Science behind the Resistance Management Strategy for the green peach aphid (*Myzus persicae*) in Australian canola

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Background information

In Australia, the green peach aphid (*Myzus persicae* - GPA) primarily attacks canola and pulse crops, as well as being a common pest in horticulture. The aphids feed by sucking sap from leaves and flower buds. When populations are large the crop's entire foliage may be covered, resulting in retarded growth of young plants. Young vegetative canola is most susceptible to GPA damage during autumn. Although they may be found in canola at later stages, GPA numbers are usually insufficient to cause significant yield loss. GPA can transmit more than 100 plant viruses, such as turnip yellows virus (TuYV) and cucumber mosaic virus (CMV).

The use of chemicals to target GPA in oilseed, pulses and vegetable crops continues to grow in Australia, placing strong selection pressure on the development of resistance in GPA. Because aphids produce offspring that are clones of the mother, resistant individuals can soon dominate a landscape if there is widespread use of the same insecticide across paddocks and farms. With resistance to multiple insecticide groups already established, growers need to understand how to minimise the further development of resistance.

To maintain the efficacy of current chemical options, growers and advisers can implement resistance management strategies that delay the development of further resistance. Chemicals within a specific chemical group usually share a common target site within the pest and thus share a common mode of action (MoA).

Table 1. Background information on the green peach aphid

Attribute	**What is known about GPA?**	**References**	**Knowledge gaps**
Economic importance to grains	• GPA has developed resistance to more insecticides than any other insect species. • Direct feeding and associated virus transmission can potentially reduce canola yield by up to 50%.	Whalon *et al.* 2008; Valenzuela & Hoffmann 2014.	Impact of direct aphid feeding damage on yield loss poorly identified and is probably underestimated (canola and pulses).
Mode of reproduction	• In Australia the majority of GPA are nearly always asexual (anholocyclic). • Populations are comprised of a mixture of holocyclic (sexual/asexual, host-alternating) and anholocyclic (asexual, non-host-alternating) clones.	Blackman 1974; Vorburger *et al.* 2003; Moran 1992.	
Life cycle (incl. # generations)	• Present all year round. GPA populations predominately peak in autumn and spring in southern grain growing areas. They have multiple generations per year. Under ideal conditions generation time is < 2 weeks. • Females give birth to live young (typically 5 instars before reaching adulthood). • In sexual clones, mating takes place on the primary host (*Prunus*), where the eggs	Van Emden *et al.* 1969; Moran 1992.	

	are laid and undergo diapause over winter (which is rare in Australia). • The optimum temperature for GPA is about 22°C, with most activity occurring during the warmer, milder months of the year. Threshold minimum and maximum temperatures for their development are approximately 5°C and 33°C respectively.		
Crop hosts	• Very broad host range. Includes oilseeds, pulses, brassicas, leafy vegetables, citrus, pome/stone fruits, cut flowers. • In grains they are known to attack maize, sorghum, canola, lupins, sunflower, faba beans, field peas, vetch & soybean. • Some plant-host preferences among GPA clones/biotypes.	Van Emden *et al.* 1969; Weber 1985; Zitoudi *et al.* 2001; Nikolakakis *et al.* 2003.	
Non-crop hosts	• There are many weeds including capeweed, wild radish, wild turnip, nightshade and other cruciferous weeds.	Van Emden *et al.* 1969; Bailey 2007.	Unclear which non-crop hosts are most important reservoirs of TuYV, and if this changes temporally and spatially.
Distribution	• Australia wide, very common across all grain growing regions as well as being a cosmopolitan species.	Bailey 2007; Bellati *et al.* 2010.	
Dispersal/moveme nt	• Aphids move by walking among leaves, tillers and from plant to plant or disperse over longer distances via the flight of winged aphids. • In winter grain crops, infestations start when winged aphids fly into crops from autumn weeds (e.g., roadside vegetation). Large infestations of GPA on seedling crops can cause leaf distortion, wilting of cotyledons, stunting of growth, premature leaf senescence and seedling death. • Aerial dispersal of winged aphids is governed by wind speed and direction; however, particular environmental conditions are required for dispersal (e.g., crowding, wind speed, rainfall, temperature, day length, light levels, humidity and crop growth stage or quality). • Crop type can affect the timing of aphid infestation within the crop. • Likely to be broad-scale movement across Australia. • Aphid populations remain relatively low during the early stages of crop growth and increase as the season progresses. • Seasonal patterns are consistent with climate and crop growth stage. • Field edges will likely act as reservoirs for aphids when there is the presence of similar host plants within field edges and the neighbouring crop, enabling the same aphid species to persist within both areas.	Vorburger *et al.* 2003; Bailey 2007; Berlainder *et al.* 2010; Parry 2013; Ward *et al.* 2020, 2021a; Barton *et al.* 2021.	Uncertainty of gene flow and long-distance dispersal capacity on a national scale (and between different regions). Landing cues and the processes that control the termination of flight. Quantification of humidity and high temperature thresholds for flight initiation.

Feeding behaviour	• Sucking pest, mostly on the underside of older plant leaves. Also found on growing tips in young plants and on developing and mature flowers. • In grains crops, GPA typically cause less direct feeding damage than other aphid species. Young vegetative canola is most susceptible to aphid damage during autumn. Although they may be found in canola at later stages, numbers are usually insufficient to cause significant yield loss through feeding. • GPA also transmit many important plant viruses, including cucumber mosaic virus, bean yellow mosaic virus and turnip yellows virus (TuYV). • The three TuYV variants in Australia (P5-I, P5-II, and P5-III) infect different crop types, with GPA able to transmit all three types. • Secretion of honeydew can cause secondary fungal growth (i.e., sooty molds), which inhibits photosynthesis and can decrease plant growth. When deposited on fruit, honeydew and sooty mold greatly reduces the marketability of horticulture produce.	Van Emden *et al.* 1969; Congdon *et al.* 2023.	Predicting TuYV risk on a local and/or regional scale ahead of the growing season remains difficult
Chemical controls	• Chemicals remain key to control within grains and as well as other industries. • There are approximately 1700 insecticide products registered in Australia, but these are mostly from 4 chemical groups – synthetic pyrethroids, neonicotinoids, carbamates and organophosphates. • Newer chemistries have been registered against GPA in Australian grain crops in recent years (e.g., sulfoxaflor, flonicamid and afidopyropen), however these are more expensive than older chemistries and used less. • Lethal effects of chemical controls on beneficial organisms vary across invertebrate groups and species.	Umina *et al.* 2014a, 2014b; Umina *et al.* 2019; Knapp *et al.* 2023; APVMA 2023.	Sub-lethal effects of chemicals on beneficial organisms.
Biological control options	• There are many effective natural enemies of aphids. • Hoverfly larvae, lacewings, ladybird beetles and damsel bugs are known predators that can suppress populations. • Field aphid mummy counts alone do not provide a clear representation of parasitism within canola fields. • As crop growth stage progresses, the incidence of aphid mummies observed in the field typically increases. • Aphid parasitoid wasps are more commonly found in the later growth stages of canola, particularly around podding/senescing, with diversity increasing in later crop growth stages.	Volkl *et al.* 2007; Barton *et al.* 2021; Ward *et al.* 2021a, 2021b, 2022; P. Mangano (Pers. Comm.)	Understanding of levels of natural enemies required to control GPA. Fungicides have toxic effects but these have yet to be quantified for the major natural enemy species

	• *Diaeretiella rapae* (M'Intosh) is the most common species of aphid parasitoid wasp in canola crops. • Inter-field variation, crop type and aphid species can all affect aphid parasitoid wasp species composition. • Warmer temperatures are likely to be advantageous for aphid parasitoid wasps, allowing females to parasitise more aphids, thus over-riding any positive impacts of rising temperature on aphid populations. • Entomopathogenic fungal diseases are also known to be important in causing rapid colony decline in cropping situations where large aphid populations exist.		

Table 2. Products with label claims for green peach aphid (and general aphid) control in Australia

IRAC MoA group	Insecticide category	Example trade name	Active ingredient	Registered crops for GPA	Registered crops for aphids (general only)
Group 1A	Carbamates	Ezycrop, Lannate -L, Electra 225, Imtrade activist 900 Veriphy	methomyl	Nectarine, peach, stone fruit	-
Group 1A	Carbamates	Aphidex 800, Conquest Pirimidex WG, Titan Atlas 500 WG	pirimicarb	Almond, beetroot, broccoli, brussels sprouts, cabbage, **canola**, cauliflower, celery, **chickpea**, Chinese broccoli, Chinese cabbage, cotton, green mustard, **lentil, lupin,** mustard, radish, rutabaga greens, stone fruit, swede, turnip, turnip greens, kale, blackberry, oilseed mustard, spring onion, sweet potato	Capsicum or pepper, chilli, eggplant, endive, fruiting vegetable, garden cress, leek, lettuce, okra, pea, shallot, spinach, tomato, watercress or nasturtium, asparagus, cucurbit, duboisia or corkwood, globe artichoke, horned melon, lima bean, ornamental, pepino, strawberry, blueberry, broad bean, nursery stock, spring onion, sweet potato, citrus, bean
Group 1B	Organophosphates	Strike-out 500 EC, Chemicide 500	chlorpyrifos	Tomato, trellis tomato, cucurbit, fruiting vegetable	-
Group 1B	Organophosphates	APS Chlorpyrifos 500 EC	chlorpyrifos / liquid hydrocarbon	Tomato	-
Group 1B	Organophosphates	Farmoz Diazol 800, Accensi Diazinon 800	diazinon	Broccoli, Brussels sprouts, cabbage, cauliflower, kale, kohlrabi, stone fruit	Ornamental nursery plant, nursery crop
Group 1B	Organophosphates	Danadim, Cropro Stalk	dimethoate	Adzuki bean, borlotti bean, **chickpea, cowpea, lupin, mungbean, navy bean, pigeon pea**	Adzuki bean, asparagus, bean, beetroot, bilberry, blackberry, blueberry, borlotti bean, capsicum, **chickpea**, citrus fruit or tree, cotton, **cowpea,** field bean**, field pea, grain legume,** lemon, lime, **lupin,** mandarin, melon, **mungbean, navy bean**, onion, orange, ornamental-flower or shrub, ornamental farm,

					ornamentals, pea, peanut, **pigeon pea,** potato, protea, raspberry, rhubarb, **sorghum,** sweet potato, tomato-field grown, tomato for processing, turnip, wildlflowers, zucchini
Group 1B	Organophosphates	Fyfanon 1000 EC, Hy-mal	malathion	Stone fruit	Bean, cabbage, carrot, cauliflower, celery, cucurbit, flower, lettuce, ornamental, ornamental-flower or shrub, protea, shrub, tomato, wildflowers
Group 1B	Organophosphates	Folimat 800, Chemag sentinel 800	omethoate	**Lupin**	Callistemon, carnation, C*hrysanthemum* or *Tanacetum,* citrus, citrus fruit or tree, cotton, *Eucalyptus* spp., geranium or pelargonium, grevillea, myrtle, tea tree or paperbark, potato, rose, wattles-*Acacia* species
Group 1B/3A	Organophosphates / Pyrethroids	Imtrade Outperform 630 EC, Pyrinex Super	chlorpyrifos / bifenthrin	Tomato-field grown	-
Group 3A	Pyrethroids	Ambush EC, Axe, Cropro Pounce	permethrin	Broccoli, brussels sprouts, cabbage, cauliflower, rhubarb	**-**
Group 3A	Pyrethroids	Richgro Beat-a-bug Naturally Based	piperonyl butoxide / chilli / garlic extract / pyrethrins	Fruit crop or tree, glasshouse or greenhouse, grapevine, nursery crop, ornamental, ornamental cut flower, rose, tree, vegetable	-
Group 3A	Pyrethroids	Amgrow Pyrethrum	piperonyl butoxide / pyrethrins	Apricot, cabbage, cherry, cucumber, flower, lettuce, peach, rose, strawberry, tomato	-
Group 3A	Pyrethroids	Mavrik RTU, Mavrik 7.5	tau-fluvalinate	Tomato	Ornamental, ornamental -flower or shrub, ornamental flowering annual, ornamental flowering perenials, rose,

					shrub
Group 3A	Pyrethroids	Weed force Dart 100SC	bifenthrin	**-**	Ornamental
Group 3A	Pyrethroids	Yates Advanced	betacyfluthrin	**-**	Broccoli, brussels sprouts, cabbage, cauliflower, ornamentals-general-garden, tomato
Group 3A/4A	Pyrethroids / Neonicotinoids	Cruiser Opti, Colam	lambda-cyhalothrin / thiamethoxam	**Canola**	-
Group 4A	Neonicotinoids	Intruder, Supreme 225 SL, Echem Acetam 225, Keytaprid 200	acetamiprid	Potato	-
Group 4A	Neonicotinoids	Conquest Sultan 225	acetamiprid / N-methylpyrrolidone / dimethyl sulfoxide	Potato	-
Group 4A	Neonicotinoids	Sumitomo Samurai Systemic	clothianidin	Nectarine, peach	-
Group 4A	Neonicotinoids	Confidor 200 SC, Nufarm Nuprid 350, Submarino 600	imidacloprid	Apricot, broccoli, brussels sprouts, cabbage, capsicum or pepper, cauliflower, cucurbit, duboisia or corkwood, eggplant, kohlrabi, melon, nectarine, peach, plum, potato, stone fruit, tomato, zucchini	**Canola**, clover pasture, cotton, forage brassicae, forage crop, **lupin**, non-bearing citrus tree, ornamental, ornamental citrus, ornamental plant, ornamental tree, pasture-seed, plants, rose, shrub
Group 4A	Neonicotinoids	Marvel 480 SC, Calypso 480 SC	thiacloprid	Stone fruit	Camellia or tea, maybush, rose
Group 4A	Neonicotinoids	Actara, Genfarm thiamethoxam 350	thiamethoxam	Tomato, tomato (glass house), **canola, barley, wheat**	-
Group 4A/15	Neonicotinoids / Benzoylureas	Cormoran	acetamiprid / novaluron	Stone fruit	-
Group 4C	Sulfoxaflor	Transform Isoclast, Expedite Full	sulfoxaflor	Adzuki bean, almond, **barley**, brassica – Asian, brassica vegetables, broom millet, cane berries, **canola,** capsicum or pepper, cashew, chestnut, chilli,	Adzuki bean, almond, **barley**, brassica vegetables, broom millet, **canola**, cashew, chestnut, forage brassicae, hazelnut, **lucerne**, **mungbean, navy**

				cotton, cucumber, cucurbit, eggplant, forage brassicae, fruiting vegetable, hazelnut, lettuce, melon, **mungbean, navy bean,** okra, pecan, pistachio, pseudocereal with husk, pseudocereal without husk, pumpkin, root vegetable, silver beet, squash, stone fruit, strawberry, sweet corn, tomato, walnut , **wheat**	**bean**, nursery stock-non-food bearing, nursery stock, pecan, pistachio, pseudocereal with husk, pseudocereal without husk, walnut, **wheat**
Group 4D	Butenolides	Sivanto Prime 200 SL	flupyradifurone	Bush tomato, chilli, cucurbit, eggplant, green bean, *Solanum capiscastrum*, sweet potato	-
Group 9B	Pymetrozine	Chess, Endgame	pymetrozine	Broccoli, brussels sprouts, cabbage, cauliflower, chard, cucurbit, green mustard, kale, potato, rocket, silver beet, stone fruit, brassica vegetables, almond, beetroot, brassica-Asian, capsicum or pepper, Chinese cabbage, cress, cut flower, eggplant, endive, lettuce, nursery stock in pots or field, pistachio, spinach, tomato	Celery
Group 9D	Afidopyropen	Versys	afidopyropen	Brassica vegetables, **canola**, carrot, celery, cotton, cucurbit, fruiting vegetables excluding cucurbits, ginger, globe artichoke, leafy and brassica leafy vegetables, ornamentals-general-garden, parsley, potato, rhubarb, strawberry, sweet corn, sweet potato	**Barley, wheat**
Group 21A	METI acaricides and insecticides	Efficon	dimpropyridaz	Brassica vegetables, leafy and brassica leafy vegetables	-
Group 23	Tetronic and Tetramic acid derivatives	Movento 240 SC, Speramet, Ozcrop 240 SC, Sunjoy 240	spirotetramat	Bean, brassica leafy vegetables, brassica vegetables, broccoli, brussels sprouts, cabbage, capsicum or pepper,	**-**

				cauliflower, celery, chicory, cucurbit, eggplant, endive, herb, kohlrabi, leafy vegetable, lettuce, pea, peppers, potato, snow pea, sugar snap pea, tomato, tomato-field grown, tomatoes (protected)	
Group 28 [1]	Diamides	Benevia	cyantraniliprole	Capsicum or pepper, eggplant, fruiting vegetable, potato, strawberry, tomato, tomato-field grown, trellis tomato	
Group 28/4A	Diamides / Neonicotinoids	Durivo, Voliam Flexi	chlorantraniliprole / thiamethoxam	Cotton, brassica vegetables, chard, Chinese broccoli, Chinese cabbage, fruiting vegetable, garden cress, kale, leafy vegetable, rocket	-
Group 28/12A	Diamides / Diafenthiuron	Minecto Forte	cyantraniliprole / diafenthiuron	Cucurbits-field, fruiting vegetables excluding cucurbits	-
Group 29	Flonicamid	Mainman Broadacre 500 WG, Aria 500	flonicamid	**Canola,** cucumber, cucurbit, potato, pumpkin, rockmelon or cantaloup, squash, strawberries- open field and protected cropping, watermelon, zucchini	Nursery stock-non-food bearing
Not member of a Group		eFUME, Vaporfaze Emate	ethyl formate	Sweet corn	Lettuce
Not member of a Group		Canopy, Parasol, Parachute nC27, D-C-Maxx nC24, Conquest CropCover	paraffinic oil, paraffinic mineral oil, paraffin oil	**Lupins,** adzuki bean**, chickpea, faba bean, field pea, lentil,** linola, **linseed crop,** lucerne**, mungbean, navy bean, pigeon pea, safflowers, soybean, sunflower, vetch, canola**	Almond, asparagus, azalea, bean, bed-plant-general, beet, begonia, camellia or tea, capsicum or pepper, christmas tree, chrysanthemum or tanacetum, conifer, corn, crown of thorns, cucurbit, deciduous shrub or tree, diffenbachia, dracaena, easter lilly, fern gardenia, field corn, flower and foliage plant, gardenia, hibiscus, jade plant, nectarine, palm, peach,

					pecan, philodendron, plum, poinsettia, prune, radish, reiger begonia, rose, shrub, tree, squash, strawberry, sugar beet, sweet corn, tomato, woody ornamental, zahnia
Not member of a Group		Velifer Biological, Broadband OD	*Beauveria bassiana*	Protected vegetables and ornamentals	-
Not member of a Group		Abrade abrasive barrier	amorphous silica	Tomato	-
Not member of a Group		AzaMax Xtra	azadirachtin A & B	-	Floriculture crops, nursery stock-non-food bearing, ornamental crops
Source: APVMA-Public Chemical Registration Information System Search (PubCRIS), Australian Pesticides & Veterinary Medicines Authority; accessed October 2023. Note: crops in **bold** are GRDC levy crops. [1] Exirel has recently been registered in canola and has suppression claims against cabbage aphids and turnip aphids.					

Industry chemical use and secondary chemical exposure:
The use (and motivations for use) of insecticides to control GPA varies from region-to-region. Industry information comes from Umina *et al.* (2019), phone survey results (2014), one-on-one conversations with advisors, and farm spray records obtained for ~100 paddocks nationally between 2014 and 2022 as part of a GRDC-funded national insecticide resistance surveillance program. GPA is regarded as a common pest, typically occurring every year, or in some locations, every 2-3 years. Canola was identified as being more vulnerable to GPA attack than pulse crops. The majority of canola crops are reportedly sown with neonicotinoid-treated seed, while a smaller proportion of pulse crops are sown with neonicotinoid-treated seed. Foliar insecticides are sprayed in about 80% (on average) of canola paddocks annually, although many of these applications do not specifically target GPA. Based on phone survey results (now outdated), when insecticides are being applied for GPA, approximately one-third of sprays are used prophylactically. With the exception of seed treatments, Group 3A, 1A and 1B products are largely used to combat GPA in grain crops nationally, with an increasing use of Group 4C since the registration of sulfloxaflor in 2013. More recently, Group 9D and 29 have been registered to control GPA in canola crops, but their use in canola remains relatively minimal to date.

In horticultural crops the prevalence and recognized pest importance of GPA is greater. Application rates of insecticides are typically much higher, particularly in capsicums, eggplants, lettuce, cabbage, cauliflowers, broccoli, tomatoes, and potatoes. It is not uncommon for some crops to be sprayed with 8-10 separate applications of insecticides from the vegetable seedling stage through to harvest (often with 2-4 plantings in a single paddock per year). There is a more extensive range of chemical groups registered for use in vegetable crops. The choice of products used to combat GPA varies considerably between regions and crop type. Group 1A, 1B, 3A, 4A, 4C, 9B, 9D, 23, 28 and 29 products are commonly used in vegetable (and other horticultural) crops to combat GPA nationally.

Table 3. Current status of insecticide resistance in the green peach aphid within Australia

Attribute	What is known?	References	Knowledge gaps
Resistance status	• Confirmed and widespread resistance to pyrethroids, neonicotinoids, organophosphates, carbamates, and increasing cases of resistance to sulfoxaflor. • Resistance to spirotetramat detected in Queensland. • Baseline sensitivity tests indicate no resistance to afidopyropen, flonicamid, or cyantraniliprole in Australia.	Umina *et al.* 2014a, 2019, 2022; Edwards *et al.* 2008; de Little *et al.* 2017; Thia *et al.* 2021; Arthur *et al.* 2022; de Little & Umina 2017; Kirkland *et al.* 2023; S. Ward (unpubl).	Extent of resistance status unknown in Northern Territory and Tasmania. Limited surveillance for R81T mutation (which confers high-level resistance to neonicotinoids).
Mechanisms of resistance & cross-resistance	• Synthetic pyrethroids: parasodium channel (mutations at kdr, superkdr loci), some cross-resistance from E4/FE4, M918L mutation encoded by the codon ctg (although the latter is not found in Australia). • Organophosphates: amplified esterases (E4, FE4). • Carbamates: modified acetylcholinesterase (MACE), some cross-resistance from E4, FE4. • Neonicotinoids: amplified P450 (CYP6CY3), modified AChR receptor, point mutation (R81T) (although the latter is not found in Australia). • Spirotetramat: A2226V mutation. • Sulfoxaflor: overexpression of a P450 (CYP380C40) and UDP-glucuronosyltransferase (UGT344P2). • Cross resistance detected between flupradifurone and acetamiprid in Greece.	Martinez-Torres *et al.* 1999; Field & Devonshire 1998; Devonshire *et al.* 1998; Moores *et al.* 1994; Puinean *et al.* 2010; Bass *et al.* 2011, 2014, 2015; de Little *et al.* 2017; Thia *et al.* 2021; Umina *et al.* 2022; Singh *et al.* 2021; Panini *et al.* 2013, 2015; Papadimitriou *et al.* 2021; Pym *et al.* 2022.	FE4 not known in Australia (associated with sexuality). Molecular diagnostics not available for several resistance mechanisms (e.g. sulfoxaflor)
Known fitness costs	• Synthetic pyrethroids: reduced motility/responsiveness to alarm pheromone, parasitoid avoidance at low temperatures (initially attributed to E4/FE4), reduced response to (E)-β-farnesene. • Organophosphates: slower migration from deteriorating leaves, poorer overwintering, reduced response to (E)-β-farnesene, reduced reproductive fitness. • Carbamates: reduced response to alarm pheromone, parasitoid avoidance, reduced reproductive fitness.	Furk *et al.* 1990; Foster *et al.* 1996, 1997, 1999, 2000, 2003, 2007, 2010, 2011; Bass *et al.* 2014.	Fitness costs never evaluated in Australia.
Genetic basis for resistance	• Synthetic pyrethroids: kdr and Super-kdr are co-dominant • Organophosphates: E4 and FE4 co-dominant and induced	Field *et al.* 1999; Field 2000; Criniti *et al.* 2008; Puinean *et al.* 2010;	Super-kdr, MACE and A2226V only found as heterozygotes in field populations in Australia;

	• Carbamates: MACE thought to be co-dominant • Neonicotinoids: P450 co-dominant, modified AChR thought to be recessive (only found homozygous) • Spirotetramat: A2226V is inherited as a dominant trait (heterozygous individuals are resistant).	Umina *et al.* 2022.	unclear if homozygotes are present
Impact of GPA control on natural enemies	• Populations of natural enemy species can be preserved through the use of 'softer' chemicals. The **Beneficials chemical toxicity table** helps growers make informed choices about the insecticides they can use. • Aphid parasitoids are sensitive to most insecticides and miticides used in grain crops, and these impacts vary between species. • NPV, *Bt,* chlorantraniliprole, afidopyropen and flonicamid are relatively 'soft' against many important natural enemies of crop aphids, including hoverflies, lacewings, predatory bugs, rove beetles, aphid parasitoids and ladybird beetles.	Overton *et al.* 2023; Knapp *et al.* 2023.	Sub-lethal impacts are still poorly understood. Little appreciation about appropriating spray timings that will effectively control GPA but limit impact to non-targets.

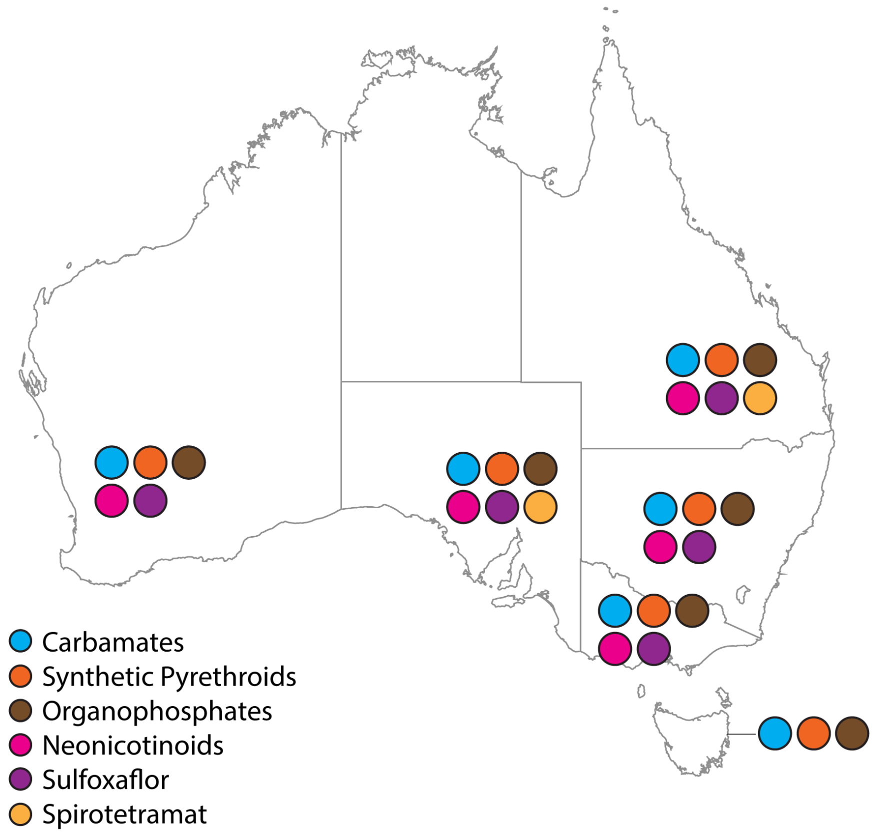

Figure 1. Insecticide resistance in green peach aphid populations in Australia (Source: Cesar Australia, June 2024)

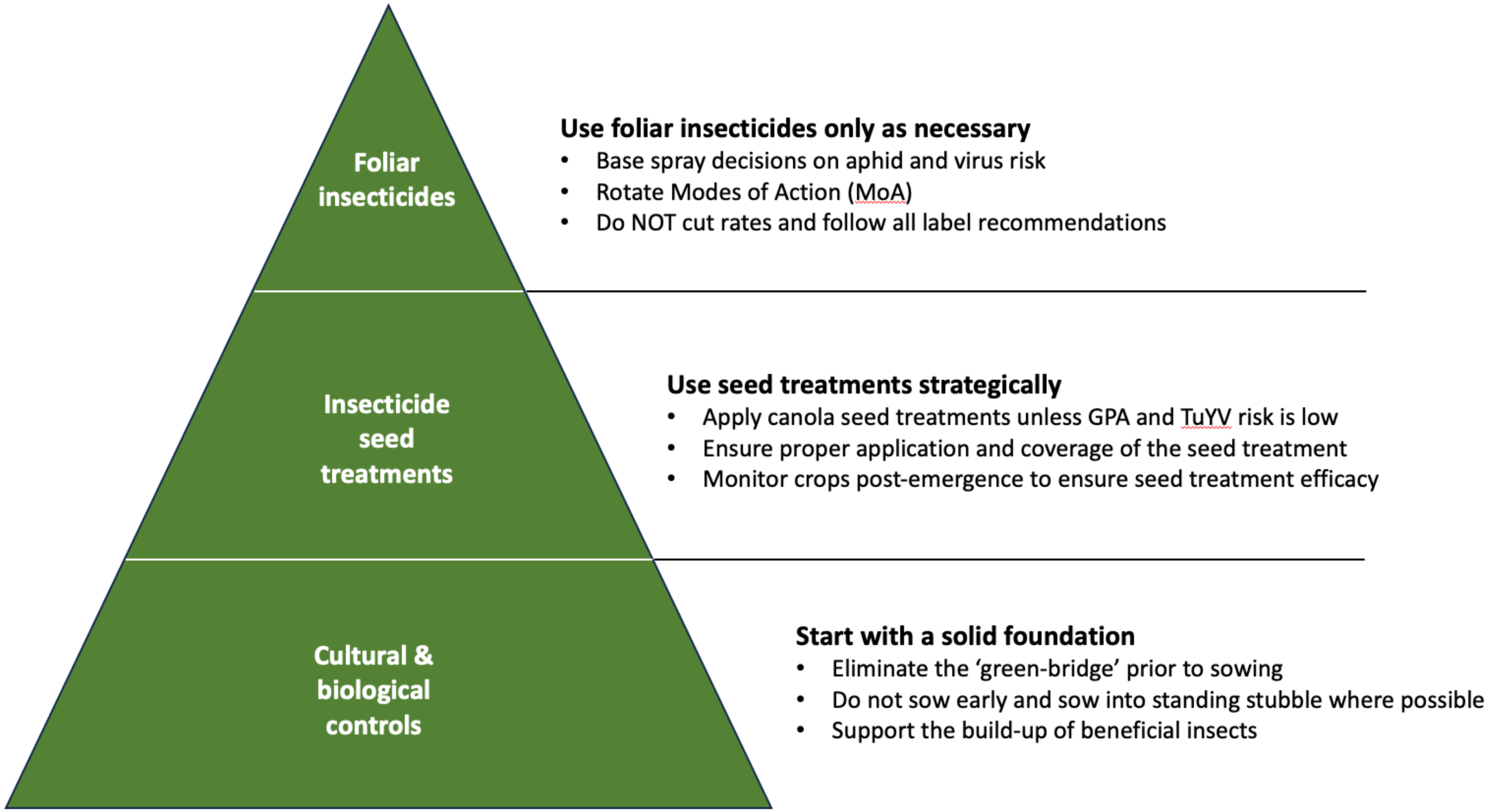

Figure 2. Infographic of key management recommendations for the green peach aphid in canola

Table 4. Chemical windowing strategy for the green peach aphid in canola

Canola windows	Insecticide recommendations	Rationale	Other considerations	Further notes	Handy tips
Pre-season	Nil - Do not apply insecticides	There is no economic benefit of controlling GPA prior to sowing. Unnecessary sprays will select for further resistance	Cultural control – eliminate green bridge a minimum of 14 days before sowing. Cultural control –avoid sowing into paddocks with bare ground; retain stubble where possible.	GPA persist between growing seasons on summer and autumn weeds; removing the 'green bridge' will reduce aphid population sizes at sowing. Aphids are more attracted to a light open stand with bare earth visible between crop rows.	GPA and TuYV host plants include radish, capeweed, volunteer canola, mallow, and turnipweed.
Sowing	A single seed treatment application of: Imidacloprid (4A) or Lambda cyhalothrin + thiamethoxam (3A + 4A) or Clothianidin + imidacloprid (4A + 4A) or Thiamethoxam (4A)	Use a seed treatment when GPA and/or virus risk is Moderate or High to protect canola from feeding damage and early TuYV infection	At 2 weeks after sowing and onwards, monitor crops for the presence of GPA, even when a seed treatment has been applied.	Most GPA in Australia possess high-level resistance to SPs and low-level resistance to neonicotinoids - these aphids are able to colonise very young canola seedings, even when a seed treatment has been applied	When monitoring the crop for GPA, inspect the undersides of plant leaves as aphid distribution can be patchy. To get a representative sample, monitor at least 5 sampling points across the paddock, examining at least 20 plants at each point. Ensure correct ID of aphids; proper ID can save growers money, and prevent unnecessary insecticide applications

Post emergence to stem elongation	A single application of: Flonicamid (29) or Afidopyropen (9D) or Sulfoxaflor (4C) or Pirimicarb (1A) If multiple sprays are required, ROTATE between these four products.	Rotating between different chemical groups will delay the evolution of resistance. Do not apply SPs or OPs to control GPA due to widespread resistance. Resistance to carbamates (e.g. pirimicarb) is commonplace in many areas; growers should test the response of GPA in a small area first to determine likely efficacy. There is low-level resistance to suloxaflor in some GPA in Australia; always use the high label rate when targeting GPA in canola crops where spray coverage may be compromised.	Monitoring is required to determine if chemical intervention is needed. There is no resistance in Australian GPA to flonicamid or afidopyropen & these products are soft on beneficial insects.	Most GPA in Australia possess resistance to SPs and OPs. Spraying these chemicals to control GPA may result in poor control and wasted money.	Monitoring should focus on both the aphids and virus. TuYV infection can express symptoms varying from stunted plants with purpling of lower leaves beginning at the margins to a reduction in the number of pods and seeds per pod. Diagnosing TuYV symptoms is not always a reliable method of assessing infection and should be coupled with leaf testing in a diagnostic laboratory.

Post stem-elongation	Insecticides are rarely warranted for GPA control. If sprays are needed, apply: Paraffinic oil (suppression only) or Flonicamid (29) or Afidopyropen (9D) or Sulfoxaflor (4C) or Pirimicarb (1A) Note: Do not use a chemical if it has already been sprayed earlier in the season	In high or medium rainfall areas, GPA are rarely in sufficient numbers to cause significant yield loss through feeding and TuYV transmission is unlikely to impact crop yield or quality post stem-elongation.	In low rainfall areas or under drought conditions, yield losses can result from the combination of moisture stress and aphid damage and/or TuYV. In most years, beneficial insects will suppress GPA populations in spring if they have not been killed by chemical sprays earlier in the season.	TuYV transmission post-stem elongation is unlikely to cause significant reductions in crop yield and quality.	Refer to the Beneficials Chemical Toxicity Table to determine the likely impacts of insecticides on GPA beneficial insects. The most important beneficial insects of GPA in Australian canola include aphid parasitic wasps, ladybird beetles and lacewings. Naturally-occurring entomopathogenic fungi also provide substantial biocontrol of GPA.

Table 5. Chemical considerations for the green peach aphid in canola

Insecticide	IRAC MoA group	Considerations
Pirimicarb (e.g. Pirimor WG)	1A	Carbamate (e.g. pirimicarb) resistance is commonplace in many areas. Growers should test the response of GPA in a small area first. Best control is achieved when applied between 20-30°C. Use highest label rate if temperatures are below 20°C.
Organophosphates (OPs)	1B	Not registered to control GPA in canola. OP resistance is commonplace. Toxic to many beneficial insects of GPA, including ladybird beetles, parasitoid wasps, hoverflies and lacewings.
Synthetic pyrethroids (SPs)	3A	Not registered to control GPA in canola. SP resistance is commonplace. Toxic to many beneficial insects of GPA, including ladybird beetles, parasitoid wasps, hoverflies and lacewings.
Neonicotinoids (e.g. Gaucho)	4A	Registered as seed treatments Only. Low-level resistance commonplace in GPA; the efficacy of canola seed treatments is likely to be reduced, particularly the length of protection.
Sulfoxaflor (Transform®)	4C	Low-level resistance in some GPA in Australia. Always use the high label rate when targeting GPA in canola crops where spray coverage may be compromised.
Afidopyropen (Versys®)	9D	No resistance in Australian GPA. Stops aphid feeding & virus transmission within a few minutes of exposure and causes mortality after 2–5 days.
Flonicamid (Mainman®)	29	No resistance in Australian GPA. Acts via direct contact and ingestion, with cessation of feeding & virus transmission within 1 hour of exposure and mortality after 2–5 days.
Paraffinic oil (e.g. Parachute®)	N/A*	Provides aphid suppression only. Best used when targeting low GPA populations and seeking to prevent the build-up to damaging levels.

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