POTATO PRODUCTION STEWARDSHIP PROGRAMME

A COLLABORATIVE INITIATIVE OF POTATOES SOUTH AFRICA, CROPLIFE SOUTH AFRICA AND THE INSECTICIDE RESISTANCE ACTION COMMITTEE

MONOGRAPH 1

Potato tuber moth insecticides, their modes of action and sensible use to prevent or delay resistance development

Principal author: Desireé van Heerden
Contributors: Dr Fienie Niederwieser, Roleen la Grange and Dr Gerhard H Verdoorn
Version 1: March 2021

Insecticides and their IRAC grouping

Insecticides are grouped according to an international system developed by IRAC, the Insecticide Resistance Action Committee. The IRAC MODE OF ACTION CLASSIFICATION, classifies each active ingredient according to a specific chemical class and a resistance group, based on the active ingredient's mode of action. The IRAC classification guides the use of different modes of action successively to prevent sensitivity shift and to **prevent or delay** the development of insecticide resistance (http/www.irac-online.org and IRAC app for smart devices). During the last few seasons higher than normal potato tuber moth (PTM) populations were reported, and the dry and hot seasons most probably contributed to these numbers. Warm winters with high day temperatures and little or no frost allow earlier than normal occurrence of the pest. Seasons with high moth "explosions" is not an unknown phenomenon and occur every few years, especially during droughts and warm periods. Insect life cycles are temperature dependent and are normally shortened by increased temperatures, which results in increased numbers of PTM generations in one season. A higher percentage of unmarketable potato tubers (> 30%) was harvested during the last three years compared to the normal expected 5 to 7 percent.

Insecticides are classified according to five different categories based on physiological functions that are affected by insecticides

Growth - Insect development is mainly controlled by juvenile hormones, by directly perturbing cuticle formation/deposition or lipid biosynthesis. Insect growth regulants are generally slow to moderately slow acting.

Midgut - Lepidopteran-specific microbes or their derived microbial toxins that are sprayed or expressed in transgenic crop varieties (not applicable to potatoes at this stage). Moderately acting.

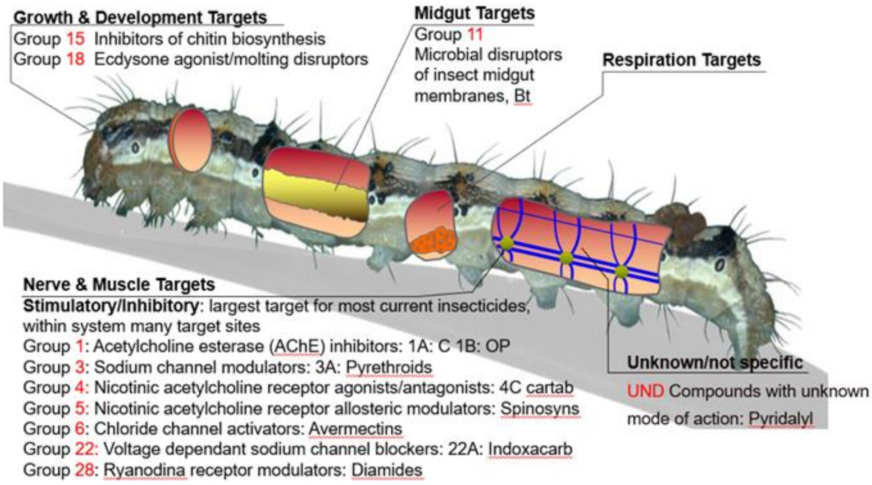
Respiration - Several insecticides interfere with mitochondrial respiration by the inhibition of electron transport and/or oxidative phosphorylation. Generally fast to moderately fast acting.

Nerve & muscle function - Most current insecticides act on nerve and muscle targets. Insecticides that act on these targets are generally fast acting.

Unclassified functions - Several insecticides are known to affect less well-described target-sites or functions, or to act non-specifically on multiple targets.

By far the largest class of insecticides affects the nerve and muscle system of insects. This collective class consists of pyrethroids, carbamates, organophosphates, avermectins, spinosyns, etc. each with a different mode of action (MoA) and specific target site; carbamates and organophosphates are both Group 1 but are categorised into sub-group 1A and sub-group 1B. To prevent sensitivity shift and the development of insecticide resistance, chemical classes of different modes of action (resistance groups) should be rotated, and consecutive insect generations should not be exposed to the same MoA continuously (Fig. 1).

Figure 1: Different target sites for controlling PTM.



Twelve different IRAC insecticide classes corresponding their equivalent resistance groups, are registered in South Africa for the control of the potato tuber moth *Phthorimaea operculella* (**Table 1**). Study the table and plan accordingly to develop a spray programme which will prevent sensitivity shift and resistance development.

Table 1: Active ingredients that are registered for the control of the potato tuber moth in potatoes.

IARC Group	Chemical class	Active ingredient	Mode of Action/Physiological functions affected
1A	Carbamate	Methomyl	Acetylcholinesterase (AChE) inhibitors Nerve action
1B	Organophosphates	Acephate, azinphos-methyl, methamidophos, methidathion, profenofos	Acetylcholinesterase (AChE) inhibitors Nerve action
3A	Pyrethroids	Alpha-cypermethrin, beta-cyfluthrin, bifenthrin, deltamethrin, esfenvalerate, gamma-cyhalothrin, lambda-cyhalothrin	Sodium channel modulators Nerve action
4A + 3A	Neonicotinoids + pyrethroids	Acetamiprid + bifenthrin	Nicotinic acetylcholine receptor (nAChR) competitive modulators Nerve action
4A + 15	Neonicotinoids + benzoylureas	Acetamiprid + novaluron	Nicotinic acetylcholine receptor (nAChR) competitive modulators & chitin synthesis inhibitors Nerve action and growth regulation
5	Spinosyns	Spinetoram, spinosad	Nicotinic acetylcholine receptor (nAChR) allosteric modulators – Site 1 Nerve action
13	Pyrroles	Chlorfenapyr	Uncouplers of oxidative phosphorylation via disruption of the proton gradient Energy metabolism
14	Nereistoxin analogue	Cartap hydrochloride	Nicotinic acetylcholine receptor (nAChR) channel blockers Nerve action
15	Benzoylureas	Diflubenzuron, lufenuron, novaluron	Inhibitors of chitin biosynthesis affecting CHS1 Growth regulation
22A	Oxadiazines	Indoxacarb	Voltage-dependent sodium channel blockers Nerve action
28	Diamides	Chlorantraniliprole, cyantraniliprole	Ryanodine receptor modulators Nerve and muscle action
28 +3A	Diamides +3A	Chlorantraniliprole + lambda-cyhalothrin	Ryanodine receptor & sodium channel modulators Nerve and muscle action

IARC Group	Chemical class	Active ingredient	Mode of Action/Physiological functions affected
UN	Pyridalyl	Pyridalyl dichloropropene derivative	Compounds of unknown or uncertain MoA
UNF	Fungus	Beauveria bassiana	Compounds of unknown or uncertain MoA
Pheromone +3A	Pheromone + pyrethroids	(E,Z)-4,7 & (E,Z,Z)-4,7,10-tridecatrienyl acetate + permethrin	Lure and sodium channel modulators Lure and nerve action

Factors that influence the performance of active ingredients

Not all the active ingredients in a specific chemical class share the same characteristics. Plant uptake can be by contact, translaminar, or systemic action while insect uptake can be through stomach or contact action. The formulation type and quality, e.g. EC, SC, WP, rain fastness, stability in sunlight, mixability and compatibility with other products, application type and method, all play a crucial role in the effectivity of an active ingredient. Choosing an active ingredient requires taking all these characteristics into account along with the plant size, level of pest infection and the pest complex present to select the best option. Be reminded that active ingredients within the same IRAC group, share the same mode of action; carbamates and organophosphates, for example are both in Group 1 and share the same mode of action. A few examples of active ingredients registered against PTM are mentioned below. **Always read the entire label to ensure that the products are applied correctly.**

Carbamates (Group 1A):

Methomyl: Contact & stomach action, efficacy greatly reduced after spray residues have dried, rapidly degrades in soil with a short half-life of (DT_{50} 4 – 8 days) at 20°C. Soil moisture and pH are important in the breakdown of methomyl. Methomyl is not compatible with alkaline products. Relatively stable in sunlight.

Organophosphates (Group 1B):

Acephate: Contact and stomach action, moderate persistence, residual activity 10 – 21 days, non-phytotoxic. Readily bio-degraded and non-persistent in soil with short half-life (DT_{50} 2 days).

Azinphos-methyl: Non-systemic, contact and stomach action. Rapidly hydrolysed in alkaline and acidic media. Half-life of several weeks under normal conditions (DT_{50} 87 days @ pH 4 and 50 days @ pH 7, only 4 days @ pH 9). Low soil mobility. Photodegrades on soil surface.

Profenofos: Non-systemic, contact and stomach action. Exhibits translaminar effect and ovicidal properties. Not compatible with sulphur, alkaline products or captab. Do not mix with metal-containing compounds or apply with nitrogen-containing foliar feeds. Short half-life in soil (DT_{50} 1 week).

Methamidophos: Systemic, contact and stomach action. Rapidly degraded in soil. Short half-life in soil (DT_{50} <2 days). Photolysis contributes to rapid degradation.

Pyrethroids (Group 3A):

Bifenthrin: Non-systemic, contact and stomach action. Not compatible with alkaline products. Long half-life in soil (DT_{50} 65 days).

Lambda-cyhalothrin: Non-systemic, contact and stomach action with repellent properties and rapid knockdown effect. Stable to light, stable in storage (> 6 months) but rapidly degraded in soil especially under dry conditions (DT_{50} 4 weeks). Strongly adsorbed to soil, does not leach.

Neonicotinoids (Group 4A):

Acetamiprid: Systemic with translaminar movement in the plant. Stomach and contact activity. High potential for bioaccumulation, mobile in soil but degrades rapidly. Low potential for leaching into groundwater. Half-life between <1 and 8.2d.

Spinosyns (Group 5):

Spinosad: Non-systemic, contact and stomach action. Short soil half-life (DT_{50} 9 – 17 days). Low pH value (< 6) of the spray mixture will decrease the residual performance. Performs best at pH 6 – 9.

Spinetoram: Non-systemic, contact and stomach action. Rapidly degrades in soil (DT_{50} 3 – 5 days).

Pyrroles (Group 13):

Chlorfenapyr**:** Limited systemic activity, mainly stomach with some contact action. Pro-insecticide (metabolized into an active insecticide after entering the host). Persistent in soil but binds very strongly to soil particles and does not leach.

Nereistoxin analogues (Group 14):

Cartap hydrochloride: Systemic with stomach and contact action. Stable in acidic conditions but hydrolyses in neutral or alkaline solution. Short soil half-life (DT_{50} 3 days).

Benzoylureas (Group 15):

Lufenuron: Insect growth regulant, non-systemic, translaminar effect with strong stomach and moderate contact activity, larvicidal, ovicidal and transovarial action, reduce egg fecundity. Stable at pH 5 – 7 and very long half-life (DT_{50} 512 days). Strong adsorption onto soil particles. Not compatible with carbamates and alkaline products.

Oxadiazines: (Group 22A):

Indoxacarb: Contact and stomach action, rapidly terminates insect feeding on crop. Moderately persistent but immobile in soil (DT_{50} 3 – 23 days).

Diamides (Group 28):

Cyantraniliprole: Systemic effect by soil uptake, with some translaminar movement, active through ingestion and contact. Ovicidal, ovi-larvicidal and adulticide activity. Low soil mobility due to high soil adsorption with moderate photodegradation and short half-life (DT_{50} 4 – 25 days). Rapidly degrades. Resistance risks seems higher than other MoAs.

Chlorantraniliprole: Stomach and contact action, weak translaminar activity. Slow soil degradation (DT_{50} 270 days). Low soil mobility due to high soil adsorption, low water solubility and slow photodegradation. Resistance risks seems higher than other MoAs.

Unclassified (UN):

Pyridalyl: Non-systemic, contact and stomach action. Moderately slow acting. Highly immobile in soil with long half-life (DT_{50} 93 – 182 days).

Effective application of insecticides to control PTM and associated good agricultural practices

Virtually no insecticide can be drenched into the soil to control PTM after senescence (maturation) and ridging; the best practice is to control them while green plant material is still available for chemical uptake and to minimise exposed tubers (**figure 3, 4 and 5**), soil cracks or soil cavities next to stems (**figure 2**), especially in shallow bearing cultivars (**figure 6**). Moths can lay eggs close to cracks and young hatching larvae can then move down the cracks to infest tubers. Make sure cracks are sealed by irrigation after ridging (**figure 7**). Potato tubers that are slightly exposed are very easy targets for larvae; field observations showed that tubers that were infested with PTM larvae are the ones very close to the soil surface with some level of exposure. It is thus strongly advisable to minimise exposed tubers to the absolute minimum.

Figure 2. Soil cracks and cavities next to potato stems

Figure 3. Tuber infested by PTM due to being exposed under leaves and not totally covered

Figures 4 and 5. Exposed tubers underneath infested leaves.

Figure 6. Cultivars bearing shallow tubers

Figure 7. Sealed ridges.

potatoes aartappels SA

IRAC Insecticide Resistance Action Committee South Africa

CropLife SOUTH AFRICA SUID-AFRIKA