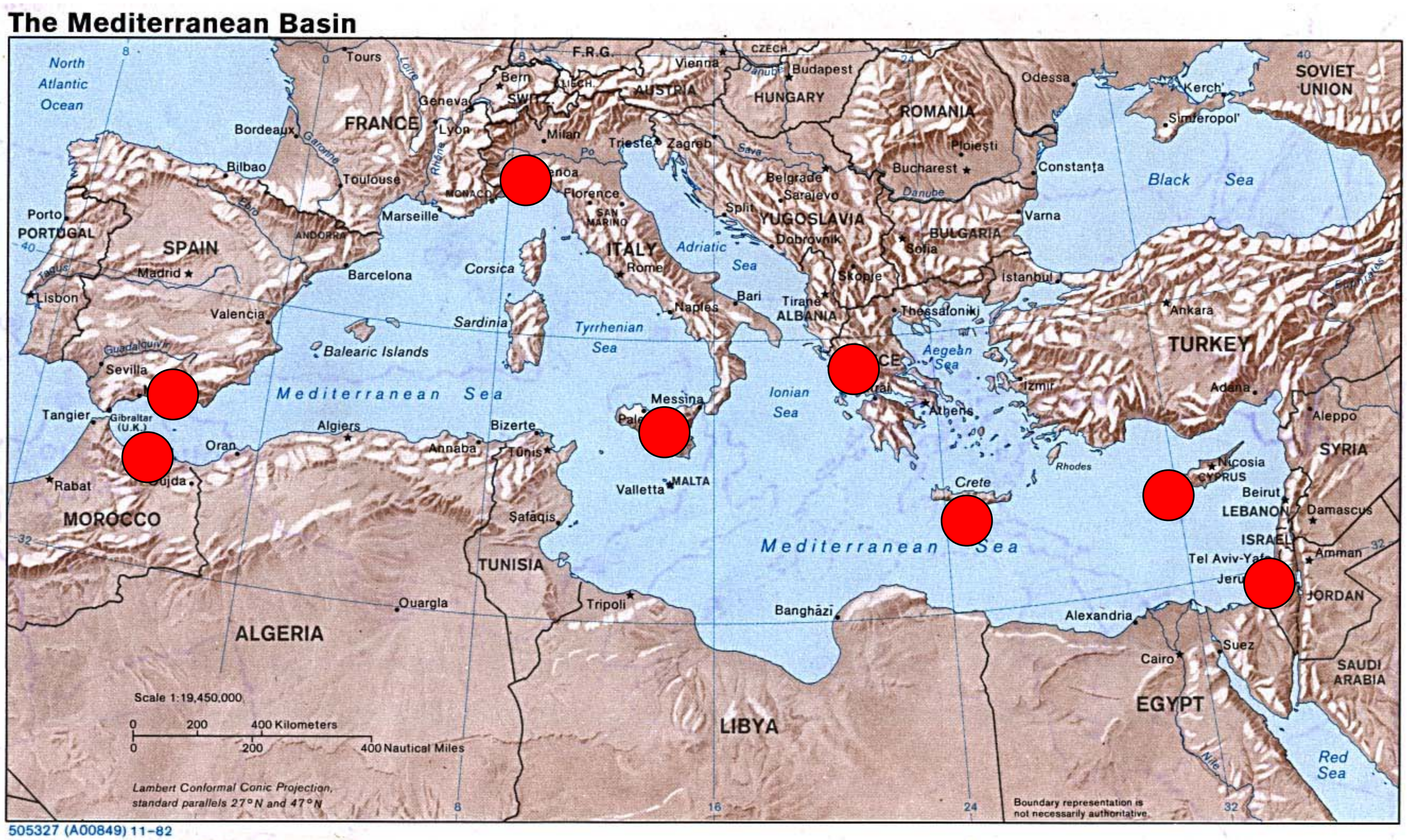


Rauch & Nauen (2003) Arch. Insect Biochem. Physiol. 54

7-Ethoxycoumarin-O-deethylase activity is a biochemical marker linked to neonicotinoid resistance in *Bemisia tabaci*

Spread of neonicotinoid resistance and Q-biotypes in the Mediterranean basin

Bemisia tabaci



Neonicotinoid cross-resistance in several strains of *Bemisia tabaci*

Strain	Origin	Date	Host plant	Biotype
CRE04-01	Crete	2004	Tomato	Q
BR-JM03	Brazil	2003	Tomato	B
ISR-02	Israel	2002	Ornamentals	B
MEX03-02	Mexico	2003	Tomato	B
TUC-03	USA	2003	Melon	B
ESP-00	Spain	2000	Pepper	Q
ALM-1	Spain	1994	Tomato	Q

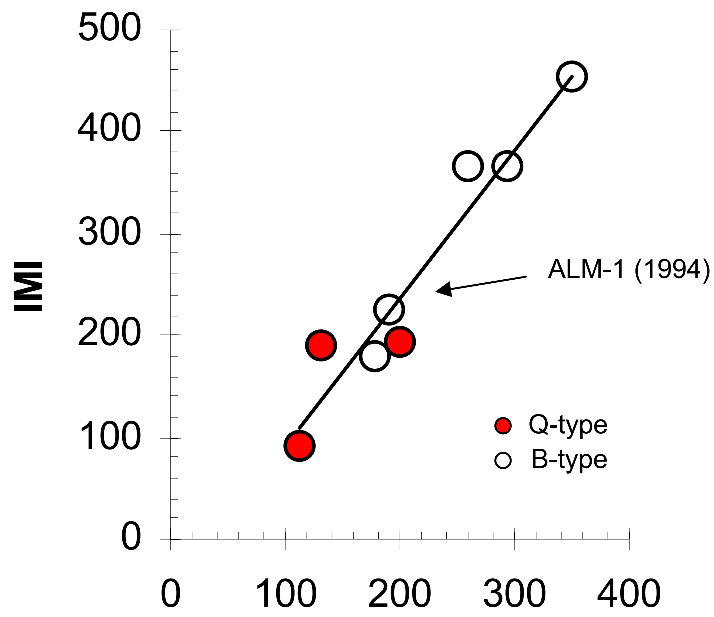
12 (!) different whitefly insecticides (i.e. covering all relevant chemical classes commercially available) were tested in a leaf-dip bioassay (3-4d) against all strains,

Strain ESP-00 (Q-type)

Compound		Concentration [ppm] 200	40	8	1,6	0,32	0,064	Sum
Spiromesifen	Mean	95	99	72	57	37	0	360
*	SEM	3,33	0,88	2,67	1	8,67	0	
Imidacloprid	Mean	57	27	10	0			94
	SEM	15,56	4,44	0	0			
Thiamethoxam	Mean	87	23	3	0			113
	SEM	6,67	4,44	4,44	0			
Dinotefuran	Mean	100	73	45	27	0		245
	SEM	0	11,11	4,44	4,44	0		
Pymetrozine	Mean	53	47	17	0			117
	SEM	22,22	11,11	5	0			
Pyriproxyfen	Mean	73	44	19	7			143
*	SEM	1,5	4,5	5	6,5			
Buprofezin	Mean	73	54	47	17			191
*	SEM	3,5	2	4,5	9,5			
Pyridaben	Mean	100	63	0				163
	SEM	0	11,1	0				
Deltamethrin	Mean	43	0					43
	SEM	24,44	0					
Monocrotophos	Mean	53	17	7				77
	SEM	4,44	8,89	4,44				
Endosulfan	Mean	100	57	40	17			214
	SEM	0	4,44	6,67	4,44			
Flonicamid	Mean	73	20	0	0			93
	SEM	4,44	4,44	0	0			

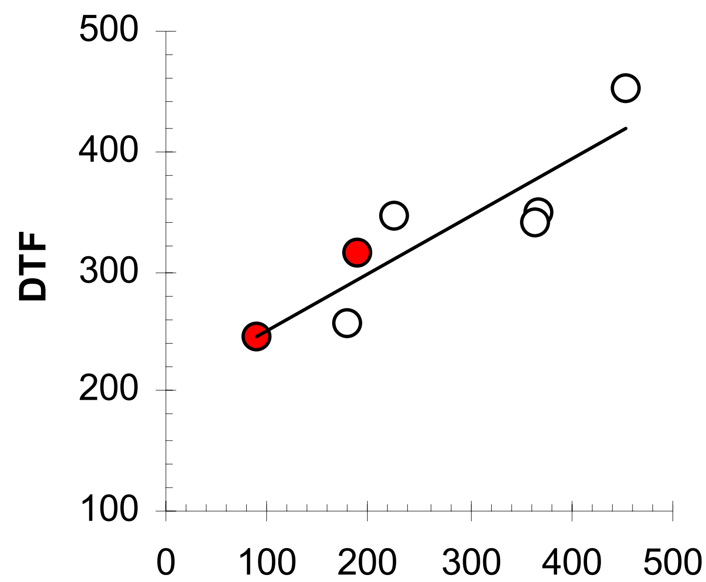
* nymphs

Neonicotinoid cross-resistance in *Bemisia tabaci*



TMX

$y = 1{,}4592x - 54{,}2$
$R^2 = 0{,}9289$



IMI

$y = 0{,}472x + 203{,}26$
$R^2 = 0{,}79$

IMI = Imidacloprid
TMX = Thiamethoxam
DTF = Dinotefuran

Correlated are efficacy indices for the compounds displayed. An efficacy index results from mortality figures scored at different concentrations and subsequently summarized.

Resistance monitoring

Example 4: *Nilaparvata lugens* (brown planthopper)

Brown planthopper damages plants by sucking. Affected plants become chlorotic, and older leaves turn progressively yellow, dry and later on die. The feeding damage is commonly referred to as **hopperburn**. *N. lugens* is also vector of rice grassy stunt tenuvirus and rice ragged stunt virus.

Hopperburn

Selection for imidacloprid resistance in BPH

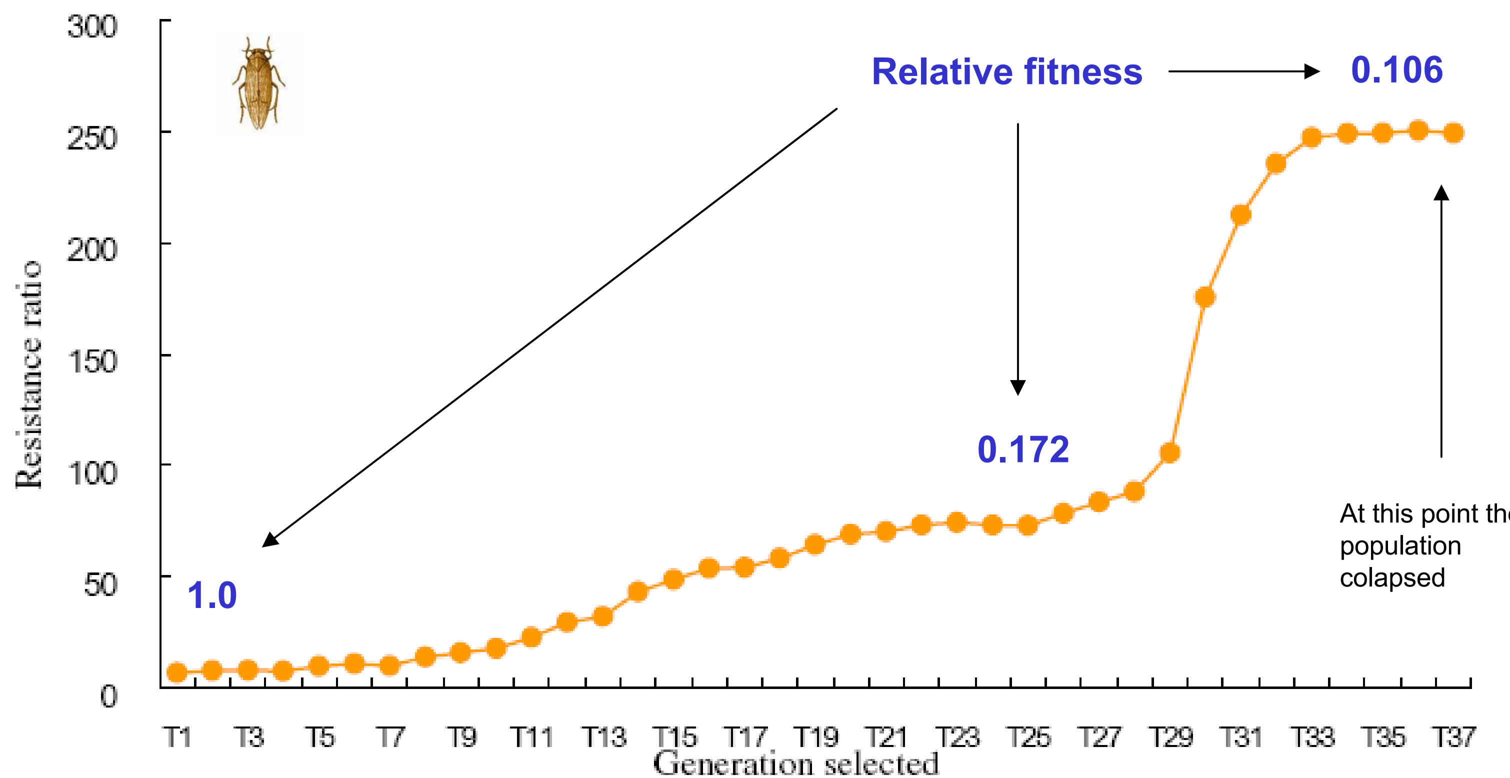
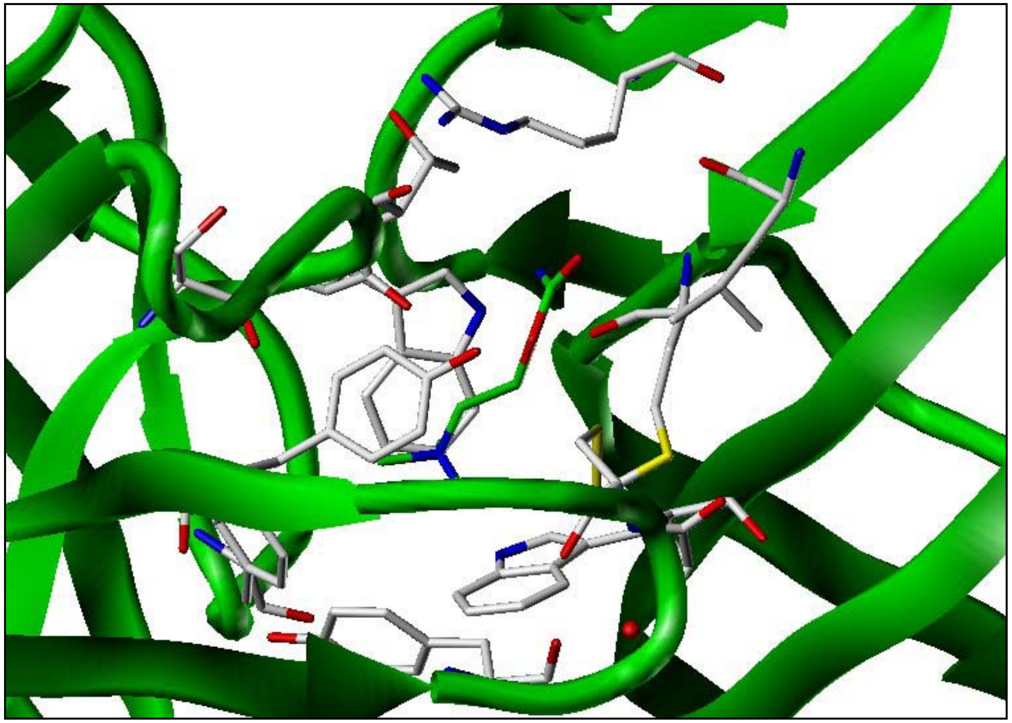
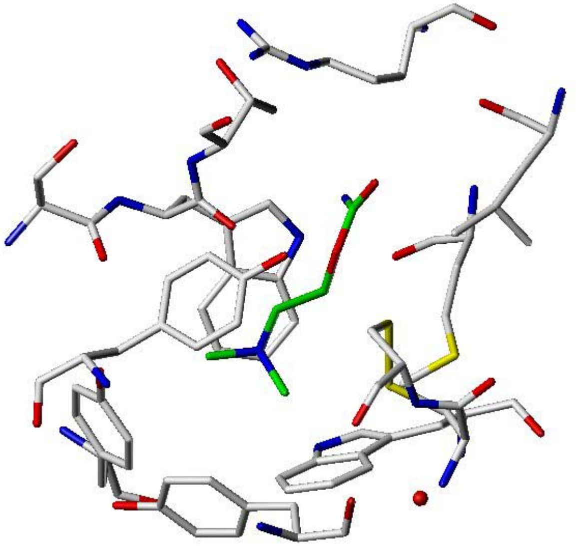


Fig 1 The dynamics of imidacloprid resistance in *Nilaparvata lugens* during resistance selection. Tn: generation selected.

Kindly provided by Zewen Liu & Zhaojun Han (in press)

A Y151S mutation in alpha subunits of the nAChR confers neonicotinoid resistance in a laboratory selected strain of *N. lugens**





- **Tyrosin and Tryptophan side-chains form a charge-transfer complex with the cholinium ion of ACh. When tyrosine-151 is replaced by a serine, the resulting interaction with both Ach and imidacloprid may be destabilized, in addition to local conformational changes.**

*Liu et al. (2005) PNAS **102**, 8420

Recommended reading

Archives of Insect Biochemistry and Physiology 58:200–215 (2005)

Resistance of Insect Pests to Neonicotinoid Insecticides: Current Status and Future Prospects

Ralf Nauen[1*] and Ian Denholm[2]

The first neonicotinoid insecticide introduced to the market was imidacloprid in 1991 followed by several others belonging to the same chemical class and with the same mode of action. The development of neonicotinoid insecticides has provided growers with invaluable new tools for managing some of the world's most destructive crop pests, primarily those of the order Hemiptera (aphids, whiteflies, and planthoppers) and Coleoptera (beetles), including species with a long history of resistance to earlier-used products. To date, neonicotinoids have proved relatively resilient to the development of resistance, especially when considering aphids such as *Myzus persicae* and *Phorodon humuli*. Although the susceptibility of *M. persicae* may vary up to 20-fold between populations, this does not appear to compromise the field performance of neonicotinoids. Stronger resistance has been confirmed in some populations of the whitefly, *Bemisia tabaci*, and the Colorado potato beetle, *Leptinotarsa decemlineata*. Resistance in B- and Q-type *B. tabaci* appears to be linked to enhanced oxidative detoxification of neonicotinoids due to overexpression of monooxygenases. No evidence for target-site resistance has been found in whiteflies, whereas the possibility of target-site resistance in *L. decemlineata* is being investigated further. Strategies to combat neonicotinoid resistance must take account of the cross-resistance characteristics of these mechanisms, the ecology of target pests on different host plants, and the implications of increasing diversification of the neonicotinoid market due to a continuing introduction of new molecules. Arch. Insect Biochem. Physiol. 58:200–215, 2005.

Conclusion

Statement regarding the current knowledge of neonicotinoid resistance in insect pests and the implications for cross-resistance within this chemical class

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To date, work on whiteflies, Colorado potato beetles and planthoppers has shown contrasting patterns of cross-resistance, no doubt related to the type of mechanism(s) present. For the time being there seems every justification for regarding neonicotinoids as a single MoA group for resistance management purposes, as is the case in the latest classification endorsed by IRAC International.

Based on a discussion at the IRAG UK Meeting , 14 April 2005 in Cambridge/UK