A review of external influences on the availability of neonicotinoid and other pesticides to the Australian Nursery Industry

Report prepared by:

AgAware Consulting Pty Ltd

30 March 2019

FINAL REPORT

Project leaders names:

Mr Peter Dal Santo
AgAware Consulting P/L
21 Rosella Avenue
Strathfieldsaye Victoria 3551
Ph: 03 5439 5916
Fax: 03 5439 3391
Email: pds@agaware.com.au

Date of report:

Project initiation – 7 September 2018
Draft report - 22 February 2019
Final report – 30 March 2019

Table of Contents

1. Purpose and background of this report 5
2. A brief history neonicotinoids 6
    - Imidacloprid 6
    - Acetamiprid 7
    - Dinotefuran 7
    - Thiacloprid 7
    - Thiamethoxam 7
    - Clothianidin 8
4. Neonicotinoid toxicity to bees 10
5. Current neonicotinoid restrictions 12
    - European Union 12
    - United States 12
    - Canadian 12
    - Australian 12
6. Current neonicotinoid uses for the Australian production nursery industry 13
7. Current neonicotinoid alternatives for the Australian production nursery industry 14
8. Agchem company comments on neonicotinoid insecticides 20
    - Adama 20
    - AgNova 20
    - BASF 20
    - Bayer 20
    - Corteva 20
    - FMC 21
    - Nufarm 21
    - Sipcam 21
    - Sumitomo 21
    - Syngenta 21
    - UPL 22
9. Overseas agencies comments on neonicotinoid insecticides 23
    - Asia 23
    - Canada 23
    - European Union - Commodity Expert Group for Ornamentals 23
    - New Zealand 24
    - US Department of Agriculture and Environment Protection Authority 24

US IR-4 Program....24
10. Impact on production nurseries to neonicotinoid removal / restrictions....26
11. Non-neonicotinoid insecticides targeted by the production nursery industry....27
12. Possible future neonicotinoid alternatives for the production nursery industry....28
13. Other restrictions on production nursery industry insecticides....29
14. Alternative pest management strategies to pesticides for the production nursery industry....30
15. Proposed future restrictions on pesticides for the production nursery industry....31
16. Recommendations for the production nursery industry....33
Beauveria bassiana....33
DC0143....33
Flupyradifurone....33
NUL3073....33
NUL3145....33
NUL3196....33
Pyrifluquinazon....33
Glossary....34
References....35
Personal communications....37
Disclaimer....38

1. Purpose and background of this report

Production nurseries have access to a suite of pesticides (fungicides, insecticides, herbicides, nematicides and others) to manage the diverse range of plant pests (diseases, insects, weeds, nematodes and other symptoms) that can impact on the extensive range of plants they produce.

The majority of pesticides available to production nurseries are via the Australian Pesticides and Veterinary Medicines Authority (APVMA) minor-use permit (MUP) program. MUP approves the use of a pesticide on a crop which is not covered by the product label.

Recently, a major Australian retailer has banned the use of a specific class of insecticides from use on any plants sold through their outlets. The specific insecticides are the neonicotinoid insecticides which are currently available to production nurseries for the control of a wide range of important insect pests. The Australian retailer made the decision they will no longer accept plants treated with neonicotinoid insecticides from 2019 due to the global concerns with bee population impact.

Neonicotinoids have been an important part of the production nursery industry's insect pest management strategy for the past two decades. This ban will severely impact the pest management strategies of production nurseries and could have subsequent knock on effects from other retailers.

The aim of this report is to provide information to production nurseries that ensures production nurseries have access to non-neonicotinoid replacement pesticides across Australia in an approved manner.

This report will review the current restrictions surrounding neonicotinoid insecticides and identify alternative insecticides that are available and could be made available to production nurseries via registration or MUP.

2. A brief history neonicotinoids

Neonicotinoids are a unique group of synthetic pesticides with six different actives registered in Australia: acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid and thiamethoxam [1].

All neonicotinoids control insects by acting on the insect's central nervous system to block the nicotinic acetylcholine receptors. This prevents impulses from transmitting between nerves and leads to the paralysis and eventual death of the insect. Neonicotinoid insecticides works by contact with and via the stomach (ingestion of plant material) of the insect.

All neonicotinoid insecticides are highly systemic within plants moving up through the xylem within the treated plant. Treated plants transport the compound throughout the plant (leaves, flowers [pollen and nectar], roots and stems).

Neonicotinoid insecticides are effective against many important agricultural pests; including sucking insects (aphids, leafhoppers, mealy bugs, mirids, psyllids, scale, thrips, whitefly), some chewing insects, (beetles, borers, bugs, canegrubs, weevils), some soil insects (fungus gnat, scarabs) and ants. Neonicotinoid insecticides can be applied as a foliar treatment, soil drench or seed treatment [2].

Although neonicotinoids breakdown rapidly in water and light (half-life of ~39 days), if incorporated into the soil profile, the half-life can be up to 3 years [3].

CropLife Australia classifies the neonicotinoids as all belonging to the Group 4A insecticide chemical group [4].

Several overseas countries began imposing restrictions on some of the neonicotinoids from as early as 2008 due to environmental concerns. The first was Germany's restriction on clothianidin due to bee kills in corn [5].

In 2013, the European Union and a few non-EU countries restricted the use of certain neonicotinoids (clothianidin, imidacloprid and thiamethoxam) for 2 years for all seed treatment uses [6]. This was then extended. The EU are phasing out clothianidin, imidacloprid and thiamethoxam for all outdoor uses from 2019 [7]. Several states in the USA have also restricted the use of neonicotinoids out of concern for pollinators and bees [5]. As at the time of preparing this report, there are no restrictions placed on the use of neonicotinoids by APVMA in Australia [1].

Imidacloprid

Imidacloprid was the first of the neonicotinoid compounds discovered and patented. This was by Bayer A. G. in 1988 [8]. The first registered use of imidacloprid, under the trade name Confidor 200 SC Insecticide (200 g/L imidacloprid), was for use in turf and ornamentals in the USA in 1994 [9]. The first registration in Europe was in 1996.

The first neonicotinoid product registered in Australia was imidacloprid in July 1998 by Bayer Cropscience Pty Ltd, under the trade name Confidor 200 SC Insecticide (200 g/L imidacloprid) [1].

Imidacloprid was seen as a replacement for the older insecticides belonging to the carbamate, organophosphate and pyrethroid groups [10]. By the late 1990's, imidacloprid was the most used insecticide in the world.

Imidacloprid's first uses in Australia were in several horticultural crops for the control of various aphid species. It's uses have now extended to multiple horticultural and field crops, forage crops, forestry, ornamentals, pastures, trees, turf and around building/structures for the control of sucking, chewing, boring and soil insect pests [1].

Acetamiprid

Acetamiprid was the second of the neonicotinoid compounds discovered and patented. This was by Nippon Soda Japan in 1993 [8].

The first registered use of acetamiprid in Australia was under the trade name Supreme 225 SL Insecticide (225 g/L acetamiprid) for use in cotton and potatoes in 2003 by Nippon Soda. Acetamiprid is now registered in cotton, ornamentals and potatoes for the control of aphids, bugs, fungus gnats, leafhoppers, mirids, psyllids, scale, thrips and whitefly [1].

Dinotefuran

Dinotefuran was the third of the neonicotinoid compounds discovered and patented. This was by Mitsui Chemical Japan in 1995 [8].

The first registered use of dinotefuran in Australia was under the trade name Starkle 200 SG Insecticide (200 g/kg dinotefuran) for use in cotton in 2015 by AgNova Technologies. Dinotefuran is now registered in cotton and mung beans for the control of various bugs and whitefly [1].

Thiacloprid

Thiacloprid was the equal fourth of the neonicotinoid compounds discovered and patented. This was by Bayer A. G. in 1996 [8].

The first registered use of thiacloprid in Australia was under the trade name Calypso 480 SC Insecticide (480 g/L thiacloprid) for use in pome fruit and stone fruit in 2001 by Bayer. Thiacloprid is now registered in pome fruit, stone fruit and certain ornamentals for the control of aphids, various bugs and moth larvae [1].

Thiamethoxam

Thiamethoxam was the equal fourth of the neonicotinoid compounds discovered and patented. This was by Novartis in 1996 [8].

The first registered use of thiamethoxam in Australia was under the trade name Actara Insecticide (250 g/kg thiamethoxam) for use in cotton in 2003 by Novartis (now Syngenta). Thiamethoxam is now registered in citrus, cotton, certain field crops, tomatoes and turf for the control of aphids, beetles, thrips, whitefly and wireworms. Thiamethoxam is also sold in combination with multiple other insecticides and/or fungicides for use in many horticultural and field crops [1].

Clothianidin

Clothianidin was the sixth of the neonicotinoid compounds discovered and patented. This was by Takeda Japan in 1997 [8].

The first registered use of clothianidin in Australia was under the trade name Shield Systemic Insecticide (200 g/L clothianidin) and Samurai Systemic Insecticide (500 g/kg clothianidin) for use in citrus, pome fruit, stone fruit and grapes in 2007 by Sumitomo Chemicals. Clothianidin is now registered in bananas, citrus, cotton, pome fruit, grapes, stone fruit and turf for the control of aphids, beetles, canegrubs, fruit fly, jassids, mealy bugs, moth larvae, psyllids, scale and weevils [1].

3. Neonicotinoid restrictions

Bunnings Warehouse, a major retailer of hardware, homeware and gardening supplies in Australia, notified industry that it will impose restrictions on the use of neonicotinoid insecticides in nursery stock sold through their retail outlets. Bunnings stopped selling the Confidor (imidacloprid) pesticide brand for homes and gardens at the end of 2018 [11]. Bunnings made the decision that they will no longer accept plants treated with neonicotinoid insecticides from 2020.

The neonicotinoid insecticides are currently available to production nurseries for the control of a range of insect pests. Neonicotinoids have been an important part of the industry's insect pest management strategy for the past two decades. This restriction will have subsequent knock on effects from other retailers.

In the article, 'Act for bees' it states: 'Welcome to 2018 which began with the very welcome news of Bunnings decision to phase out the sale of neonicotinoid pesticide based garden products by the end of the year. And they are going further by working closely with their plant suppliers and will stop using neonicotinoid pesticides on garden plants.' [12]

The last review of imidacloprid by APVMA was in February 2014 [2]. The report, Overview Report Neonicotinoids and The Health of Honey Bees in Australia, stated that:

- Honey bee populations in Australia are not in decline
- Bees are an important agent in the pollination of many important agricultural crops in Australia
- Neonicotinoid insecticides range from slightly to highly toxic to bees, but this is no different to many other insecticides in common use
- The recorded number of cases of neonicotinoid insecticides causing poisoning or adverse impact on bees, other than through misuse, is limited, and no more common than other insecticide classes
- Pollinator decline in some parts of the world is likely to be caused by multiple factors

APVMA concluded that 'if new information particularly relevant to neonicotinoid use in Australia becomes available, the APVMA may update this overview report.' [2]

4. Neonicotinoid toxicity to bees

The symptom 'Colony Collapse Disorder' (CCD) occurs when the majority of worker bees in a colony disappear and leave behind a queen and a few nurse bees to care for the remaining immature bees [2].

Several European countries started seeing an increase in CCD from 1998. Dramatic increases in CCD were occurring from late 2006 [13] in conjunction with a drastic rise in the number of disappearances of honey bee colonies in North America [14].

Several reviews concluded that the cause of CCD cannot be attributed to any single factor, but a range of causes which together have led to the critical decline in bee populations worldwide [15]. These could include:

- Pesticides (especially neonicotinoids and some fungicides)
- Varroa mite
- Habitat loss
- Climate change
- New crops
- Nutrition
- Intensive agriculture

Researchers have reported that pesticides may have a direct and indirect impact on bees. The direct impact is death by contact with the pesticide. But with exposure to a very low dose, the indirect impact is less obvious and could have a sublethal effect on bees, not killing them outright, but instead impairing their development, foraging behaviour, communication, immunity, memory and mobility. Bees can have indirect exposure to pesticides by feeding on pesticide treated plant flowers, leaf residues and nectar [2].

The first reported incident of neonicotinoid impact on bees was in Germany in 2008 where dust from clothianidin treated corn seed blew over adjacent bee hives in a canola crop. It was reported that 50-100% of the hives died. In 2009, Germany suspended the use of clothianidin on corn [16].

Studies conducted in Switzerland and Canada have found that thiamethoxam and clothianidin are highly toxic to, particularly queen bees, affecting their physiology, anatomy and overall reproductive success [16,17].

When first released, it was reported that neonicotinoids had low toxicity to many non-pest insects, safe to humans and mammals and effective at very low dose rates. From information gathered over the past two decades, it appears that neonicotinoids have a deleterious impact on bees and many other beneficial insects at very low doses [18].

In 2012, the European Food Safety Authority (EFSA) conducted a study of three neonicotinoid insecticides, clothianidin, thiamethoxam and imidacloprid, in response to growing concerns about the impact of neonicotinoids on honey bees. The study was published in January 2013 [18]. The review found:

- A high acute risk to honey bees from exposure via dust drift from seed treatment uses in maize, oilseed rape and cereals

- A high acute risk from exposure via residues in nectar and/or pollen
- The science upon which regulatory agencies' claims of safety have relied may be flawed and contain data gaps

The review recommended:

- Bee exposure from pollen and nectar - only uses on crops not attractive to honey bees were considered acceptable
- Bee exposure from dust - a risk to honey bees was indicated or could not be excluded, with some exceptions, such as use on sugar beet and crops planted in glasshouses, and for the use of some granules
- Bee exposure from leave sap (guttation) - the only completed assessment was for maize treated with thiamethoxam. In this case, field studies showed an acute effect on honey bees exposed to the substance through guttation fluid

The neonicotinoid product labels registered in Australia (acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid and thiamethoxam) all have cautions in relation to bees. The typical 'Protection of Livestock' statements include: 'Dangerous to bees', 'Highly toxic to bees' as well as additional precautionary information [2].

The agricultural/horticultural situations in Australia which might lead to insect pollinators being exposed to neonicotinoid insecticides includes [2]:

- plant/crop grown from treated seed (or in treated soil) and is attractive to pollinators
- plant/crop has foliar spray applied but not at a time near flowering
- plant/crop has foliar spray applied at or near flowering

5. Current neonicotinoid restrictions

European Union

In response to the EFSA report, the European Commission recommended a restriction of the use of three neonicotinoid insecticides, clothianidin, thiamethoxam and imidacloprid, across the European Union. On 29 April 2013, 15 of the 27 EU member states voted to restrict the use (partial ban) of three neonicotinoids (clothianidin, thiamethoxam and imidacloprid) for two years starting 1st December 2013 [6]. On 27 April 2018, the European Union agreed upon a total ban on clothianidin, thiamethoxam and imidacloprid use, as they posed a high risk to both domestic and wild bees, except within closed greenhouses. The ban will be phased in from 2019 to 2023.

The United Kingdom did not support the ban on neonicotinoid insecticides in 2013 and 2018 and stated, 'it will be very difficult, if not impossible, to maintain production of many UK crops if neonicotinoids are more widely restricted or banned completely. Furthermore, if groups of chemistries are limited by legislation, the remaining groups will be more widely used, resulting in an increased risk of pests developing resistance to them'. It is unclear of the UK position on this issue following Brexit.' [7].

United States

In 2012, the US Environmental Protection Authority (EPA) began reviewing the registrations of acetamiprid, clothianidin, dinotefuran, thiacloprid, and thiamethoxam. The EPA said that it expected to complete the review for the neonicotinoids in early 2019 [19].

Canadian

In late 2015, Canada banned all neonicotinoid uses in agriculture, amenities, home garden, ornamentals, forestry and recreation areas [20].

Australian

As at the time of preparing this report, the are no restrictions/bans placed on the use of neonicotinoid insecticides by APVMA in Australia [1].

6. Current neonicotinoid uses for the Australian production nursery industry

The majority of pesticides available to production nurseries are via the APVMA minor-use permit (MUP) program [1].

Table 1: List of production nursery MUP containing neonicotinoid insecticides (in bold).

Permit No.	Description	Pests controlled by neonicotinoids	Expiry Date	Permit holder
PER9795	Bifenthrin, **imidacloprid** and mancozeb / Selected nursery stock / Quarantine pests	Identified quarantine pests	31-Mar-27	DAF WA
PER14856	Bifenthrin, Chlorothalonil, Chlorpyrifos, **midacloprid**, Mancozeb / Nursery stock (non-food) / Quarantine pests	Identified quarantine insect pests	31-May-23	NGIA / AgAware
PER81707	Insecticides (acephate, alpha-cypermethrin, Bacillus thuringiensis, bifenazate, buprofezin, chlorantraniliprole, chlorantraniliprole + **thiamethoxam** (seed treatment), diafenthiuron, emamectin, etoxazole, fenoxycarb, fipronil, **imidacloprid**, indoxacarb, petroleum oil, pymetrozine, pyrethrins, pyriproxyfen, spirotetramat) / Nursery Stock (Non-Food) and ornamentals / various insect pests	Imidacloprid – aphids, ants, fungus gnats, lace bugs, mealy bugs, psyllids, scales, scarab beetle larvae, whiteflies. Thiamethoxam – aphids, leafhoppers, thrips, whiteflies.	30-Sep-20	NGIA / AgAware
PER84742	Starkle (**dinotefuran**) / Nursery Stock, cut flower and foliage / various insect pests	Aphids, borers, leaf beetles, mealy bugs, mirids, scales, thrips, weevils, whiteflies.	30-Nov-20	NGIA / AgAware
PER85010	Spinner Turf (cyantraniliprole + **thiamethoxam**) / Nursery stock (non-food) and fruit trees (non-bearing) / various insect pests	Beetle larvae, weevil larvae	28-Feb-23	NGIA / AgAware

NOTE: Some permits have restrictions on their use. Please check details on each permit before using. Information on Australian permit pesticides can be found at the APVMA website: https://portal.apvma.gov.au/permits

7. Current neonicotinoid alternatives for the Australian production nursery industry

Production nurseries already have a range of insecticides available as alternatives to neonicotinoids for the control of a range of insect pests [1].

Table 2: List of current available insecticide alternatives to imidacloprid.

Insect pest	Alternative insecticide	Permit number
Aphids	Alpha-cypermethrin Diafenthiuron Petroleum oil Pymetrozine Spirotetramat	PER81707
	Flonicamid	PER83964
	Pirimicarb	PER84735
	Sulfoxaflor	PER85011
Ants	Fipronil	PER81707
	Chlorpyrifos	PER85259
Fungus gnats	Bacillus thuringiensis Fipronil Pyriproxyfen	PER81707
	Cyromazine	PER83506
Lace bugs	Nil	
Mealy bugs	Buprofezin Fipronil Spirotetramat	PER81707
	Flonicamid	PER83964
	Sulfoxaflor	PER85011
Psyllids	Abamectin Bifenthrin Methomyl	PER84229
	Azadirachtin Chlorpyrifos Methomyl	PER84953
Scales	Buprofezin Fenoxycarb Petroleum oil Spirotetramat	PER81707
	Sulfoxaflor	PER85011
Scarab beetle larvae	Fipronil	PER81707

Table 2: List of current available insecticide alternatives to imidacloprid (cont).

Insect pest	Alternative insecticide	Permit number
Whiteflies	Buprofezin Diafenthiuron Pyriproxyfen Pymetrozine Spirotetramat	PER81707
	Flonicamid	PER83964
	Sulfoxaflor	PER85011
	Dimethoate	PER86930

Table 3: List of current available insecticide alternatives to thiamethoxam.

Insect pest	Alternative insecticide (as a seed treatment)	Alternative insecticide (as a foliar treatment)	Permit number
Aphids	Nil	Alpha-cypermethrin Diafenthiuron Petroleum oil Pymetrozine Spirotetramat	PER81707
		Flonicamid	PER83964
		Pirimicarb	PER84735
		Sulfoxaflor	PER85011
Beetle	Nil	Fipronil	PER81707
Leafhoppers	Nil	Buprofezin Petroleum oil	PER81707
Thrips	Nil	Acephate Alpha-cypermethrin Fipronil Petroleum oil Pyrethrins Spirotetramat	PER81707
		Flonicamid	PER83964
		Azadirachtin	PER84953
Weevil	Nil	Fipronil Indoxacarb	PER81707
Whiteflies	Nil	Buprofezin Diafenthiuron Pyriproxyfen Pymetrozine Spirotetramat	PER81707
		Flonicamid	PER83964
		Sulfoxaflor	PER85011
		Dimethoate	PER86930

Table 4: List of current available insecticide alternatives to dinotefuran.

Insect pest	Alternative insecticide	Permit number
Aphids	Alpha-cypermethrin Diafenthiuron Petroleum oil Pymetrozine Spirotetramat	PER81707
	Flonicamid	PER83964
	Pirimicarb	PER84735
	Sulfoxaflor	PER85011
Borers	Azadirachtin	PER84953
	Fipronil	PER81707
Leaf beetles	Nil	
Leafminer	Cyromazine	PER83506
Mealy bugs	Buprofezin Fipronil Spirotetramat	PER81707
	Flonicamid	PER83964
	Sulfoxaflor	PER85011
Mirids	Emamectin	PER84229
	Flonicamid	PER83964
	Sulfoxaflor	PER85011
	Dimethoate	PER86930
Scales	Buprofezin Fenoxycarb Petroleum oil Spirotetramat	PER81707
	Sulfoxaflor	PER85011
Thrips	Acephate Alpha-cypermethrin Fipronil Petroleum oil Pyrethrins Spirotetramat	PER81707
	Flonicamid	PER83964
Weevils	Fipronil Indoxacarb	PER81707

Table 4: List of current available insecticide alternatives to dinotefuran (cont).

Insect pest	Alternative insecticide	Permit number
Whiteflies	Buprofezin Diafenthiuron Pyriproxyfen Pymetrozine Spirotetramat	PER81707
	Flonicamid	PER83964
	Sulfoxaflor	PER85011
	Dimethoate	PER86930

Table 5: List of registered non-neonicotinoid insecticides per target insect pest.

Insect pest	Alternative insecticide	Registration (chemical group)	Registered crops
Aphids	acephate	Lancer (Group 1B)	Ornamentals
	afidopyropen	Versys (Group 9D)	Ornamentals (field only)
	Beauveria bassiana	Broadband (biological)	Protected ornamentals
	Bifenthrin	Compel Pro (Group 3A)	Ornamentals
	Carbaryl	Carbaryl (Group 1A)	Ornamentals
	Dimethoate	Danadim (Group 1B)	Ornamentals
	Emulsifiable botanical oil	Eco-Oil (oil)	Ornamentals, nursery and GH grown tomatoes and flowers
	Esfenvalerate	Sumi-alpha (Group 3A)	Ornamentals (outdoor)
	Maldison	Fyfanon (Group 1B)	Ornamentals and flowers
	Paraffinic oil	Bioclear (oil)	Ornamentals
	Petroleum oil	Biocover (oil)	Ornamentals
	Phorate	Thimet (Group 1B)	Ornamentals
	Pirimicarb	Aphidex (group 1A)	Ornamentals
	Potassium salts of fatty acids	Natrasoap (biological)	Ornamentals
	Pymetrozine	Chess (Group 9B)	Nursery stock (non-food)

Table 5: List of registered non-neonicotinoid insecticides per target insect pest (cont).

Insect pest	Alternative insecticide	Registration (chemical group)	Registered crops
Ants	Hydramethylnon	Amdro Ant Bait (Group 20A)	Nursery stock (non-food)
	Metaflumizone	Siesta Ant bait	Nursery stock (non-food)
Beetles	Carbaryl	Carbaryl (Group 1A)	Ornamentals
Borers	Carbaryl	Carbaryl (Group 1A)	Ornamentals
Fungus gnats	diazinon	Diazinon (Group 1B)	Ornamentals
Lace bugs	Dimethoate	Danadim (Group 1B)	Ornamentals
	Esfenvalerate	Sumi-alpha (Group 3A)	Ornamentals (outdoor)
	Maldison	Fyfanon (Group 1B)	Ornamentals and flowers
Leafhoppers	Dimethoate	Danadim (Group 1B)	Ornamentals
	Esfenvalerate	Sumi-alpha (Group 3A)	Ornamentals (outdoor)
Mealy bugs	Bifenthrin	Compel Pro (Group 3A)	Ornamentals
	Potassium salts of fatty acids	Natrasoap (biological)	Ornamentals
Mirids	Dimethoate	Danadim (Group 1B)	Ornamentals
	Phorate	Thimet (Group 1B)	Ornamentals
Psyllids	Dimethoate	Danadim (Group 1B)	Ornamentals
Scales	Carbaryl	Carbaryl (Group 1A)	Ornamentals
	Maldison	Fyfanon (Group 1B)	Ornamentals and flowers
	Paraffinic oil	Bioclear (oil)	Ornamentals
	Petroleum oil	Biocover (oil)	Ornamentals

Table 5: List of registered non-neonicotinoid insecticides per target insect pest (cont).

Insect pest	Alternative insecticide	Registration (chemical group)	Registered crops
Scarab beetle larvae	Chlorpyrifos	Chlorpyrifos (Group 1B)	Ornamentals (potted)
	Dimethoate	Danadim (Group 1B)	Ornamentals
Thrips	*Beauveria bassiana*	Broadband (biological)	Protected ornamentals
	Bifenthrin	Compel Pro (Group 3A)	Ornamentals
	Dimethoate	Danadim (Group 1B)	Ornamentals
	Esfenvalerate	Sumi-alpha (Group 3A)	Ornamentals (outdoor)
	Phorate	Thimet (Group 1B)	Ornamentals
	Potassium salts of fatty acids	Natrasoap (biological)	Ornamentals
	Spinetoram	Success Neo (Group 5)	Ornamentals
Whiteflies	*Beauveria bassiana*	Broadband (biological)	Protected ornamentals
	Bifenthrin	Compel Pro (Group 3A)	Ornamentals
	Dimethoate	Danadim (Group 1B)	Ornamentals
	Emulsifiable botanical oil	Eco-Oil (oil)	Ornamentals, nursery and greenhouse grown tomatoes and flowers
	Paraffinic oil	Bioclear (oil)	Ornamentals
	Petroleum oil	Biocover (oil)	Ornamentals
	Potassium salts of fatty acids	Natrasoap (biological)	Ornamentals
	Pymetrozine	Chess (Group 9B)	Nursery stock (non-food)
	Pyriproxyfen	Admiral (Group 7C)	Nursery stock

As can be seen from the information in Tables 2-5, the production nursery industry have a suite of non-neonicotinoid insecticides available to control key insect pests.

8. Agchem company comments on neonicotinoid insecticides

All major agchem companies were contacted regarding the future of neonicotinoid insecticides and any replacement insecticides they have. Their comments follow.

Adama

Adama indicated that they invested significantly into the development of neonicotinoid insecticide, acetamiprid, and will continue to do so in the future [a].

Adama have several new non-neonicotinoid insecticides under development that will target; aphids, borers, bugs, beetles, leafhoppers, mealy bugs, mirids, psyllids, scale, scarab, weevils and whitefly. No registrations are expected within the next 3-5 years.

Acetamiprid is currently on the EU Annex 1 list (products that can be sold/used) but only on certain protected and field crops. Acetamiprid has a registration in the EU until 2023.

AgNova

AgNova have no insecticides close to commercialisation that could replace neonicotinoids in the nursery industry [b].

BASF

BASF registered Versys Insecticide (afidopyropen), a new Group 9D insecticide in April 2018. Versys is registered for the control of many different aphid species and suppression of Silverleaf whitefly in various vegetables, cotton and ornamentals. Versys has very low bee, pollinator and beneficial toxicity. Versys has low human risk, so is unscheduled. Versys can only be applied as a foliar treatment to field crops only [c]. BASF are investigating the use in protected cropping. Versys is an excellent replacement for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) for the production nursery industry.

BASF are working on a biological insecticide, Velifer (*Beauveria bassiana*), for the control of aphids, mites, thrips and whiteflies in vegetables and ornamentals grown in protected cropping. Registration is expected in mid 2019. Velifer will be an excellent replacement for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) for the production nursery industry.

Bayer

Bayer have 2 new insecticides they are developing in Australia:

- DC0143 / beetles, borers and weevils
- Flupyradifurone / aphids, beetles, leafhoppers, mealybugs, psyllids, scale, thrips and whiteflies

Unfortunately, no information on their status was made available [d].

Corteva

Corteva are expanding the crops on the label for Transform (sulfoxaflor), a Group 4C insecticide. Transform is an excellent replacement for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) and is currently available to the production nursery industry via a permit [e].

Corteva are developing new insecticides, but they are many years from commercialisation.

FMC

FMC have a non-neonicotinoid insecticide currently available; Avatar (indoxacarb) for the control of beetles, borers, mirids and weevils [f]. Avatar is an excellent replacement for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) and is currently available to the production nursery industry via a permit.

FMC are developing new insecticides, but they are many years from commercialisation.

Nufarm

Nufarm are developing several biological and conventional insecticides (NUL3073, NUL3145 and NUL3196) with activity against many insect pests that are currently controlled by neonicotinoid insecticides. These are all expected to be commercialised in the next 2 years [g]. They will all be potentially excellent replacements for neonicotinoid insecticides for the production nursery industry.

Sipcam

Sipcam are developing pyrifluquinazon (new mode of action) for the control of aphids, thrips and whiteflies in cotton only at this stage. Registration is still several years away [h]. Pyrifluquinazon could be a replacement for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) for the production nursery industry.

Sumitomo

Sumitomo indicated that they will continue with their neonicotinoid insecticide, clothianidin [i].

Clothianidin is currently on the EU Annex 1 list (products that can be sold/used) but only on certain protected and field crops. Acetamiprid will be phased out during 2019.

Sumitomo are developing new insecticides, but they are many years from commercialisation.

Syngenta

Syngenta commented that they currently have a range of insecticides that control the target pests controlled by neonicotinoid insecticides, e.g. Pirimor (pirimicarb), Chess (pymetrozine) and Pegasus (diafenthiuron) [j]. Each of these products are excellent replacements for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) and are currently available to the production nursery industry via permits.

Syngenta have several new insecticides under development (foliar and soil treatment), but with nothing due for registration within the next 5 years.

Syngenta expects all neonicotinoid insecticides to be banned/withdrawn from sale in the EU. This will not be based on public health or environmental issues, but consumer pressure. Thiamethoxam is currently on the Annex 1 list (products that can be sold/used) but only on certain protected and

field crops. The phase out will be during 2019. Syngenta expect all neonicotinoids to be phased out by 2021. Syngenta expect the EU phase out to first be in all field crops and protected crops reliant on bees, followed by all protected crops.

UPL

UPL have a non-neonicotinoid insecticides currently available; Mainman (flonicamid) for the control of aphids, mealybugs, mirids, thrips and whiteflies [k]. Mainman is an excellent replacement for neonicotinoid insecticides (dinotefuran, imidacloprid and thiamethoxam) and is currently available to the production nursery industry via a permit.

UPL have no other molecules close to commercialisation that could replace neonicotinoids for the production nursery industry.

9. Overseas agencies comments on neonicotinoid insecticides

Key overseas regulatory or industry agencies were contacted regarding the future of neonicotinoid insecticides and possible changes. Their responses follow.

Asia

Many Asian countries (China, South Korea and Japan) are following the lead of the EU.
No additional information is available.

Canada

The Canadian Nursery Landscape Association [l] that:

- Imidacloprid has a good sucking insect label for floriculture and a narrow one for white grubs in outdoor grown nurseries. Thiamethoxam is not available to greenhouse ornamentals but is important for some hard to control pests in outdoor nurseries (e.g. root weevils). Acetamiprid has a broad ornamental label. Clothianidin is only used in the turf sector.
- A few years ago most of our big box retailers started requiring our nursery and floriculture growers to stop applying neonicotinoid insecticides (imidacloprid, thiamethoxam and clothianidin) to plant material. Growers selling to these retailers were required to ensure that neonics were not used in production.
- Both nurseries and floriculture made a decision to start pursuing neonic alternatives a few years ago, focusing our attention on other chemical classes as we saw forthcoming issues with the registration of the traditional neonics, due to unfavourable recent pollinator and aquatic organism assessments.
- In the past few years, we have been able to register a number of alternative products including spirotetramat and flonicamid. These products are now in place and provide our growers with options. Additionally have registered other neonics-like sulfoxaflor.
- Moving forward we continue to look for alternative chemistry to neonics and focus more on non-neonic technologies.

European Union - Commodity Expert Group for Ornamentals

The EUCEGO [m] commented that:

- If the neonicotinoids (acetamiprid, imidacloprid, thiamethoxam, thiacloprid) and pyrethroids are removed from sale for all crops, this would have a major impact for all European countries on the proper control of aphids, mealybugs and whiteflies, and a minor impact on the control of beetles, bugs, cicads, leaf fleas, etc.
- Products such as flonicamid and spirotetramat will increase in use for mealybugs and scale insects control.
- For whiteflies, pyriproxyfen, indoxacarb, pymetrozine and the biopesticides *Beauveria bassiana* and *Isaria fumosorosea* will be extensively used. (Confidor was an important insecticide for the difficult to control Bemisia variants that occurs).
- For aphid control, the disappearance of neonicotinoids means a complete loss of effective aphid management. Despite the fact that there are other alternatives (flonicamid, spirotetramat, azadirachtin, pirimicarb, pymetrozine) in recent years even with the

neonicotinoids there were still a lot of problems with aphid management in roses, rhododendron and chrysanthemums.

- The loss of Actara (thiamethoxam) is important because of its control of thrips (especially Echinothrips) and springtails in potting soils. Actara provided an alternative to spinosad and abamectin.
- Confidor (imidacloprid) is the best product against leaf fleas.
- Gazelle (acetamiprid) is the best product against cockerels.
- Calypso (thiacloprid) is the best product against bugs, cicadas, weevils and saw wasps.
- For the main pests (aphids, whiteflies and mealybugs) a combination of biological control with the remaining insecticides (IPM) will have to offer the best solution. But if this is successful, these IPM schemes will be many times more expensive than one or a few chemical treatments.
- For the use of IPM in outdoor conditions, the combination of biologicals/beneficials, which can be difficult establishment (too cold, too hot, poor beneficial performance, production losses) in combination with selective pesticides, can often not work satisfactorily, leading to grower frustration.

New Zealand

New Zealand are currently reviewing their use of neonicotinoids. Several agchem companies have been asked for the product data packages to review. This process has been accelerated by the recent change of government [n].

US Department of Agriculture and Environment Protection Authority

The USDA [9] and EPA in association with university researchers and private companies are conducting a nationwide project; 'Protecting Pollinators with Economically Feasible and Environmentally Sound Ornamental Horticulture'. The project began in late 2017 and will run for 5 years. The project covers all key factors that can impact on pollinators:

- Objective 1. Pollinator Attractiveness of Ornamental Horticulture Crops
  - What and how much do bee pollinators eat?
  - Are plants good forage materials for bees?
  - How many pollinator forage plants are in the landscape?
- Objective 2. Risk Assessment Data Gaps
  - What residues are present in pollen and nectar?
- Objective 3. Economic, Efficacy, and Toxicological Comparisons of Alternatives
- Objective 4. Public Perception of Management Practices and Point-of-Purchase Display Materials
- Objective 5. Best Management Practices and Outreach

This project is yet to produce reportable results.

US IR-4 Program

IR-4 commented that; '*the largest US retailer and some regional retailers have made similar decisions to no longer accept plant products which have been treated with neonicotinoids or*

require growers to include labels indicating treatment. Some growers have already shifted, but others are maintaining judicious use of neonicotinoids when they are needed.' [o].

IR-4 are involved in the USDA project and will be collecting data to support risk assessment decisions for systemic insecticides, including neonicotinoids. IR-4s goal is to provide USDA and EPA with information relevant to the environmental (ornamental) horticulture industry based on practices growers use to produce thousands of different species and cultivars. One primary focus area is determining whether the highest volume crops (and hence the most likely to impact pollinators when treated by growers) are in fact pollinator attractive. Breeders have bred out many of the pollinator useful traits (i.e. pollen production) for aesthetic purposes. The other primary focus area is examining the level of residues in nectar and pollen occurring after treatment with systemic insecticides.

Preliminary results show that less than 10% of the plant units sold are attractive to pollinators.

10. Impact on production nurseries to neonicotinoid removal / restrictions

At the time of preparing this report, APVMA have no plans to restrict the use of neonicotinoid insecticides in the nursery industry or for any other agricultural use [q].

Information provided by John McDonald, National Biosecurity Manager, Nursery and Garden Industry Australia (NGIA) [p], suggests that the future use of neonicotinoid insecticides in production nurseries will only be restricted to growers who supply Bunnings Warehouse.

But it should be noted that overseas trends do seem to be indicative of future Australian trends, therefore there is value in finding alternatives that keep in line with overseas requirements.

As presented in Tables 2-5, production nurseries have a suite on non-neonicotinoid insecticides available to control key sucking, chewing and boring insect pests.

The only use pattern which is not covered by alternative insecticides is PER85010 - Spinner Turf (cyantraniliprole + thiamethoxam) / nursery stock (non-food) and fruit trees (non-bearing) / African black beetle, scarab beetle larvae, chafer beetle larvae and stem weevil larvae, used as a soil drench.

At the time of preparing this report, production nurseries are not required to exclude the use of neonicotinoid insecticides, other than those nurseries supplying Bunnings Warehouse [p].

11. Non-neonicotinoid insecticides targeted by the production nursery industry

During 2018, NGIA submitted 4 minor-use permit applications to APVMA for insecticides that will control some/most of the pests currently controlled by neonicotinoid insecticides for the production nursery industry [p]. The insecticides selected follow.

Table 6: List of permit applications with APVMA for non-neonicotinoid insecticides.

Active ingredient (product name)	Crop	Target pest	Expected permit issue date
Spinetoram (SUCCESS NEO)	Nursery stock (non-food)	Psyllids including Tomato Potato Psyllid and thrips	May 2019
Clitoria ternatea extract (SERO-X)	Nursery stock (non-food)	Heliothis, mirids and whitefly	May 2019
Dimethoate (DANADIM)	Nursery stock (non-food)	Spiriling whitefly and mirids	APVMA permit PER86930 issued 30-Nov-18 for 5 years
Sulfoxaflor (TRANSFORM)	Nursery stock (non-food)	Stink bugs including Brown Marmorated Stink Bug, psyllids including Tomato Potato Psyllid	June 2019

12. Possible future neonicotinoid alternatives for the production nursery industry

As present in Table 2-5, the production nursery industry already has many non-neonicotinoid alternative insecticides available to control a wide range of sucking, chewing and boring insect pests.

Key agchem companies are working on a range of new insecticides that could easily fit into the production nursery industry as neonicotinoid replacement. Some key products are listed below.

Table 7: Key neonicotinoid replacement insecticides under development in Australia.

Pesticide (Trade name) (Manufacturer)	**Comments**	**Target pests**	**Likely date for registration in Australia**
Beauveria bassiana (VELIFER) (BASF)	Biological insecticide. Will be registered in protected ornamentals only. Replacement for Broadband.	Aphids Mites Thrips Whiteflies	Mid 2019
DC0143 (Bayer)	Under development.	Beetles Borers Thrips Weevils	Unknown
Flupyradifurone (Bayer)	Under development. New chemical group.	Aphids Beetles Leafhoppers Mealybugs Psyllids Scale Thrips Whiteflies	Unknown
NUL3073 (Nufarm)	Under development. New chemical group (biological).	Aphids Bugs Mirids Weevils	2020
NUL3145 (Nufarm)	Under development. New chemical group (biological).	Aphids Bugs Flies Mirids Thrips	2020
NUL3196 (Nufarm)	Under development. New chemical group.	Aphids Flies Mirids Thrips	Late 2019/early 2020
Pyrifluquinazon (Sipcam)	Under development. New chemical group.	Aphids Thrips Whiteflies	2020/21

Each of these agchem companies have been contacted regarding their new pesticides and their use in the production nursery industry.

13. Other restrictions on production nursery industry insecticides

Following discussions with APVMA in late 2018 [q], they have no intension of imposing any restriction on the use of neonicotinoid insecticides in Australia. But as stated earlier, 'if new information particularly relevant to neonicotinoid use in Australia becomes available, the APVMA may update this overview report.' [2].

In regard to 'other pesticides', APVMA are constantly monitoring and reviewing the use of pesticides to ensure they are used correctly, and their use follows 'Good Agricultural Practice'. APVMA conduct a 'chemical review' program which assesses the risks and determines whether regulatory changes are necessary to ensure the pesticide can continue to be used safely and effectively [1]. The list of insecticides 'under review' with relevance to the nursery industry are:

- Chlorpyrifos (registered in ornamentals)
- Diazinon (registered in ornamentals)
- Fipronil (permit in nursery stock)
- Maldison (registered in ornamentals)

Chlorpyrifos, diazinon and maldison are very old organophosphate (Group 1B) insecticides. Following the APVMA review, their use in the nursery industry (ornamentals) could be restricted due to worker exposure, environmental safety and/or public health issues [1].

APVMA's review of fipronil is based on:

- concerns over toxicity, primarily related to skin irritation and skin sensitisation
- the potential for fipronil to form toxic photodegradation products
- occupational health and safety issues
- animal safety
- the adequacy of label instructions.

Following the APVMA review, the use of fipronil in the nursery industry could be restricted based on one or more of these issues [1].

14. Alternative pest management strategies to pesticides for the production nursery industry

The development of an effective pest management strategy in the production nursery industry that has minimal input from pesticides and still maximises the potential of each crop is difficult. The production nursery industry has specific factors that impact on pest management:

- Crops grown in field and protected situations
- Plants grown in very close proximity to each other
- Plants grown all year round
- Varieties grown for their aesthetic value, not their pest tolerance
- Regular overhead irrigation
- Controlled environments
- Quick turnover of crops
- No plant-free periods
- Consumer demand for 'perfect' plants

All of these factors can contribute to the establishment and proliferation of diseases and insect pests.

Possible alternative mechanisms to pesticides in the production nursery industry are:

- Isolation – set up the production facility is an isolate area
- Quarantine – exclude/restrict entry to the production facility
- Barriers – install pest exclusion netting to the production facility (only possible in greenhouses)
- Genetics – selection of plant varieties that also addresses pest management
- Biological – the use predators, parasites and/or microbial pathogens to suppress/control pests
- Chemicals
    - Only apply pesticides after careful structured crop monitoring of the crop for pest populations, current and potential damage
    - Selection of pesticide that controls the target pest but has the least impact on beneficials
- Integrated pest management (IPM)
    - Structured crop monitoring undertaken at appropriate frequencies relevant to crops produced (e.g. annuals v's perennials) used to inform decision making in selecting pest management procedures
    - The use of selective, biological and low impact pesticides in association with beneficial and other biological control agents, in association with managerial and cultural practices for pest control
    - IPM is regarded as a highly effective approach to pest control that minimises the use of pesticides
- Establishment of beneficial insect repositories within or along the borders of the production facility

15. Proposed future restrictions on pesticides for the production nursery industry

As stated earlier in this report, APVMA regularly reviews all pesticides to ensure they comply with 'Good Agricultural Practice' and that the risks associated with their use, handling and consumption of produce meets all regulatory requirements [1].

There are some pesticides currently registered in ornamental crops (chlorpyrifos, diazinon and maldison) which are very old organophosphate (Group 1B) insecticides. Following the APVMA review, their use in the nursery industry (ornamentals) could be restricted due to worker exposure, environmental safety or public health issues [1].

Many countries periodically review the registration of pesticides, generally every 10-15 years, to confirm that the pesticides remains safe when used as directed; to the user, the public and the environment. The reviews concentrate on older pesticides [1,6,7,9,21].

Table 8: Pesticides that have been identified for review in either Australia, Canada, the EU or the USA with possible impact on the production nursery industry.

Pesticide (Aust trade name)	**Target pests**	**Category**
Acephate (Orthene and others)	Aphids, thrips,	Insecticide
Captan (Captan and others)	Damping-off	Fungicide
Carbaryl (Bugmaster and others)	Aphids, beetles, borers, scales	Insecticide
Chlorothalonil (Bravo and others)	Various diseases	Fungicide
Dithiocarbamates (mancozeb, metiram, thiram, propineb, zineb, ziram) (various trade names)	Various diseases	Fungicide
Fenbutatin oxide (Torque and others)	Mites	Insecticide
Fosetyl-Al (Aliette)	Pythium	Fungicide
Glyphosate (Roundup and others)	Weeds	Herbicide
Iprodione (Rovral and others)	Various diseases	Fungicide
Methomyl (Lannate and others)	Various insects	Insecticide
Organophosphates (acephate, chlorpyrifos, diazinon, fenamiphos, fenthion, ,maldison, phorate, trichlorfon, + others) (various trade names)	Various insects	Insecticide
Propargite (Omite and others)	Mites	Insecticide

Table 8: Pesticides that have been identified for review in either Australia, Canada, the EU or the USA with possible impact on the nursery industry (cont).

Pesticide (Aust trade name)	**Target pests**	**Category**
Synthetic pyrethroids (bifenthrin, cyhalothrin, cypermethrin cyfluthrin, deltamethrin, fenvalerate, permethrin, + others) (various trade names)	Various insects	Insecticide
Triazoles (cyproconazole, difenoconazole, epoxiconazole, fluquinconazole, flusilazole, flutriafol, hexaconazole, myclobutanil, penconazole, propiconazole, tebuconazole, triadimefon, triadimenol, + others) (various trade names)	Various diseases	Fungicide

It is very difficult for the production nursery industry to plan a strategy to address the loss of some or all of the pesticides listed in Table 8; given the extent of the list and the unknown regulatory changes that may be imposed.

Production nurseries need to keep abreast of worldwide regulatory and retailer changes, assess the impact on the Australian nursery industry and then act appropriately to address the changes for the industry.

16. Recommendations for the production nursery industry

This report highlights the importance of the neonicotinoid insecticides (acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid and thiamethoxam) to Australian agriculture and the importance of dinotefuran, imidacloprid and thiamethoxam to the Australian production nursery industry by controlling major sucking, chewing and soil insect pests.

An aim of the report was to identify potential replacement insecticides to the neonicotinoids. Production nurseries through NGIA have been very active in recent years to identify replacement insecticides and obtain access via APVMA minor-use permits. These insecticides include: azadirachtin, Clitoria ternatea, flonicamid, pirimicarb, spinetoram, spirotetramat and sulfoxaflor.

Production nurseries are constantly seeking new non-neonicotinoid insecticides to add to their pest management toolbox. These were identified in Table 6.

Information on new non-neonicotinoid insecticides follows:

Beauveria bassiana

- Will control aphids, mites, thrips and whiteflies
- For use in protected crops only
- Supported by BASF for a permit in the production nursery industry (PURSUE)

DC0143

- No support from Bayer until this product is registered.

Flupyradifurone

- No support from Bayer until this product is registered.

NUL3073

- Will control aphids, bugs, scale and weevil
- Supported by Nufarm for a permit in the production nursery industry (PURSUE)

NUL3145

- Will control aphids, bugs, scale and weevil
- Supported by Nufarm for a permit in the production nursery industry (PURSUE)

NUL3196

- Will control aphids, flies, mirids and thrips
- Supported by Nufarm for a permit in the production nursery industry (PURSUE)

Pyrifluquinazon

- No support from Sipcam until this product is registered.

As listed above, there are four new insecticides that can be pursued for APVMA minor-use permits on behalf of the production nursery industry. Before proceeding, reconnecting with each agchem company will be required.

Glossary

APVMA ….. Australian Pesticides and Veterinary Medicines Authority

EU …… European Union

CCD ……. Colony Collapse Disorder

EFSA …… European Food Safety Authority

EPA …….. USA Environment Protection Authority

IPM …….. Integrated Pest management

NGIA …… Nursery and Garden Industry Australia

MUP ……. Minor-use permit

References

[1] Australian Pesticides and Veterinary Medicines Authority. [Online]

[2] Australian Pesticides and Veterinary Medicines Authority. [Report] (2014). Overview Report Neonicotinoids and The Health Of Honey Bees In Australia

[3] Fossen, M. (2006) 'Environmental Fate of Imidacloprid'.

[4] CropLife Australia (2018). 'Insecticide Resistance Management Review Group: Mode of Action Classification for Insecticides.'

[5] Wood, T. & Goulston, D. (2017). The environmental risks of neonicotinoid pesticides: a review of the evidence post 2013. Environmental Science and Pollution Research International. Springer.

[6] McDonald-Gibson, C. (29 April 2013). "'Victory for bees' as European Union bans neonicotinoid pesticides blamed for destroying bee population". The Independent.

[7] Rothamsted Research 175 (2017), 'Rothamsted questions EU pesticide bas as chemicals industry eyes Brexit for breakthrough on bees'.

[8] Thompson W. T. (2001). 'Agricultural Chemicals Book 1 – Insecticides'.

[9] U.S. Environmental Protection Agency. [Online].

[10] Yamamoto, I & Casida, J (1999). "Nicotine to Nicotinoids: 1962 to 1997". Nicotinoid Insecticides and the Nicotinic Acetylcholine Receptor. Tokyo: Springer-Verlag.

[11] Schultz A (2018). Bunnings to pull pesticide allegedly linked to bee deaths. Sydney Morning Herald.

[12] Act for bees [article] (2018) 'Bee safe gardens on the horizon as Bunnings will stop selling neonicotinoid treated plants.'

[13] AFSSA 2008: https://www.anses.fr/fr/system/files/SANT-Ra-MortaliteAbeilles.pdf

[14] Pennsylvania State University College of Agricultural Sciences (2007) "Honey Bee Die-Off Alarms Beekeepers, Crop Growers and Researchers".

[15] 3 News NZ, 2013 "Multiple causes for colony collapse' [report].

[16] Federal Office of Consumer Protection and Food Safety, Germany, July 2011 Press Release 'Maize seed may now be treated with "Mesurol " again'

[17] Harrison D. (2015). Honeybee queens highly vulnerable to two neonics. Greenhouse Canada.

[18] EFSA: http://www.efsa.europa.eu/en/press/news/130116?wtrl=01 ‘EFSA identifies risks to bees from neonicotinoids.’ 16 January 2013.

[19] Pesticide Action Network (2013). Beekeepers and Public Interest Groups Sue EPA Over Bee-Toxic Pesticides.

[20] City of Montreal (2015). "Montreal neonicotinoid ban". [article]

[21] Gates C. and Jandricic S. (2018). Growing cut flowers is about to get more challenging. Greenhouse Canada.

Personal communications

[a] Adama (Aust) technical staff (2018)

[b] AgNova (Aust) technical staff (2018)

[c] BASF (Aust) technical staff (2018)

[d] Bayer (Aust) technical staff (2018)

[e] Corteva (Aust) technical staff (2018)

[f] FMC (Aust) technical staff (2018)

[g] Nufarm (Aust) technical staff (2018)

[h] Sipcam (Aust) technical staff (2018)

[i] Sumitomo (Aust) technical staff (2018)

[j] Syngenta (Aust) technical staff (2018)

[k] UPL (Aust) technical staff (2018)

[l] Isaacson, P. Canadian Nursery Landscape Association (2018)

[m] Vissers M. European Union Commodity Expert Group for Ornamental (2018)

[n] New Zealand Food Safety, New Zealand Government (2018)

[o] Palmer, C. United States Interregional Program Number 4. (2018)

[p] McDonald, J. Nursery & Garden Industry Australia (2018)

[q] Norden, A. Australian Pesticides and Veterinary Medicines Authority (2018)

Disclaimer

The information in this report is general information only and is not intended to constitute a recommendation or advice. The report has been prepared from the information provided by the industry without taking into account the total objectives, situations or needs of the industry or any individual. Therefore before acting on the information in this report, you should consider whether the information is appropriate in light of your objectives, situation and needs. You may wish to consult a professional adviser for further advice.

While AgAware Consulting Pty Ltd has taken all care and responsibility in producing the information in this report, we make no representation in respect of, and, to the extent permitted by law, exclude all warranties in relation to, the accuracy or completeness of the information. AgAware Consulting Pty Ltd exclude all liability whatsoever for any loss or damage, howsoever, arising out of reliance, in whole or in part, on the information.

Information on Australian registered pesticides can be found at the APVMA website:

- Registered products: https://portal.apvma.gov.au/pubcris
- Permits: https://portal.apvma.gov.au/permits