IRAC Guidelines for Management of Resistance to Group 4 insecticides

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IRAC Sucking Pest Working Group

Introduction

The use of IRAC Group 4 nicotinic acetylcholine receptor agonists (nAChR) has grown considerably since the introduction of the neonicotinoid insecticide imidacloprid, which was commercialized in 1991. Ten insecticidal compounds are currently classified within this mode of action group, however registration status differs between compounds and depending on region not all of them are available to farmers for the control of agricultural and horticultural insect pests. The ten insecticides are classified in four sub-groups 4A-4D as shown below. All the insecticides principally share the same binding site on the nicotinic acetylcholine receptors and therefore are considered to share the same mode of action. Sub-classification is based on structural differences of the insecticide molecules, which in many cases explain the lack of metabolic cross-resistance between subgroups.

4 **Nicotinic acetylcholine receptor (nAChR) agonists** Nerve action {Strong evidence that action at one or more of this class of protein is responsible for insecticidal effects}	**4A** Neonicotinoids	Acetamiprid, Clothianidin, Dinotefuran, Imidacloprid, Nitenpyram, Thiacloprid, Thiamethoxam,
	4B Nicotine	Nicotine
	4C Sulfoxaflor	Sulfoxaflor
	4D Butenolides	Flupyradifurone

Source: IRAC MoA Classification v 7.3, February 2014 www.irac-online.org

The guidelines presented here are designed by the Sucking Pest Working Group of the Insecticide Resistance Action Committee (IRAC). They are based on guidelines published by Elbert et al. in 1996 and 2005, respectively, and adapted from the original June 2008 IRAC Neonicotinoid IRM guidelines. In addition, Neonicotinoid IRM guidelines from IRAC USA in March 2004 have been taken into account

As pest problems and control practices differ considerably between countries, crops and climatic conditions, these guidelines must cover a wide range of flexible options thus allowing regional experts to develop, implement and adapt these options to take local conditions into account.

The information provided is based on published information and to the best of IRAC Internationals knowledge at the time of writing (December 2014).

Status of Resistance to Neonicotinoids

Several of the insect pests which are the prime target for Group 4A neonicotinoid insecticides have been shown to have the potential to develop resistance. The following table indicates the current known status of Group 4 resistance in the different subgroups as of December 2014.

As new findings come available and are published, the information in this table will change. IRAC declines responsibility for the performance of individual products based on this list, since these findings are usually linked to specific geographic regions, and new resistance mechanisms may evolve with time. For latest information please contact IRAC directly via the website

Common Name	Species	Region resistance reported	Host Crop	Form of resistance	Sub-groups affected by group 4 resistance	Reference
Cotton Jassid	*Amrasca bigutalla*	India	Cotton	Unknown	4A - Confirmed 4C - Unknown 4D - Unknown	Kshirsagar et al, 2012
Cotton aphid	*Aphis gossypii*	North East Asia	Vegetables	Target Site (R81T)	4A – Confirmed 4C – Unknown 4D - Unknown	Hyun-Na Koo 2014
Potato psyllid	*Bactericera cockerelli*	USA & Mexico	Potato	Unknown	4A – Confirmed 4C – Unknown 4D - Unknown	Chavez et al, 2010
Tobacco whitefly	*Bemisia tabaci (adults & pupae)*	Global	Vegetables, Soybean, Ornamentals	Metabolic (CYP6CM1)	4A – Confirmed 4C – Unaffected 4D – Unaffected	Nauen et al, 2002
Asian citrus psyllid	*Diaphorina citri*	USA	Citrus	Unknown	4A – Confirmed 4C – Unknown 4D - Unknown	Tiwari et al, 2011
Mango leafhopper	*Idioscopus clypealis*	South Asia	Mango	Unknown	4A – Confirmed 4C – Unknown 4D - Unknown	Elbert et al, 2008
Small brown planthopper	*Laodelphax striatellus*	Asia	Rice	Unknown	4A – Confirmed 4C – Unknown 4D – Not registered	Ma et al, 2007
Colorado potato beetle	*Leptinotarsa decemlineata*	North America	Potato	Unknown	4A – Confirmed 4C – Unknown 4D - Unknown	Olson et al, 2000
Green peach aphid	*Myzus persicae*	Europe	Peach	Target site (R81T)	4A – Confirmed 4C – Confirmed 4D - Confirmed	Bass et al, 2011
Brown Planthopper	*Nilaparvata lugens*	Asia	Rice	Metabolic (CYP6ER1)	4A – Confirmed 4C – Unaffected 4D – Not registered	Bass et al, 2011
Glasshouse whitefly	*Trialeurodes vaporariorum (adults & pupae)*	Europe	Protected Vegetables	Unknown	4A – Confirmed 4C – Unknown 4D - Unknown	Gorman et al, 2007
Damson hop aphid	*Phorodon humuli*	Europe	Hops	Unknown	4A – Confirmed 4C – Unknown 4D - Unaffected	Nauen et al., 2015

Status December 2014

Guidelines for use of Group 4 nAChR insecticides and resistance management

1. **Always use products at the recommended label rates and spray intervals with the appropriate application equipment**.
Group 4 insecticides used at rates higher or lower than recommended on the label can result in resistance and/or unwanted effects on non-target organisms and the environment. Always make sure that all the spray equipment is in good condition and that there is no blocking of nozzles or filters as this results in incorrect rates.

2. Rotation of insecticide Groups acts against rapid selection of resistant populations.
By diversifying the mode of action used in the crop cycle, the farmer is avoiding prolonged selection for one resistance mechanism. Carefully planned rotation of active ingredients from different mode of action groups provides the best option for minimizing resistance development. Sufficient intervals should be left between applications of active ingredients with the same modes of action. When spraying a product to control a multi-generation pest, the choice of insecticides in the rotation strategy needs to allow for follow up applications with other active ingredients enabling the farmer to prevent season long exposure of the target pest to a single chemical group or mode of action. Adopt a window strategy by limiting Group 4 treatments onto one generation of the target pest, and switching to other modes of action in the subsequent generation. Avoid using Group 4 compounds for more than 50% of the total crop cycle
The unique systemic properties of certain members of the nAChR chemical class allow these products to be applied either directly to the soil, as a seed treatment or as foliar spray. This also needs to be taken into account when planning chemistry rotation in order to prevent resistance developing and it is recommended to use an effective foliar product with different mode of action after the use of a Group 4 compound as either a seed treatment or a soil application.
In many countries, the IRAC Group class number is now given on the label of the product. It can also be found on the MOA Classification published on www.irac-online.org

3. Use suitable rotation partners for Group 4 nAChR insecticides.
An extensive range of insecticides with different modes of action which can be used as rotation partners for Group 4 insecticides, are available to the farmer. Advice on suitable rotation partners can be obtained from IRAC's mode of action classification available here. Local rotation strategies should be developed according to the insecticides registered for the particular use in question and commercially available to the farmer. Other factors which need to be considered include: the crops grown in the agrisystem, prevalent refuge crops, the insect pest complex, seasonal distribution and resistance profiles of the target insects, together with occurrence and relevance of beneficial organisms. When using mixtures containing a Group 4 compound as one of the components, always use the full recommended rates of the individual active ingredients. The use of mixtures whether as a premix or tank mix, containing two effective active ingredients with different modes of action is becoming very popular either to increase the spectrum of insect pests controlled or to prevent the development of resistance. More and more mixtures containing both a pyrethroid and a Group 4 insecticide are being used against difficult to control insect pests. The use of such mixtures in any form is not recommended if the target pest is already resistant to one of the modes of action in the mixture! Do not develop an over reliance for a specific mixture as this can result in selection for multi-resistant populations which are very difficult to control. When using mixtures always be sure to change the active ingredient combinations and not to repeatedly use only one mixture of the same active ingredients or modes of action within a single cropping cycle.

4. Rotation of subgroups 4A, 4C and 4D
Successive generations of a pest should not be treated with compounds from the same Mode of Action Group. In the absence of other alternatives it may be possible to rotate compounds between sub-groups if it is clear that cross-resistance mechanisms do not exist in the target populations. Compounds from subgroups 4A, 4C and 4D are chemically distinct, and evidence based on current resistance mechanisms indicates that the risk of metabolic cross-resistance is low. If there are no other alternatives, compounds from groups 4A, 4C and 4D may be rotated in situations where cross-resistance mechanisms are known to be absent in the insect population to be treated. Group 4B (Nicotine) is no longer widely used in commercial agriculture, and thus is not considered in this document.

5. Using insecticide mixtures
IRAC has issued a statement and a leaflet for the use of insecticide mixtures. In principle any two insecticides from the same Group should not be tank-mixed or co-formulated as a means to manage resistance.

6. The use of Group 4 insecticides against different pests in the same crop.
Multiple uses of different Group 4 insecticides against more than one pest species in the same crop is feasible but needs at the local level, to take into account the pest populations dynamics, overlapping of the various species, their relative importance and each species' potential risk for developing resistance. When two species appear simultaneously always use the recommended rate for the more difficult to control species. When they appear independently at different crop stages then always use the individual recommended rate for each species.

7. Do not control a multi-generation pest exclusively with one mode of action.
Using Group 4 insecticides continuously across a single crop season increases the risk of resistance developing to the different chemical classes in the Group, even if insect pests show different levels of sensitivity to the different Group 4 insecticides commercially available.

8. Never use Group 4 insecticides for follow up treatments where resistance has already reduced their effectiveness.
The use of follow up treatments after a product failure more often than not necessitating higher rates than recommended, whether as solo treatments or in mixtures, may continue to promote and contribute to escalating resistance levels and thus should be avoided.

9. The use of non-specific mode of action products helps to prevent the development of resistance.
Plant protection products such as oils and soaps which have a non-specific mode of action are good resistance management tools which should be recommended for use in rotation or combination with Group 4 insecticides, provided that they effectively control both susceptible and resistant target pest populations.

10. Plan the use of Group 4 insecticides in such a way that they complement the efficacy of the prevalent beneficial organisms.
The contribution of beneficial organisms to pest control can be significant in many cropping systems and can also play an important part in resistance management. They can effectively help control the target pests irrespective of their degree of resistance or resistance mechanism and thus can help slow down the resistance selection process. In many crops some Group 4 insecticides may be best suited as soil treatments either incorporated as granules, applied through irrigation systems or as seed treatments. These techniques help conserve the above ground beneficial organisms so their activity can then complement the initial control provided by the insecticide. Thought should also be given to intelligent timing of the applications of foliar insecticides with low selectivity to periods of lower beneficial organism activity or during their protected life stages when they are less likely to come into contact with the insecticide treatment.

11. Good agricultural practices should be applied alongside physical and biological pest control methods.
There are many ways today's farmer can help prevent resistance developing by simply complying with the concepts of integrated crop management. Monitoring and adhering to recommended pest and/or damage thresholds, respecting the usefulness of natural enemies, simple sanitation and removal of post-harvest residues in the fields, the use of resistant crop varieties and even by simply avoiding continuous year round cultivation of a single crop can all help to slow down and even prevent resistance development.

12. Integrate escape crops into the cropping system.
The use of escape crops not treated with Group 4 insecticides can form an important reservoir for susceptible pest populations. Neighboring crops that are not treated at all, allow interbreeding between the treated and untreated insect populations thus diluting the genes for resistance. This has proved to be one of the most successful strategies for insecticide resistance management and should be actively continued to maintain susceptibility to these products in the future.

13. Monitor problematic pest populations in order to detect first shifts in sensitivity.
Baseline sensitivity data for representative field populations should be established before the products became widely used. Re-examining the insecticide sensitivity of these populations at regular intervals can detect possible changes in susceptibility. Monitoring for the major agricultural pests have been established by IRAC and can be found on the IRAC website www.irac-online.org/teams/methods/. Following up reports of field failures is also a good way to detect early shifts in pest sensitivity.

References

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