The official Australian reference guide for

organic, synthetic and biological pesticides

The essential role of pesticides in agriculture, environmental conservation and human health

CropLife Australia

About CropLife Australia

CropLife Australia is the national peak industry organisation representing the plant science sector in Australia.

CropLife's members are the world-leading innovators, developers, manufacturers and formulators of crop protection and crop biotechnology products.

The plant science industry, worth more than $20 billion a year to Australian agricultural production, provides products to protect crops against pests, weeds and diseases, as well as developing crop biotechnologies key to the nation's agricultural productivity, profitability and sustainability. CropLife is part of the plant science industry's 91 country international federation.

Acknowledgement – Rohan Rainbow

CropLife Australia gratefully acknowledges Dr Rohan Rainbow for providing technical advice and input, as the primary author of this guide.

Rohan Rainbow is the Managing Director of Crop Protection Australia, providing consultancy services relating to integrated, sustainable farming systems. Dr Rainbow is one of Australia's leading scientists in the field of conservation and no-till farming systems and is highly regarded for his crop protection expertise at both a national and international level.

With a family background in farming and more than 30 years of research, communication and industry leadership in crop protection agronomy and farming systems, Dr Rainbow is passionate about delivering new agricultural technologies and strategies for Australian farmers to induce industry practice change.

Printed March 2021

Foreword

The innovations of the plant science industry, specifically new seed varieties and chemical crop protection products, along with the adoption of modern scientific methods of farming, were at the centre of the Third Agricultural Revolution.

The Green Revolution, as it is more commonly referred to, occurred more than half a century ago and remains the foundation of our modern farming systems that delivered a step change in production.

It is the innovations of the plant science industry that will be at the core of the fourth agricultural revolution, which will be required to achieve another leap in production and enable farming to become even more environmentally sustainable. This fourth revolution will need to be done by the farming sector and supporting industries under even more challenging circumstances in every sense; climatically, economically, socially and scientifically.

The world needs to produce as much food over the next 50 years as we have since the beginning of humanity, more than 30,000 years ago. That is a staggering challenge requiring a massive effort from the entire agricultural sector. Farmers will need access to all and every safe tool, product and innovation to do it, especially pesticides – be they organic, synthetic or biologically based.

Plant science companies invest billions of dollars in research and development every year to develop new products. It now requires the evaluation of more than 140,000 compounds to develop just one new pesticide – up from 50,000 just two decades ago – and it takes over 11 years, at a cost of more than $280 million (US) to bring just one new successful crop protection product to the market.

In Australia, like the rest of the developed world, food has never been safer and never has there been such variety of produce available to consumers. Now more than ever, there is peak interest in food amongst growing urban populations correlating with peak ignorance in how food is produced and farming generally. Pesticides have had a hugely positive impact on global food production yet there remains a serious lack of understanding about their safety and importance, not just to farming but to the protection and restoration of our natural environment and human health.

Matthew Cossey, Chief Executive Officer, CropLife Australia

Crop protection chemistry remains vital to supporting modern food production. Almost three quarters of all food produced in Australia is directly attributed to the use of crop protection products. That means more than $20 billion of Australian crop production is enabled by pesticides. Without pesticides the world would lose up to 50 per cent of crucial food crops, devastating global food supply.

At the same time, the effectiveness of current products and the development of new and modern technologies means farmers are now applying on average 95 per cent less pesticide per hectare to achieve the same level of pest control.

Australia's agricultural sector continues to grow with confidence in the knowledge that advanced crop protection technologies will continue to successfully manage the dynamic, evolving and ever challenging pest risks that farmers face now and into the future. This will allow our farming sector to continue delivering for Australian consumers, who are increasing their demand for a greater variety of high quality safe foods, as well as remain a globally competitive agricultural exporter to even more international markets.

Better informed and fact based discussion and public policy development are crucial for Australia to meet its farming goals and aspirations. This Guide seeks to constructively contribute to that outcome.

Matthew Cossey
CEO CropLife Australia

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Pesticide facts

Why do we need them?

Crop protection products, commonly referred to as pesticides, are essential to maintaining and improving Australia's agricultural productivity to ensure it can meet future global food security challenges.

A Deloitte Access Economics report released in 2018 estimates that up to $20.6 billion of Australian agricultural output (or 73 per cent of the total value of Australian crop production) can be directly attributed to the use of chemical crop protection products.[1]

Without access to these tools, Australian farmers face significant losses of up to 80 per cent[2] of their crop to invertebrate pests, weeds and diseases.[1]

Pesticides are essential for agricultural production, environmental conservation and human health.

The value of pesticides to Australia

The overall average cost of weeds across Australia is estimated at over $5 billion.[1,3] The combination of herbicide costs and production losses in the grain, beef and wool industries accounts for most of these costs. The value of herbicide use in all Australian crops is estimated at $8.3 billion per annum.[1] Overall costs have increased by more than 20 per cent since 2004.[4]

Aggregated across the six major Australian grain crops in 2013, the **estimated loss due to invertebrate pests totalled $359.8 million per annum**.[4] The value of insecticide use in all Australian crops was estimated at $8 billion per annum.[1]

Under current control systems, production **losses due to crop disease in Australian grain crops are valued at between $920 million to $1 billion per annum** – an $80 million increase since 2010.[5] The value of fungicide use in all Australian crops is estimated at $11.7 billion per annum.[1]

1 Deloitte Access Economics (2018) Economic activity attributable to crop protection products.
2 Oerke E.C. Crop losses to pests. J. Agric. Sci. 2006;144:31–43.
3 https://invasives.com.au/wp-content/uploads/2019/01/Cost-of-weeds-report.pdf
4 https://grdc.com.au/resources-and-publications/all-publications/bookshop/2013/02/the-current-and-potential-costs-of-invertebrate-pests-in-grain-crops
5 http://ccdm.com.au/about-us/

Global community benefits of crop protection

Crop protection products improve food quality and quantity, maintain and improve human health, protect the environment by allowing for more sustainable practices and make significant contributions to both the Australian and global economies.

Even with the modern technologies available to producers today, crop losses due to pests, weeds and diseases can range from 10-90 per cent, averaging 35-40 per cent, for all global food and fibre crops.[6] Even with crop protection products, up to 50 per cent of the global wheat crop and 40 per cent of global maize, rice and potatoes are lost.[7] Crop losses caused by crop pathogens alone cost the global economy US$220 billion annually.[8] These crop losses continue to present the risk of famine around the world.

The United Nations estimates there will be 9.7 billion people on Earth by 2050, around 30 per cent more than in 2017. Nearly all this population growth will occur in developing countries.[9] This will require raising overall food production by a staggering 70 per cent between 2005 and 2050 and production in the developing countries would need to almost double.[10]

The Food and Agriculture Organization of the United Nations (FAO) estimates that in developing countries 80 per cent of the necessary increases in food production will come from higher yields and the number of times per year crops can be grown on the same land. Only 20 per cent of new food production is expected to come from expansion of farming land.

The global COVID-19 human health epidemic has significantly impacted crop protection technology research and development, regulatory approvals, training and certification, access to personal protective equipment and international crop input supply chains.[11] The impact of COVID-19 has highlighted the importance of access to pesticide technologies, particularly to address agricultural labour shortages and timely crop protection intervention to maintain agricultural production and food supply in both low and high-income countries.

Pesticides will continue to prevent large crop losses globally and support increased global food production to meet the needs of a hungry and growing world population.

The value of Australian agriculture output attributable to crop protection products is over $20 billion.

6 Peshin R. (2002) Economic Benefits of Pest Management. *Encyclopedia of Pest Management, Marcel-Dekker 224-227*.

7 Oerke, E.C. (2006) Crop losses to pests. Journal of Agricultural Science (2006),144, 31–43.

8 Savary S., Willocquet L., Pethybridge S.J., Esker P., McRoberts N., Nelson A. The global burden of pathogens and pests on major food crops. Nat. Ecol. Evol. 2019;3:430–439. doi: 10.1038/s41559-018-0793-y.

9 www.who.int/en/news-room/fact-sheets/detail/pesticide-residues-in-food

10 www.fao.org/fileadmin/templates/wsfs/docs/Issues_papers/HLEF2050_Global_Agriculture.pdf

11 Lamichhane, J. R., & Reay-Jones, F. P. (2021). Editorial: Impacts of COVID-19 on global plant health and crop protection and the resulting effect on global food security and safety. Crop protection (*Guildford, Surrey*), 139, 105383. https://doi.org/10.1016/j.cropro.2020.105383

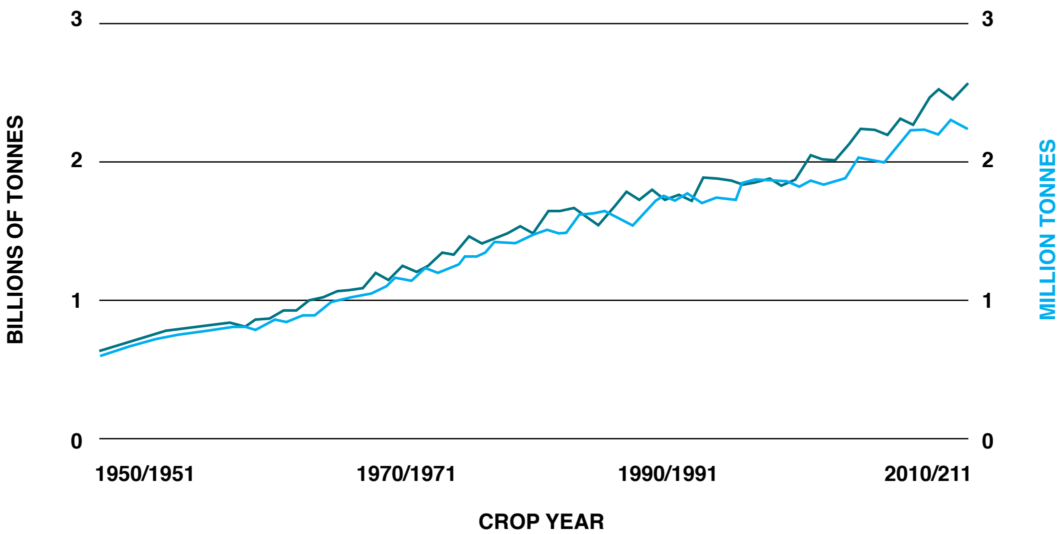
73 per cent of crop production is attributable to the use of crop protection products. Fungicides contribute more than half of this figure showing how important they are to the production of vegetables, fruit and nuts. This includes organic crop production, which uses non-synthetic crop protection products.

Pesticide fact – Plant science innovations putting more food on the world's plate

Crop protection products have had a significant impact on global food production. Farmers are now applying 95 per cent less pesticide per hectare to achieve the same level of control. Food produced per tonne of active ingredient has increased by more than 10 per cent in the last 40 years.[12]

Crop protection products continue to be developed to improve their efficacy and ensure the highest levels of safety. This is vital in ensuring they meet regulatory standards, so farmers have access to the best possible tools to provide nutritious, safe and affordable food.

FIGURE 01: GLOBAL GRAIN PRODUCTION (PER YEAR) AND AMOUNT OF PESTICIDE USED (PER HECTARE)



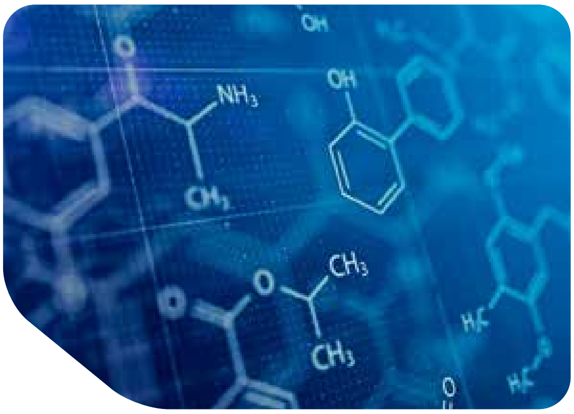
Source USDA www.darrinqualman.com/feeding-the-world-our-struggle-to-multiply-global-grain-production
https://croplife.org/wp-content/uploads/2018/11/Phillips-McDougall-Evolution-of-the-Crop-Protection-Industry-since-1960-FINAL.pdf

12 Phillips McDougall (2019) Evolution of the Crop Protection Industry since 1960.

What are pesticides and what do they do?

Crop protection products or pesticides are used to kill pests, including insects, weeds, fungi, bacteria and rodents. Pesticides are used in agriculture to kill pests that damage crops, in environmental land management to control invasive species and in public health to kill vectors of disease, such as mosquitoes.

Most common pesticides are classified by the types of pests and diseases they target i.e., insecticides, herbicides, bactericides, fungicides etc.



Herbicides, fungicides, insecticides and plant growth regulators

Herbicides, fungicides, insecticides and plant growth regulators (PGRs) are common pesticides used to protect crops from pests. Invertebrate insects, bacteria, fungi, nematodes and weeds are regarded as pests when they cause damage to crops and stored food. These pests can significantly reduce crop yields, reduce the quality of crops, cause losses after harvest and increase the cost of food and fibre production.

Pesticide products can be applied as foliar sprays, granular formulations, seed treatments or as a soil or grain treatment, such as a gas. Producers also use other pest management products such as acaricides (for spiders), pheromones (used as attractants in baits), molluscicides (for snails and slugs) and nematicides (for nematodes). Producers use PGRs to manage crop height and the ability of plants to stay upright, as well as flower management and crop thinning to improve fruit quality and tree health.

Pesticide fact – Key pesticide types and their use

Herbicides – pesticides that kill weeds so crops can flourish. Weeds and other invasive plants are the most damaging pests for many agricultural crops because they compete for vital nutrients, space, water and sunlight.

Insecticides – pesticides that control insects that could damage crops by eating them or infecting them with diseases. Fighting these pests is difficult in part because of the wide variety of insects and because new invasive species are continually being introduced as a result of globalisation. Insecticides protect against insects like locusts, lawn-devouring grubs, tree-smothering caterpillars, maggots that tunnel through fruit crops and moths/aphids that can devastate grain crops.

Fungicides – pesticides that protect plants from disease-causing organisms called fungi, like the one that caused the infamous Irish potato famine of the 1800s. In people's home gardens, roses, tomatoes and peppers are particularly susceptible to fungi. On a farm, a fungus can spread quickly from one plant to destroy an entire field.

Plant growth regulators – also called plant hormones, PGRs contain numerous chemical substances that profoundly influence the growth and differentiation of plant cells, tissues and organs. Plant growth regulators function as chemical messengers for intercellular communication. They are used in agriculture for managing crop height and the ability of plants to stay upright or for crop flowering management for crop thinning.

A new generation of pesticides

Double-stranded RNA (dsRNA) pesticides are a highly specific new generation crop protection technology that can be used to control targeted invertebrate insect pests, using a cellular mechanism called RNA interference (RNAi).[13] When the pest insect ingests the pesticide, its ability to create essential proteins is compromised, resulting in either stunted growth or death.[14]

While these RNAi pesticides can be applied as a topical or spray form to the plant, either on their own or in combination with conventional pesticides, they can also be genetically engineered into agricultural crops to enable the plant to create its own defense mechanism.

These RNAi pesticides are strongly bound to soil particle surfaces and degrade in solution, with potential uptake by soil microorganisms. Research indicates that dsRNA is unlikely to persist or accumulate in the environment.[15]

This new generation of biochemical technology offers significant opportunities to design effective pesticide tools for crop protection, while providing additional tools for managing pests and pesticide resistance.

Case study: Winegrapes

Access to a wide range of chemical pest controls has given Australian winegrape producers a broader set of tools to assist them in sustainably producing high-quality, clean and healthy fruit. Award-winning viticulturist, Liz Riley, says, “Agchem remains a key tool to the Australian wine industry to help it achieve its production and sustainability goals into the future.” As new pests and diseases emerge – and some current ones develop resistance to existing control technologies – it is ever more important that the winegrape industry continues to have access to safe and effective chemical solutions.

“It [agricultural chemical products] is used judiciously in concert with other inputs and activities. Access to a wide range of agchem activity groups and options – including emerging biological options – remains important into the future,” said Liz Riley, “Long term viability of agchem helps directly with pest control but also with management of input costs as products move into the generic phase of their lives.”

13 Environmental Fate of RNA Interference Pesticides: Adsorption and Degradation of Double-Stranded RNA Molecules in Agricultural Soils Kimberly M. Parker, Verónica Barragán Borrero, Daniël M. van Leeuwen, Mark A. Lever, Bogdan Mateescu, and Michael Sander Environmental Science & Technology 2019 53 (6), 3027-3036

14 https://phys.org/news/2019-03-fate-rna-pesticides-soils.html

15 Dubelman S, Fischer J, Zapata F, Huizinga K, Jiang C, Uffman J, Levine S, Carson D. Environmental fate of double-stranded RNA in agricultural soils. PLoS One. 2014 Mar 27;9(3):e93155. DOI: 10.1371/journal.pone.0093155

Active constituents and formulated products

Active constituents, ingredients or substances or just 'actives' are the chemicals in a pesticide that enable the product to do its job. The pesticide is the final, formulated product sold to users. Apart from one or more actives, a formulated pesticide commonly contains other ingredients that help the product achieve its objective.

In Australia, as in other parts of the world, this information is written on the pesticide product label. The Australian national regulator, the Australian Pesticides and Veterinary Medicines Authority (APVMA), individually assesses these instructions for each product and approves the label to ensure that the product, when used in accordance with its instructions, is safe for use.

Pesticide fact – Formulation benefits

Aquatic friendly – glyphosate has been specifically formulated for use in environmentally sensitive areas. Formulations have been developed using surfactants suitable for use near aquatic areas, such as around streams, creeks, dams, channels and drains. This allows environmentally safe control of a broad spectrum of annual, perennial and aquatic weeds.

Microencapsulated pesticide formulations have been rapidly increasing in popularity over the years. These pesticides have been formulated such that the active ingredient is encapsulated by a protective coating and, when mixed with water, is applied as a spray. The coating breaks down over time, potentially providing slow release of the active constituent contained inside the capsule, which can offer safety and environmental benefits.

Industry investment in crop protection

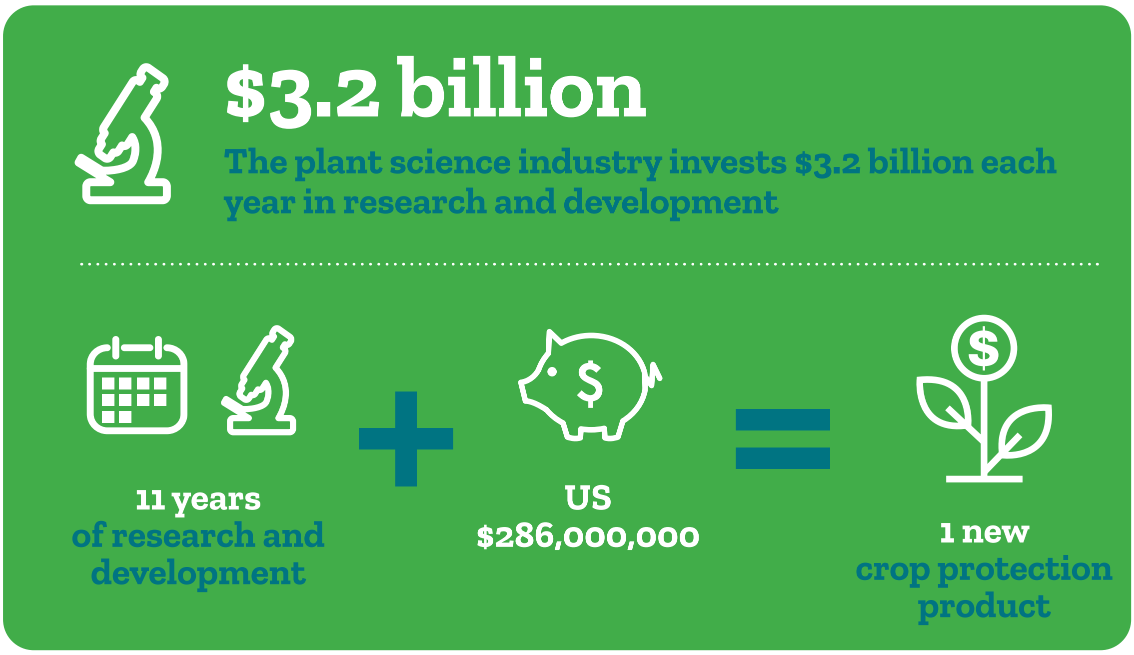
Every new active constituent that reaches the market in the form of a crop protection product requires an average investment of US$286 million and 11 years of research and development to ensure the highest safety and efficacy standards.[16]

The plant science industry spends a total of US$3.2 billion per year on new innovations and the cost of bringing a new product to market has increased by 55 per cent over the past 16 years.[17] Much of the increase in cost can be attributed to a rise in the volume and complexity of environmental safety and toxicology data required by regulatory bodies to ensure products are safe.

Pesticide fact – Investment in development of new novel synthetic chemistries

Synthetic chemistries still dominate the broader crop protection market, comprising 94 per cent of global sales in 2016. This suggests that the amount of capital deployed into developing naturally derived products may not be precisely aligned with market needs. Over the last four years, investment into companies involved in the discovery and development of novel synthetic chemistries has increased steadily.

Companies working on discovery and development of new synthetic chemistries are increasing in number and attracting investor attention. This trend may only intensify, as to a certain extent naturally derived products have yet to demonstrate their advantages over synthetic treatments. In addition, the number of available synthetic tools is decreasing due to increased regulation and plants becoming more resistant. Consequently, there will be pressure to further develop synthetics that have improved environmental and human safety profiles.



16 Phillips McDougall Report March 2016 - The Cost of New Agrochemical Product Discovery, Development and Registration in 1995, 2000, 2005-8 and 2010 to 2014. R&D expenditure in 2014 and expectations for 2019. A Consultancy Study for CropLife International, CropLife America and the European Crop Protection Association

17 Based on development investment in 2014

Case study: Pesticides used in organic wine production

In the temperate zones of south-eastern Australia, powdery mildew and botrytis rot are widely recognised as the most important diseases affecting crop yields and profitability. For powdery mildew, levels of infection above three to five per cent result in unacceptable wine quality. The application of potassium bicarbonate, sulphur and copper based 'natural products' mixed with vegetable oils in organic vineyards can provide commercially acceptable control of grapevine powdery mildew when disease pressure is low to moderate on vines that are not highly susceptible.[18]

...organic farmers can manage pests with non-synthetic pesticides.

18 Crisp et. al. (2007) Sustainable control of powdery and downy mildew diseases of grapevine and impacts of control on wine quality and vineyard health. UA03/03 final report Grape and Wine Research and Development Corporation. https://www.wineaustralia.com/getmedia/39a0c72a-67d5-49d9-b70f-e89fc6853e17/UA-03-03-Final-report

Organic pesticides

There is a common misconception that the use of pesticides is not permitted in organic farming. Organic farmers are, in fact, permitted to use pesticides, but are limited to using pesticides that are derived from 'natural' compounds rather than synthetic compounds.

'Natural' is a word that is often used to portray a product as good, healthy or safe, particularly when it is used in conjunction with organic farming or produce. It is important to understand, however, that some of the most toxic substances that exist are in fact 'natural'. For example, cyanide is a natural substance, as is spider venom and plant toxin. Organic produce is not an indication it is more or less safe than conventional produce.

Organic marketing standards vary worldwide but in general feature practices that strive to conserve biodiversity, cycle resources and promote ecological balance. Conventional farming, however, can also feature these practices.

The safety of a pesticide – whether the product is derived from a synthetic or 'natural' chemical – is a core component of the APVMA's assessment for product registration. Australians can have confidence they are buying safe produce, whether they choose to buy organic or conventionally grown.

Pesticide fact – Pesticides are used in both conventional and organic farming

Like conventional farmers, organic farmers need to manage destructive pests, weeds and diseases. The difference is organic farmers use non-synthetic chemical pesticides.

Pesticide fact – Use of 'natural' pesticides and consumer marketing

Organic foods and ecolabelling markets are creating new opportunities for growers who are willing to reduce or exclude synthetic chemicals in their production practices. Environmentally friendly products appeal to consumers too. Organic food sales are growing at a rate of 20 per cent per year in Australia.[19] Yet policy analysts report that only 0.05 per cent of agricultural research is devoted to organic farming practices.[20,21]

Crop protection is, however, a major area of organic production R&D investment. Fifty-eight per cent of pesticide companies globally are currently developing biological pesticides, with 38 per cent of global companies launching a biological pesticide in 2020.[22]

Availability of alternative pest-management tools will be critical to meet the production standards and stiff competition expected in these niche markets. Globalisation policies and practices are affecting pest management on and off the farm. Reduction in trade barriers increases competitive pressures and provides extra incentives for farmers to reduce costs and increase crop yields.

It is likely that trade will increase the spread of invasive pest species and pose risks to domestic plants and animals, as well as populations of native flora and fauna. To meet those emerging global pest problems, researchers will need to develop effective, environmentally compatible and efficient pest controls as a complement to a suite of prevention strategies.

19 https://austorganic.com/industry/publications/market-report/
20 https://organicindustries.com.au/sites/default/files/Library/Research/
21 https://grdc.com.au/__data/assets/pdf_file/0013/142402/public-investment-in-agricultural-rd-and-extension.pdf.pdf RIRDC06-103.pdf
22 www.agribusinessglobal.com/plant-health/biostimulants/state-of-the-industry-exclusive-survey-results-on-biological-products/

Biological pesticides

Organisms capable of eradicating specific pests have existed since the beginning of life on earth. A new and interesting area that the plant science industry has been significantly investing in is biologically-based crop protection products, known as 'biologicals'. In nature, populations of beneficial insects and organisms that are the naturally occurring enemies of unwanted pests and pathogens assist plants. Often, these populations are too small or develop too late to protect plants, resulting in diseased or damaged crops and associated crop losses.

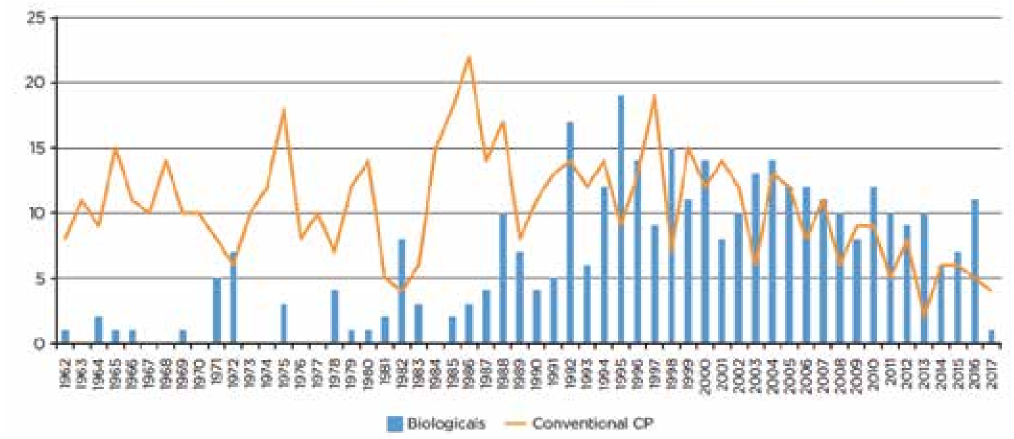
The number of new biological products registered globally has increased each year, overtaking traditional chemistry in 2010.[23] Significant research and development has been undertaken globally to identify these beneficial organisms, consisting of viruses, bacteria, fungi, nematodes or insects and develop them into products to suppress pests and diseases in crops. Recent breakthroughs in technology have delivered cost effective mass production of particularly efficacious biological crop protection products. Biosecurity regulation requirements in Australia restricts introduction of some of these biological products from overseas or adds significant cost to their commercialisation.

While there are recognised risks for producers using farming systems that rely solely on biological crop protection products – often due to their slower acting strategic use requirement – new biological crop protection technologies are increasingly being successfully used in production agriculture. New technology and innovative agricultural chemical crop protection products will remain a foundation of sustainable agricultural productivity. Biological technologies used in combination with a suite of chemical crop protection tools are a best practice strategy for effective and sustainable crop production.

Pesticide fact – Use of biological pesticides

In nature, populations of beneficial insects and organisms that are naturally occurring enemies of unwanted pests and pathogens assist plants. Beneficial insects, such as lady beetles, can help plants by suppressing invertebrate pests, which can also be vectors of disease. Many naturally occurring organisms have been developed into commercial biological pesticides for crop protection.

FIGURE 02: PRODUCT INTRODUCTIONS FOR BIOLOGICAL AND SYNTHETIC PESTICIDES



Source: https://agribusinessintelligence.informa.com/resources/product-content/evolution-of-the-crop-protection-industry-since-1960

23 Popp, J., Pető, K. and Nagy, J. (2013) Pesticide productivity and food security. A review. Agronomy for Sustainable Development 33: 243. https://doi.org/10.1007/s13593-012-0105-x

Community confidence

Profitable farm production is the lifeblood of a rural community. Growers and the community must have confidence that access to suitable crop protection tools will be maintained and improved, to ensure agricultural industries avoid catastrophic loss of production, or trade restrictions. It is also critical that communities are confident that chemical products are being used appropriately and applied to the intended target with no environmental or human health impacts. Globally, regulatory standards are becoming more sophisticated and at the same time, innovations in plant science are delivering increasingly safe and environmentally sustainable crop protection products. Along with human pharmaceuticals, pesticides are among the most regulated products in the world. To register one new active chemical, more than 150 studies are required to provide the regulator with confidence that the efficacy of a product, as well as its safety to users, consumers and the environment has been demonstrated.

Australia's independent statutory authority, the APVMA, regulates agricultural and veterinary chemicals and monitors compliance according to the *Agricultural and Veterinary Chemicals Code Act 1994* (Agvet Code) up to the point of sale. Beyond the point of sale, states and territories are responsible for regulating the use of pesticides by all users, including producers, spray contractors, local councils and home gardeners.

Consistent with other international agricultural chemical regulators, the APVMA utilises a risk-based, weight-of-evidence approach to assess the full range of risks posed by a chemical product. This approach ensures products are safe for use and for the environment, before they can be made available to Australian farmers and other users, as well as considering how human exposure can be minimised through instructions for use and safety directions.

One of the many benefits of crop protection

With

Without

1950s

2400 g

today

70 g

Farmers in the 1950s used up to 2,400 grams of active ingredient per hectare to control pests, weeds and diseases. Farmers today need only 70 grams per hectare!

Sustainable production

History of plant protection – origins to future innovations

Since the early development of agriculture about 10,000 years ago,[24] plants grown and harvested for food required protection against weeds, pests and diseases. The first recorded use of insecticides, around 4500 years ago, was the use of sulphur compounds by Sumerians, to control insects and mites.[25] For more than 2,000 years, pyrethrum, derived from the dried flowers of *Chrysanthemum cinerariaefolium*, has been used as an insecticide.[26]

In 1882, 'Bordeaux mixture', a combination of copper sulphate and lime, revolutionised pest control in vineyards, when it was discovered it could control vine downy mildew.[27] This pesticide is still used today against various fungal diseases in crops including vegetables, fruit trees and viticulture.[28]

Synthetic chemicals were developed after the Second World War, to reduce the rate of application required to treat a crop, improve selectivity and reduce the phytotoxicity of these organic crop protection products.[29] Widespread adoption of these new pesticides, in combination with the improved plant genetics of The Green Revolution and agricultural mechanisation, has delivered transformational food and fibre production increases.[30]

Modern plant protection

During the 1970s, substantial investment was channeled into the discovery and development of more selective, user-friendly and environmentally sustainable crop protection products. This resulted in the introduction of some of the most important pesticides we still use in agriculture today.

Since the 1970s, agrochemical companies have continued to invest heavily in the discovery and development of more selective crop protection products and technologies with reduced toxicity profiles and environmental impacts. It is, however, becoming increasingly difficult to develop new crop protection products with novel modes of action. As a result, considerable efforts at refining existing chemistries are being made.

Despite the challenging innovation environment, novel pesticides continue to be introduced into the global crop protection market.

As a result of the considerable investment in improving technologies available to growers to protect their valuable crops, a wide range of synthetic crop protection products, many based on naturally occurring compounds, are now available for safe, targeted and effective control of pests, weeds and diseases.

It is critical that Australian producers and the community have access to the world's best and safest pesticide products and technologies. Australian Government investment policy and regulatory frameworks that support this investment will ensure a viable, sustainable and internationally competitive agricultural industry.

24 Kislev, M.E., Weiss E. and Hartmann, A. (2004) Impetus for sowing and the beginning of agriculture: Ground collecting of wild cereals; Proceedings of the National Academy of Sciences, 101 (9) 2692-2694.

25 A.E. Smith, A.E. and Secoy, D.M. (1976) A Compendium of Inorganic Substances Used in European Pest Control before 1850. J. Ag. Food Chem. 24 (6) 1180.

26 https://agrochemicals.iupac.org/index.php?option=com_sobi2&sobi2Task=sobi2Details&catid=3&sobi2Id=31

27 www.apsnet.org/edcenter/apsnetfeatures/Pages/Fungicides.aspx

28 A.E. Smith, A.E. and Secoy, D.M. (1976) A Compendium of Inorganic Substances Used in European Pest Control before 1850. J. Ag. Food Chem. 24 (6) 1180.

29 CropLife Canada (2002) A History of Crop Protection and Pest Control in our Society.

30 Popp, J., Pető, K. and Nagy, J. (2013) Pesticide productivity and food security. A review. Agronomy for Sustainable Development 33: 243. https://doi.org/10.1007/s13593-012-0105-x

Role of pesticides in farming system improvement

Herbicides, fungicides and insecticides are critical to maintaining and improving Australia's agricultural productivity and farmer profitability.

As pests, weeds and diseases continue to be major threats to Australia's natural environment and agricultural productivity, it is crucial that the crop protection toolbox remains full. Producers today use a combination of pesticides, crop rotation, new crop genetics and cultural non-pesticide solutions in sustainable integrated crop protection programs for pest, weed and disease management.

Conservation farming

Australian farmers are global innovators and adopters of technology, with over 85 per cent adoption of both no-tillage farming and GPS guided auto steer in broadacre production, the highest rate of adoption in the world. Their key focus on reducing inputs, labour and costs while adopting farming systems that reduce energy and water use has enabled Australian farmers to weather the highly variable Australian climate while remaining internationally competitive.

The development of conservation farming practices, such as no-tillage farming, has been part of the evolution of broadacre grain growing technology. Conservation agriculture practices can reduce emissions from fossil fuels by up to 60 per cent, with a significant contribution to carbon sequestration, capturing 0.1-0.5 tonnes per hectare of organic carbon under humid temperate conditions.[31]

No-tillage farming has revolutionised the way Australian farmers can produce grain with less physical effort, less fuel and less erosion and environmental impact.

The terms 'no-tillage', 'direct drilling' or 'direct sowing' collectively refer to any method of sowing or system of crop establishment whereby seed is placed into previously untilled soil, in contrast to conventional seeding, which may have several tillage operations prior to seeding.

The discovery of the bipyridinium herbicides paraquat and diquat in 1954, and subsequent commercial release in 1961, was a key factor that drove farming systems scientists to initiate intensive research into no-tillage farming systems.

In 1970, the discovery of the systemic herbicide glyphosate further increased the global research effort in no-tillage farming, particularly due to its improved efficacy on a broad range of weed species compared with other herbicides.

No-till crop production systems have been transformational in terms of reducing soil erosion and environmental impacts of crop production, while significantly improving the reliability of sustainable crop production. No longer do we see the regular dust storms as we did in previous decades.

Pesticide fact – No-till pesticides a key tool for conservation agriculture adoption

With an effective alternative weed control system to replace tillage prior to sowing, the practice of no-tillage farming has since gained global momentum. The widespread use of genetically modified crops in recent years such as canola, maize and soybeans resistant to glyphosate and glufosinate has significantly facilitated increased adoption of no-tillage farming systems and resulted in substantial environmental benefits.

31 www.fao.org/3/I9542EN/i9542en.pdf

Integrated Pest Management (IPM) and resistance management

Integrated Pest Management (IPM) systems combine effective monitoring and use of all effective pest control technologies to reduce the incidence of catastrophic pest populations and reduce the volume of agrochemicals used in the production of high yielding crops. Nearly two thirds of Australian grain growers today have adopted integrated pest management practices.[32]

Pesticide fact – Integrated Pest Management (IPM)

No single pest management strategy will work reliably in all managed or natural ecosystems.

Pesticide use should be evaluated in conjunction with all other alternative management practices not only with respect to efficacy, cost and ease of implementation but also with respect to long-term sustainability, environmental impact and health.

Crop protection products are integral to a successful IPM approach to managing pests, weeds and disease. However, the development of resistance to these crop protection products continues to increase in Australian agriculture and around the world, occurring in as little as two to four years if not managed appropriately.[33]

Resistance management is an integral part of IPM and an essential stewardship approach to maintaining the efficacy of critical crop protection products. Access to fewer crop protection tools would facilitate faster development of resistance among target pests, diminishing the efficacy of remaining chemical options. This makes the adoption of an effective resistance management strategy for chemical crop protection products vital to the long-term viability and profitability of Australian farming. Herbicide-resistant weeds represent the single largest threat to Australian and global food security and cost the Australian grains industry more than $200 million each year.[34]

While pesticide resistance costs the global agriculture sector tens of billions annually, the cost of pesticide resistance could be considered impossible to value in terms of its impact on human lives. If insecticide-coated bed nets and complementary insecticide spraying failed to slow the transmission of malaria by pesticide-resistant mosquitoes, the human health costs in Africa and Asia could be catastrophic.[35]

Understanding a pesticide's mode of action, or the way the active ingredient works on the target pest, is key to managing resistance. The more frequently farmers use the same mode of action, the more likely resistance will occur. Rotating and mixing different modes of action is one way to delay or avoid resistance.

Australia was the first country in the world to introduce a recognised resistance classification scheme integrated with resistance management strategies, including mandatory mode of action labelling on registered product labels.[36]

32 GRDC grower survey 2017 https://grdc.com.au/__data/assets/pdf_file/0034/328966/GRDC-Grower-Survey-2017-Report.PDF

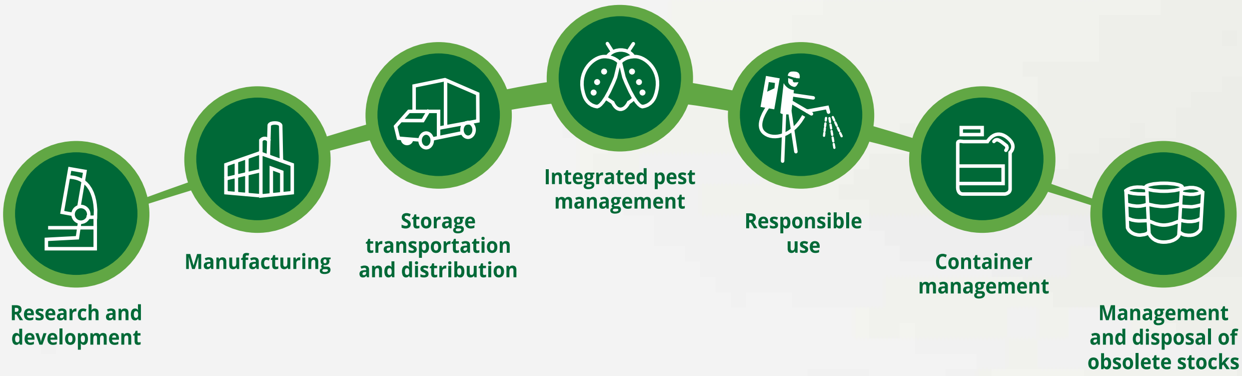
33 www.fao.org/3/a-bt561e.pdf

34 https://weedsmart.org.au/the-high-cost-of-herbicide-resistance/

35 Gould, F., Brown, Z.S. and Kuzma, J. (2018) *Wicked evolution: Can we address the sociobiological dilemma of pesticide resistance? Science*; 360 (6390): 728.

36 www.croplife.org.au/wp-content/uploads/2020/06/Herbicide-Resistance-Management-Strategies.pdf

Agricultural chemical product lifecycle



Case study: How are growers guided?

"Pesticide resistance is primarily managed by following the guidelines provided by CropLife which are published in the Accolade Wines Spray Policy and Spray Diary. Resistance Management Strategies give us the information we need to guide our growers in best-practice resistance management. All of our growers are advised to follow these strategies and their adherence to the strategy is monitored through analysis of their spray diaries."

Senior viticulturist for CCW Co-operative Limited, Ian Macrae. With 530 winegrape grower members in South Australia's Riverland region, CCW covers around 7,530 hectares of winegrapes, producing on average 200,000 tonnes.

Pesticide stewardship

Modern crop protection products and tools are a foundation of food production. The safe and sustainable use of these products is of critical importance. Successful stewardship requires collaboration, engagement and support by all stakeholders.

Stewardship is a whole-of-life-cycle approach to responsible and ethical product management – from discovery and development to use and final disposal of any waste. The overall aim of the stewardship approach is to maximise the benefits and minimise any risk from using crop protection products.

Industry stewardship is an important part of modern farming as it fosters the responsible and sustainable use of pesticides.

Successful stewardship requires collaboration, engagement and support by all stakeholders. Where this occurs, the community can be assured that best practices are being consistently applied for the safety of users, consumers and the environment.

CropLife Australia Resistance Management Strategies can be searched at croplife.org.au/resistance

Future innovations in plant protection

New chemical and biotechnology products are being developed to ensure that food remains available to a growing world and is produced in a manner that protects human and environmental safety.

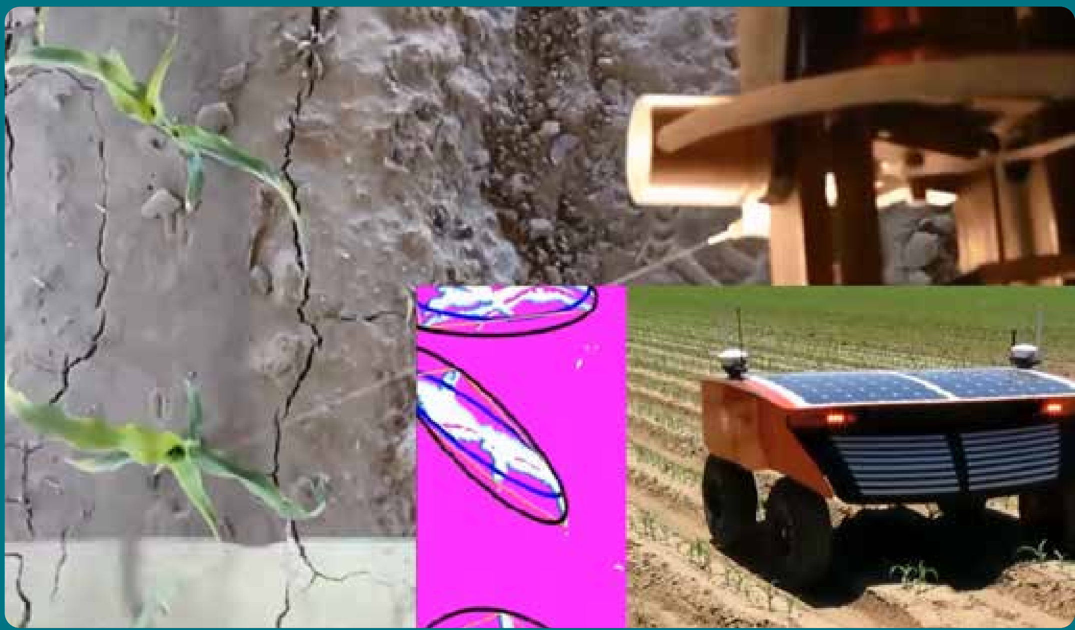
For Australian producers to remain internationally competitive, they must have access to the world's best crop protection technologies, including agricultural biotechnologies, RNAi and biologicals. It is essential that these new technologies are accessible in a timely manner with science-based regulatory certainty.

Pesticide fact – What we gain from innovation

Ever wonder what innovation actually looks like in agriculture?

New pesticide spray application technologies continue to advance the efficacy and targeting of crop protection products. Technologies such as innovative spray nozzles, camera spray technologies, spray shrouds, air assist systems and new chemical adjuvants can be used to improve spray targeting, manage spray drift, reduce chemical use and subsequently, on-farm costs. Improved chemical loading and mixing systems improve farm spray application efficiency and operator safety. Differential GPS guidance and auto-steer with automatic spray section control reduce overlap, wastage and crop damage, while reducing pest, weed and disease escapes from underlaps.

Australian farmers are renowned for their enthusiastic and rapid adoption of new technologies and innovations and were the first in the world to embrace the use of autonomous tractors, including the use of robots for pesticide application. Autonomy and the use of robot technology will be an important tool in the future for further improving the safety and environmental stewardship of pesticide use.



Used with permission Agerris Pty Ltd Source www.youtube.com/watch?v=Li9eWpLGFiU

Case study: Australian application innovation, development of camera sprayers

Reflectance activated spot spraying, known today as camera spray technology, was originally developed in Australia from research conducted in Tamworth in the 1980s[41] but was eventually commercialised overseas. Used successfully across Australia for many years for green (weeds) on brown (bare earth) fallow weed control, this technology has reduced chemical use by more than 90 per cent. Camera spray technology is now off-patent and has been developed into a number of systems globally.

A new Australian designed precision ground vehicle is RIPPA™ (Robot for Intelligent Perception and Precision Application). VIIPA™ (Variable Injection Intelligent Precision Applicator) is shown here autonomously shooting weeds at high speed using a directed micro dose of liquid.

Food and nutritional security

Feeding the world into the future

Crop protection products are a key tool used to improve food quality, keep people healthy, protect the environment and make a significant contribution to both the Australian and global economies. Famine from crop disease and invertebrate pests has been reported and documented over many thousands of years.

The increase in worldwide production of staple foods such as rice, wheat and maize is the result of foundational use of crop breeding, improved agronomy and the reduction of crop losses through the use of pesticides to control weeds, pests and diseases.

It is estimated that the worldwide universal adoption of pesticides for controlling weeds, insects, and disease pathogens has delivered production gains in rice of 26 per cent (156 million tonnes), wheat by 18 per cent (106 million tonnes) and maize by 18 per cent (132 million tonnes).[37]

Crop losses due to pests and diseases can range from 10-90 per cent, averaging 35-40 per cent, for all potential global food and fibre crops.[38] Losses despite the current crop protection practices are about 50 per cent in wheat and 40 per cent for maize, rice and potatoes.[39] These crop losses continue to present the risk of famine across the world.

Pesticide fact – Ensuring food security

There will be no sustainable future without eradicating poverty and hunger. Ensuring food security for all is both a key function of and a challenge for agriculture, which faces ever-increasing difficulties as populations rise, urbanisation increases and incomes grow. The agricultural sector will continue to be under mounting pressure to meet the demand for safe and nutritious food.[40]

37 Gianessi , L.P. (2013) The Potential for Worldwide Crop Production Increase Due to Adoption of Pesticides; Rice, Wheat & Maize. Croplife Foundation.

38 Peshin R. (2002) Economic Benefits of Pest Management. Encyclopedia of Pest Management, Marcel-Dekker 224-227.

39 Oerke, E.C. (2006) Crop losses to pests. Journal of Agricultural Science (2006),144, 31–43.

40 FAO. 2018. The State of Agricultural Commodity Markets 2018. Agricultural trade, climate change and food security. Rome.

Pesticide fact – Managing rice production and food security in Asia

Rice blast (*Magnaporthe oryzae*) is a key challenge in combating global food security given the disease is responsible for approximately 30 per cent of rice production losses globally—the equivalent of feeding 60 million people.[41] Application of mainly systemic fungicides is the most common and effective method to control blast disease in rice. They are applied in different ways as seed treatment, soil drenching and foliar spray. However, in developing countries, poor farmers sometimes cannot meet the expense of pesticides to control blast disease.[42]

Globally, crops must compete in fields with:

Weeds **Pests** **Diseases**

...and in storage, bugs, moulds and rodents can also cause damage!

26-40% of potential crop production worldwide is lost annually to pests. Without crop protection, losses to fruit and vegetable crops could easily reach 50-90%.

41 Nalley L, Tsiboe F, Durand-Morat A, Shew A, Thoma G (2016) Economic and Environmental Impact of Rice Blast Pathogen (*Magnaporthe oryzae*) Alleviation in the United States. PLoS ONE 11(12): e0167295. https://doi.org/10.1371/journal.pone.0167295

42 Srivastava, Deepti & Shamim, Md & Kumar, Mahesh & Mishra, Anurag & Pandey, Pramila & Kumar, Deepak & Yadav, Prashant & Siddiqui, Mohammed & Singh, Kapildeo. (2017). Current Status of Conventional and Molecular Interventions for Blast Resistance in Rice. Rice Science. 25. 10.1016/j.rsci.2017.08.001.

Crop protection products protect much of the world's field crops, vegetables, fruit and nut crops to reduce risks of crop loss, global malnutrition and starvation.

...pesticides reduce risks of crop loss, global malnutrition and starvation.

Environmental conservation

Ensuring environmental health

Protecting the Australian environment is a battle for environmental land managers. The Australian environment is constantly under attack from invasive weeds and other pests. Like farmers, Australia's environmental land managers, such as the parks and wildlife services, rely on the use of pesticides to effectively defend and protect our natural environment from threats.

Invasive weeds and other pests can have major negative impacts on Australia's natural environments as they can damage the diversity and balance of ecosystems. These changes threaten the survival of many native plants and animals because weeds compete for space, moisture, nutrients and sunlight.

The plant science industry provides Australia's land managers with the innovative tools that are crucial to controlling invasive weeds and pests throughout Australia's national parks, in public parks, golf courses, gardens and to control weeds alongside roads, buildings, pathways and other public infrastructure.

Invasive species: The greatest threat to Australia's endangered wildlife

Endangered species face numerous threats, including development, pollution and climate change. The greatest threat they face is from established invasive species. Crop protection products are crucial tools employed by environmental land managers in protecting Australia's endangered species.

Without the use of a range of specialised pesticides and the hard work of park rangers, spray contractors and other environmental land managers, ecosystems such as those in the Kosciuszko National Park would succumb to the significant threat of invasive species.

Case study: Pesticides for sustainable environment management

In a great example of environmental conservation targeted weed control, the ACT Parks and Conservation Service has used the tools of the plant science industry to successfully control the spread of blackberries in the wet sclerophyll forests of the northern area of the Namadgi National Park.

While we all love blackberries in fruit salad, in the pristine environments of national parks the blackberry bush can spread rapidly if not controlled, destroying the native flora and compromising the natural ecosystem.

The plant science industry provides Australia's environmental land managers with the innovative tools that are crucial to controlling invasive weeds and insects throughout Australia's world-renowned national parks.

Responsible pesticide application

While the adoption of no-tillage farming practices has contributed greatly to the environmental sustainability of Australian agriculture, it has also presented growers with additional challenges. Producers have been required to step up their responsibility in practicing appropriate product stewardship, particularly in relation to managing spray drift, which can be impacted by unforeseen weather events, such as sudden wind gusts and air inversion events at dusk, overnight and dawn.

The application of crop protection products, whether from a ground boom sprayer, knapsack or aerial platform, needs to be properly planned and carefully executed to minimise the risk of off-target chemical movement. The most common cause of off-target movement is spray drift.

Spray drift is the movement of agricultural chemicals through the air away from the target site of application. Drift leads to economic and productivity losses, potential neighbouring crop damage and loss of beneficial insects. If not managed responsibly, in certain climatic conditions drift can spread kilometres away from the intended target site of application.

Case study: Responsible application of crop protection products – A community approach

A passionate group of Macquarie Valley grain and cotton farmers, agricultural chemical suppliers and agronomists have joined forces to address concerns related to off-target spray drift in the region. The Stop Off-target Spray Macquarie Valley (SOS MV) runs a range of community-led activities to engage with local farmers and drive change in spray application behaviours.

The success of this community-focussed approach has seen farming communities in other regions keen to implement similar programs, with SOS Riverina Valleys now operational. The SOS team is working with industry stakeholders and the NSW Environment Protection Authority to expand the SOS platform across NSW.

By expanding throughout NSW, the SOS team aims to support local communities to take ownership and drive better pesticide spray practices in their own regions. This would be achieved by establishing structures for collaboration, building awareness and capability, developing relationships, coordinating initiatives, reducing duplication of effort and facilitating resource and knowledge sharing.

Find out more:
facebook.com/SOSMacquarieValley
facebook.com/SOSRiverinaValleys

Pollinator protection

While farmers need access to safe and effective pesticides to continue to feed and clothe the growing global population, they are also reliant on a healthy and growing pollinator population. Bees are very important to both the natural environment and Australian agriculture, with 65 per cent of Australian crops reliant on honeybees for pollination.[43] Responsible pesticide use is therefore just as important to farmers as it is to beekeepers.

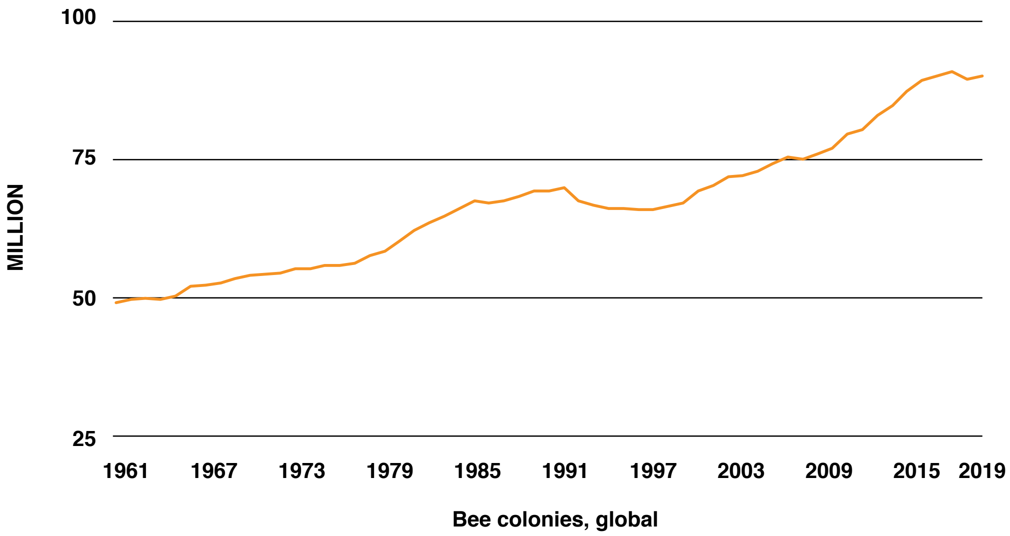
For several years, there has been a plethora of media articles and web blogs on the apparent decline of the world's European honeybee population. However, research proves the reality is something very different.

Australia continues to have one of the healthiest honeybee colonies in the world[44] and year after year it has been growing. Alongside the responsible management of hives and good farming practices, this is largely due to Australia being free of the parasitic mite *Varroa destructor* and Colony Collapse Disorder, which have devastated some bee colonies overseas.

Registered beekeepers in Australia have increased from 13,000 in 2014-15 to over 30,000 today, operating approximately 669,000 hives, providing pollination services worth $4-6 billion per year.[45]

While pollinator health is complex and multifactorial,[46] experts agree that the biggest threats to bees are the *Varroa destructor* mite, apiary management and loss of native habitat through climate change and fires, urbanisation and the intensification of farming, which have resulted in less forage diversity.[47,48]

FIGURE 03: THE GLOBAL HONEYBEE POPULATION HAS RISEN BY NEARLY 65% SINCE 1961



Source www.fao.org/faostat/en/#data/QA

43 https://honeybee.org.au/pdf/PollinationAwareFactSheet.pdf
44 https://ecos.csiro.au/its-official-our-honey-bees-are-some-of-the-healthiest-in-the-world
45 www.planthealthaustralia.com.au/industries/honey-bees
46 https://static1.squarespace.com/static/59b55b2b37c581fbf88309c2/t/5a2f5a149140b7e21b646daa/1513052694656/Pollinator-Health-Puzzle.jpg
47 EFSA. Towards holistic approaches to the risk assessment of multiple stressors in bees. EFSA Scientific Colloquium Summary Report, 15–16 May 2013, Parma, Italy
48 www.ipbes.net/global-assessment-report-biodiversity-ecosystem-services

Varroa destructor is a parasite of honeybees, which feeds on the fat body and haemolymph (the bee version of blood) of both larvae and adult bees, exhausting them and making them more susceptible to viruses.[49] Together, *Varroa destructor* and the Deformed Wing Virus have been one of the most common causes of colony losses worldwide over the last 50 years.[50]

Nevertheless, pesticides, particularly 'neonicotinoids' are often highlighted as one of the main contributors to poor honeybee health. Large-scale losses of honeybee colonies are not new to beekeeping. In fact, reports of this nature can be found around the world as far back as 1869. Most of these reports occurred before the introduction of neonicotinoid pesticides in the 1990s.[51] The weight of scientific evidence, including real-world scenario field trials, does not support the claim of neonicotinoid pesticides impacting on bee decline. Australia has been using neonicotinoid insecticides since 1990 and has not reported increased honeybee losses.[52]

In Australia, neonicotinoids are applied as a coating on seeds, rather than being sprayed over the top of a crop. Seed treatment uses anywhere from four to 20 times less pesticide per plant compared to foliar spray.[53] In this scenario, bee exposure is very low, because only very tiny traces (about one drop in an Olympic-sized swimming pool) of the substance is found in the flowers, particularly the nectar and pollen, of plants grown from treated seed.[54-58] Under realistic field conditions, these concentrations have been shown to be safe to honeybees. Use of seed treatments is an appropriate IPM and environmental strategy, especially when planting pest-sensitive crops in areas that have traditionally high pest levels.

Case study: Pesticide stewardship – Seed Treatment Stewardship Strategy

Seed treatments are an excellent example of how the seed and crop protection industries provide Australian farmers with pioneering tools to deliver better outcomes for Australian agriculture.

Seed treatments act as a delivery mechanism for pest and disease management products to improve crop production and yield opportunities. They are specifically tailored to meet farmers' pest and disease control needs while minimising risks to health, safety and the environment.

CropLife Australia's Seed Treatment Stewardship Strategy includes four specific stewardship and best practice guides. These outline measures to reduce risks from dust generated during handling and planting of treated seed and provide guidance on industry best-practices to minimise off-target movement of pest and disease management products.

Find out more at croplife.org.au/seed-treatment-stewardship-strategy

49 Alaux C, Dantec C., Parrinello H, Le Conte Y: Nutrigenomics in honey bees: digital gene expression analysis of pollen's nutritive effects on healthy and varroa-parasitized bees. BMC Genomics 2011, 12:496.

50 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0079018

51 www.ncbi.nlm.nih.gov/pmc/articles/PMC2715894/pdf/pone.0006481.pdf

52 Mcafee, A. (2017). A brief history of pesticides. American Bee Journal. 157. 781-783.

53 Maus, Ch., Curé, G., Schmuck, R. (2003): Safety of imidacloprid seed dressings to honey bees: a comprehensive overview of compilation of the current state of knowledge. Bulletin of Insectology: 56: 51-57.

54 https://apvma.gov.au/node/18541

55 Schmuck, R., Keppler, J. (2003): Clothianidin – Ecotoxicological profile and risk assessment. Pflanzenschutz-Nachrichten Bayer: 56: 26-58.

56 Schmuck, R., Schöning, R., Sur, R. (2005): Studies on the Effects of Plant Protection Products Containing Imidacloprid on the Honeybee, Apis mellifera L. In: Forster, R., Bode, E., Brasse, D. (Hrsg): Das ‚Bienensterben' im Winter 2002/2003 in Deutschland – Zum Stand der wissenschaftlichen Erkenntnisse. Bundesamt für Verbraucherschutz undLebensmittelsicherheit (BVL), Braunschweig: 68-92

57 Blacquière, T., Smagghe, G., van Gestel, C.A.M., Mommaerts, V. (2012): Neonicotinoids in bees: a review on concentrations, side-effects and risk assessment. Ecotoxicology, DOI: 10.1007/s10646-012-0863-x.

58 Pilling, E., Campbell, P., Coulson, M., Ruddle, N., Tornier, I. (2013): A Four-Year Field Program Investigating Long-Term Effects of Repeated Exposure of Honey Bee Colonies to Flowering Crops Treated with Thiamethoxam. PLOS ONE, e77193. doi: 10.1371/journal.pone.0077193

Pesticide fact – Neonicotinoid effect on honeybees

Q: Can neonicotinoids affect honeybees sublethally, by altering their homing ability or foraging behaviour?

A: No studies conducted under realistic environmental and use conditions have demonstrated chronic or sublethal effects caused by neonicotinoids. Some studies have reported sublethal effects on honeybees following neonicotinoid exposure. These studies frequently used higher concentrations than would be seen in realistic field conditions, as well as other unrealistic exposure and unvalidated test procedures.[69-69]

Improper use of pesticides, however, including spray drift onto bee colonies from farms while forage plants (including agricultural crops) are flowering can cause harm to bees.

CropLife's Pollinator Protection Initiative, launched in 2014, includes the Seed Treatment Stewardship Strategy, as well as the award-winning BeeConnected app. This initiative provides resources to ensure modern, innovative crop protection products are used responsibly and in a manner that minimises risk to pollinators.

BeeConnected™

Case study: Pesticide stewardship – BeeConnected – connecting beekeepers and farmers

Building on the success of BeeConnected in Australia, CropLife Australia is now working with organisations across the globe to roll out the award-winning app to help protect bees. This world-first smart phone app and web tool launched in Australia in 2014 and has now been launched by CropLife in Asia, Canada and Brazil.

BeeConnected connects registered beekeepers with registered farmers and contractors, enabling two-way communication on the location of hives and crop protection activities. Contractors and farmers are able to input information on their crop protection activities that may be of interest to a beekeeper and beekeepers are able to notify nearby farmers of the location of their hives. This opens up a line of communication through an internal messaging system.

BeeConnected assists in ensuring the safety of bees pollinating close to spraying activities. The free app can be downloaded on both Apple and Android or accessed via desktop.

Find out more at croplife.org.au/beeconnected

59 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0168603
60 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5093180/
61 https://setac.onlinelibrary.wiley.com/doi/abs/10.1002/etc.3183
62 https://journals.
63 https://peerj.com/articles/652.pdf plos.org/plosone/article?id=10.1371/journal.pone.0118748
64 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0077193
65 https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0030023
66 http://www.apidologie.org/articles/apido/full_html/2010/03/m09161/m09161.html
67 https://jee.oxfordjournals.org/content/102/2/616
68 https://academic.oup.com/jee/article-abstract/100/3/765/2198751?redirectedFrom=fulltext
69 https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.12689

Chemical container recycling

For over 25 years, Agsafe, CropLife Australia's internationally recognised and awarded stewardship organisation, has worked with rural businesses to promote workplace health and safety practices regarding agricultural and veterinary products. By becoming a member of Agsafe, premises are supported in understanding their responsibilities amid the complex and detailed regulatory requirements for managing dangerous goods and hazardous agricultural and veterinary chemical products in a manner that minimises any potential risks to workers, customers, the community and the environment.

Agsafe is improving environmental stewardship throughout regional Australia through the stewardship programs ***drum****MUSTER* and ChemClear®. These stewardship programs are funded by a levy (6c per litre/kg) that product manufacturers pay to AgStewardship Australia.

Since ***drum****MUSTER* started operations in 1999, more than 41,000 tonnes (36.8 million containers) of agricultural and veterinary plastics have been diverted from landfill sites into recycling programs. There are over 800 collection sites throughout Australia for farmers and chemical users to deliver their drums, including over 350 local council sites.

Given the safety imperatives of proper chemical disposal, Agsafe developed ***drum****MUSTER*'s sister program, ChemClear®, in 2003 using funds from the ***drum****MUSTER* levy. ChemClear® operates as a collection and disposal service for unused or obsolete agricultural and veterinary chemicals. Farmers and other agricultural industry professionals register their waste with the program and relinquish chemicals for safe disposal. Group one chemicals, including those housed in their original container with a readable label and participating in the ***drum****MUSTER* program, are eligible for free collection.

Case study: Pesticide stewardship – A recycling success story *drum* ***MUSTER***

The container recycling management program has already saved councils an impressive $31 million in landfill costs, by diverting empty, clean containers towards recycling schemes since 1999. This has provided chemical users with an affordable, accessible way to dispose of unwanted drums.

It is only by collaborative efforts that Australia's oldest product stewardship program continues its success, with 814 collection sites operated by 350 councils and more than 100 other collection agencies nationwide.

Dookie Lions Club near Shepparton, Victoria has been operational for 44 years and has collected 40,000 drums since 2013, raising $10,000 towards a public fitness station operating in Dookie.

"The ***drum****MUSTER* program is great for community groups like us as the funds go straight back into the local area and it's great to see the environmental benefits," said club member and ***drum****MUSTER* inspector, Peter McManus.

"People understand that by working with ***drum****MUSTER* we help farmers keep their farms clean and seeing what we've achieved, the club wants to keep going."

As an extension to ***drum****MUSTER*, ChemClear® operates a collection service for unwanted agvet chemicals in each state and territory through an online booking service.

Find out more at www.agsafe.org.au

Managing biosecurity risk and containment

Pesticides are a key tool in industry biosecurity response plans for exotic pests, both for containment response following incursion and when containment fails and industries quickly have to turn to ongoing pest management options.

The National Priority Plant Pests is a list of the most serious exotic plant pest threats to Australia's agricultural production.[70] The Department of Agriculture, Water and the Environment is currently developing national action plans for the National Priority Plant Pests.

The Australian grains industry has strategic plans in place for exotic pests, including surveillance of exotic cereal rust pathotypes, plus planning measures to address the threat of exotic incursions of pests and pathogens, such as race Ug99 and its derivatives.[71]

Pesticide fact – Emergency pesticide permit, a key component for RWA control

The incursion of Russian Wheat Aphid (RWA) into Australia in 2016 presented significant issues for the Australian grains industry in terms of potential yield loss and control costs. The grains industry's coordinated and well-managed response was largely the result of a formalised pre-planned management and containment plan. This included surveillance, biotyping programs and trials already undertaken to support the establishment of an emergency pesticide control permit with the APVMA.

If left untreated, yield losses from RWA can reach 50 per cent and losses of up to 0.5 t/ha have been reported in South Australia. A number of insecticides have been an essential tool for producers in managing the devastating impact of this insect pest.

Similarly, various biosecurity plans and surveillance programs have been developed by the sugar, forestry, honeybee, nursery and horticulture industries including fruit, grapes and vegetables.[72] The Emergency Plant Pest Response Deed (EPPRD)[73] is a formal legally binding agreement between Plant Health Australia, the Australian Government, all state and territory governments and various national plant industry bodies. The EPPRD outlines the management and funding of responses to emergency plant pest incidents.

Each of the national plant industry signatories on the EPPRD has developed a national biosecurity plan. Currently, there are 35 national biosecurity plans, covering various fruits, vegetables, tree nuts, truffles, grains, honeybees, coffee, sugarcane, viticulture, cut flowers, nurseries, plantation forests, rice and tea tree.

A number of significant exotic pest threats to Australia's $1.64 billion horticulture crop have been identified and biosecurity plans developed to combat them, should they reach Australia's shores. It is estimated that more than 92 per cent would be dramatically impacted by the American serpentine leafminer, while more than 73 per cent would be significantly impacted by an incursion of the brown marmorated stink bug.[74] Of the damaging pests already present in Australia, the diamondback moth is considered the main insect pest of brassica vegetables, including cabbage, cauliflower, broccoli etc. This destructive pest attacks 136,000 hectares of major brassica crops in Australia every year. Managing resistance is critical to ensuring the industry continues to have access to critical crop protection products to manage diamondback moth in Australia.

70 www.agriculture.gov.au/pests-diseases-weeds/plant/national-priority-plant-pests-2019

71 Rainbow, R.W. (2011) Fungicide strategies for managing the Ug99 stem rust threat - Australian and international perspectives. Borlaug Global Rust Initiative Technical Workshop 13-16 June 2011 in St. Paul, Minnesota USA.

72 www.planthealthaustralia.com.au/national-programs/national-plant-biosecurity-status-report/

73 www.planthealthaustralia.com.au/biosecurity/emergency-plant-pest-response-deed/

74 https://ausveg.com.au/app/uploads/2020/02/Vegetable-BP-v3.1.pdf

Pesticides – A key tool for rapid biosecurity response

The APVMA administers an emergency use permit scheme, which allows for the legal use of chemicals in the event of a pest incursion. Situations where the proposed use is generally unforeseen, such as the outbreak of an exotic pest or disease or where unusual weather patterns have caused higher or more frequent pest or disease incursions, are considered to be an emergency.[75] An emergency use permit is issued provided sufficient scientific data is available for the regulator to be satisfied that the same safety, trade and efficacy requirements necessary for product registration can be met.

The grains industry is well prepared for future incursions to a range of exotic pests of winter cereal, maize, pulse and oilseed crops,[76] with emergency permits in place for pesticide control of various exotic pests such as Khapra beetle,[77] sunn pest and cabbage seed weevil in various field crops.[78] Similarly, emergency response permits are currently in place for the devastating exotic pest citrus canker[79] and the exotic leaf miner in root and leafy vegetables.[80]

It is critical that Australian producers and the community have access to pesticides to contain or control exotic pests in crops and plants. It is estimated that the combined cost (economic losses and control) of invasive species in Australia during 2001-02 was $9.8 billion. This rose to $13.6 billion in 2011-12.[81] Pesticides have a key role in reducing these impacts.

Case study: Pesticides for managing plague and loss

The Australian plague locust is the most serious pest species in Australia due to the frequency of outbreaks and the large areas infested. Locusts can cause widespread and severe damage to pastures, cereal crops and forage crops. In closely settled areas they may also damage vegetable and orchard crops.

The Australian Plague Locust Commission manages locust populations across 2 million square kilometres of eastern Australia using the aerial application of chemical and biological control agents to protect agricultural production. This occurs via a preventative control strategy involving ultralow-volume spray equipment to distribute small droplets of chemical and biological insecticides over a target area.[82] The economic value from chemical locust management in Australia is significant with the Australian population receiving a benefit-to-cost ratio of between 26:1 and 29:1.[83]

75 https://apvma.gov.au/node/10926
76 http://permits.apvma.gov.au/PER82267.PDF, http://permits.apvma.gov.au/PER80969.PDF and http://permits.apvma.gov.au/PER80964.PDF
77 http://permits.apvma.gov.au/PER85450.PDF
78 http://permits.apvma.gov.au/PER85447.PDF
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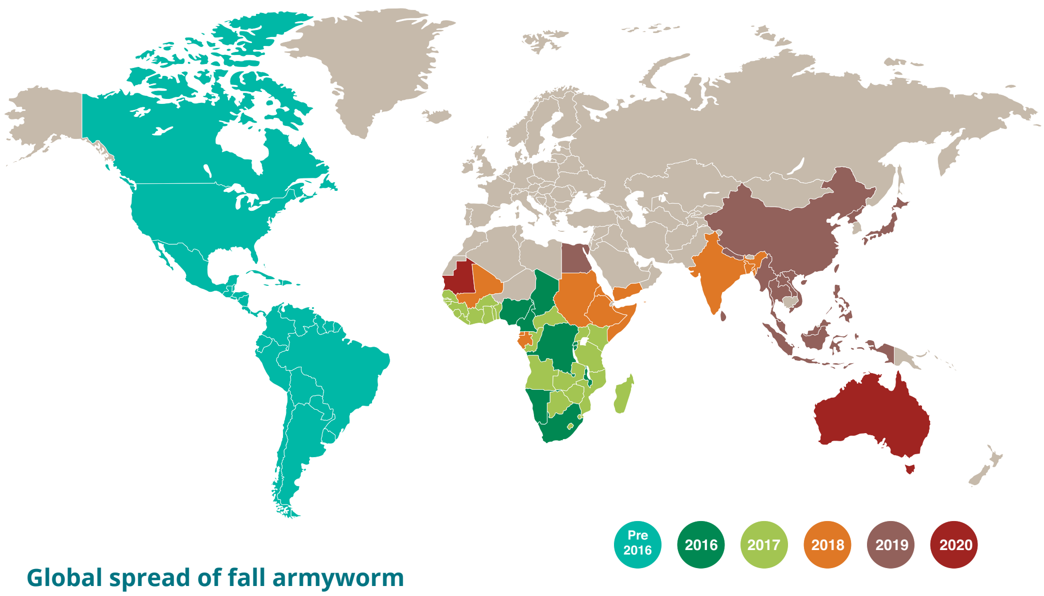
80 http://permits.apvma.gov.au/PER81876.PDF
81 Hoffmann BD, Broadhurst LM (2016) The economic cost of managing invasive species in Australia. NeoBiota 31: 1-18. https://doi.org/10.3897/neobiota.31.6960
82 Story, P.G., Walker, P.W,, McRae, H. nd Hamilton, J.G. (2005) A case study of the Australian plague locust commission and environmental due diligence: Why mere legislative compliance is no longer sufficient for environmentally responsible locust control in Australia. Integrated Environmental Assessment and Management. Volume 1, Number 3. pp. 245–251.
83 Wright, D.E. (1986). Economic assessment of the actual and potential damage to crops caused by the 1984 locust plague in southeastern Australia. J. Environ Management 23: 293–308.



Global spread of fall armyworm

Source: Adapted by GRDC from original FAO, used with permission. http://www.fao.org/fall-armyworm/monitoring-tools/faw-map/en

Case study: Pesticide tools to prevent global crop loss

Invasive insects cost a minimum of US$70 billion per year globally, while associated health costs exceed US$6.9 billion per year.[84] The recent incursion into Australia in early 2020 of the rapidly spreading global pest fall armyworm has highlighted why agriculture needs pesticide crop protection tools to prevent significant losses from this pest in a large number of crops.

Recent fall armyworm outbreaks in Africa and southern Asia have resulted in maize yield losses as high as 50 per cent. In Africa, where the pest arrived in 2016, it costs 12 major maize-growing countries a total of US$1–4 billion in lost crops a year.[85] Based on 2018 estimates, every year up to 17.7 million tonnes of maize are lost to this pest in Africa alone. This amount of maize could feed tens of millions of people and represents an economic loss of up to US$4.6 billion.[86]

There are several strains of fall armyworm including the C-strain (historically designated the corn-strain), typically found on corn, sorghum and cotton. The fall armyworm strain that has been detected in Australia is the r-strain (rice-strain), which is believed to favour small grass crops and maize.[87]

Emergency pesticide permits are a critical tool to contain or control incursions of exotic plant pests such as fall armyworm. The APVMA has approved more than 30 permits for control of this devastating pest since March 2020.

84 Bradshaw, C., Leroy, B., Bellard, C. et al. Massive yet grossly underestimated global costs of invasive insects. Nat Commun 7, 12986 (2016). https://doi.org/10.1038/ncomms12986

85 Nature: Caterpillar's devastating march across China spurs hunt for native predator https://www.nature.com/articles/d41586-019-01867-3

86 www.fao.org/news/story/en/item/1253916/icode/

87 Good Fruit and Vegetables: www.goodfruitandvegetables.com.au/story/6662483/armyworm-continues-march-across-nq/ (accessed on 31/03/2020)

Delivering safe food

Delivering food safety with pesticides

While only a very small number of food safety issues in the past 20 years have been associated with fresh produce in Australia, infrequent contamination of fresh produce with pathogenic microorganisms can occur.[88]

Growers value the investment in development of crop protection product labels which deliver market confidence for agricultural produce, including compliance with market maximum residue limits or MRLs.

Confidence in markets

While Australian agriculture is a relatively small market in a global context, it is a major global exporter of food produce. The recent free trade agreements signed with a number of international markets have increased opportunities for Australian growers to deliver high-quality crop food and animal feed produce. Domestically, market demand is increasing for a greater diversity of foods to meet the needs of our multicultural society.

Australia has a robust regulatory system for crop protection products, which ensures that the product delivered by agricultural industries is safe for human consumption. This confidence can be demonstrated by the significant investment in the development of crop protection products and the comprehensive information contained on crop protection product labels.

Pesticides for food toxin management

Mycotoxins are naturally occurring toxic compounds produced by certain types of moulds. Moulds that can produce mycotoxins grow on numerous foodstuffs such as cereals, dried fruits, nuts and spices. Mould growth can occur before harvest or after harvest, during storage and on/in the food itself often under warm, damp and humid conditions. Most mycotoxins are chemically stable and survive food processing. The effects of food-borne mycotoxins can be acute with symptoms of severe illness and even death appearing quickly after consumption of highly contaminated food products. Long-term effects on health of chronic mycotoxin exposure include the induction of cancers and immune deficiency.

There are, however, a number of historical, current and potential threats to food and feed safety from naturally occurring mycotoxins. This includes aflatoxin in peanuts and maize, plus deoxynivalenol in wheat and maize, which are well-known and managed using pesticides and other management practices by producers. Increased adoption of conservation farming practices including stubble retention, while significant for environmental sustainability, has increased the risk of human food and animal feed toxins. Fungicides used in crop production are a key tool to manage these food safety risks for consumers. Herbicides are also a key control strategy for weed contaminants containing the harmful pyrrolizidine alkaloid toxin.

Pesticides are a key strategy to manage food toxin risks, which are produced by plants as a natural defence mechanism against predators, insects or microorganisms.

88 www.foodstandards.gov.au/code/proposals/documents/P1015%20Horticulture%20PPPS%201CFS%20SD2%20Illness%20review.pdf

Confidence in produce

Most major agricultural industries in Australia demonstrate stewardship of crop protection products through an industry funded National Residue Survey (NRS). The NRS is a vital part of the Australian system for managing the risk of chemical residues and environmental contaminants in Australian food products. NRS programs encourage good agricultural practices, help to identify potential problems and indicate where follow-up action is needed.

The NRS is the public report card for agricultural industries to demonstrate the quality and safety of crop food and feed produce in meeting pesticide maximum residue level (MRL) requirements. The NRS confirms Australia's food safety credentials in using pesticides by facilitating access to key export markets and confirming Australia's status as a producer of clean food.

World-leading science and regulation

The World Health Organization (WHO), in collaboration with the Food and Agriculture Organization (FAO), is responsible for assessing the risks to humans of pesticides – both through direct exposure and through residues in food – and for recommending adequate protections.[89] Risk assessments for pesticide residues in food are conducted by an independent, international expert scientific group, the Joint FAO/WHO Meeting on Pesticide Residues (JMPR). These assessments are based on all of the data submitted for national registrations of pesticides worldwide from both supervised trials that reflect approved pesticide use in accordance with 'good agricultural practice', as well as all scientific studies published in peer-reviewed journals. After assessing the level of risk, the JMPR establishes limits for safe intake to ensure that the amount of pesticide residue people are exposed to through eating food over their lifetime will not result in adverse health effects.

JMPR conducts dietary risk assessments and recommends specific MRLs to the Codex Committee. The Codex Committee on Pesticide Residues (CCPR) is responsible for establishing Codex MRLs for pesticide residues in specific food items or in groups of food or feed that move in international trade. These acceptable daily intakes are used by governments and international risk managers, such as the Codex Alimentarius Commission (the intergovernmental standards-setting body for food), to establish MRLs for pesticides in food.

Codex standards are the reference for the international trade in food, so that consumers everywhere can be confident that the food they buy meets the agreed standards for safety and quality, no matter where it was produced.

Pesticide fact – Codex Alimentarius delivers global confidence

Codex Alimentarius[90] delivers international food standards, guidelines and codes of practice that contribute to the safety, quality and fairness of the international food trade. Consumers can trust the safety and quality of the food products they buy and importers can trust that the food they ordered will be in accordance with their specifications. Since its foundation in 1963, the Codex risk-based assessment system has evolved in an open, transparent and inclusive way to meet emerging challenges. International food trade is a US$2,000 billion a year industry, with billions of tonnes of food produced, marketed and transported. While Codex standards are recommendations for voluntary application by members, they often serve as a basis for national legislation. Australia is an active participant in Codex.

89 www.who.int/en/news-room/fact-sheets/detail/pesticide-residues-in-food

90 www.fao.org/fao-who-codexalimentarius/about-codex/en/

Food Standards Australia New Zealand (FSANZ) is an independent statutory agency that is part of the Australian Government's health portfolio delivering food safety to Australian consumers. Amongst the broad role of managing food safety risks in Australia, FSANZ assesses the risks of pesticide residues in the diet and works closely with the APVMA on these assessments. FSANZ is also responsible for considering requests to harmonise MRLs with international limits. The MRL harmonisation process looks at how Australian MRLs can align with international limits. FSANZ, under its legislated role, also has the objective of achieving consistency between domestic and international food standards when considering the development of the Food Standards Code.

Safeguards and regulation

Establishment of a trusted Australian pesticide regulator

From 1945 to 1993, each Australian state and territory had its own legislation in place to control the registration of chemicals, including agricultural and veterinary chemicals.

The National Registration Authority for Agricultural and Veterinary Chemicals was formed by the Commonwealth on 15 June 1993 as part of a microeconomic reform process to eliminate duplication and inconsistencies. As part of its establishment, it was agreed that specialist assessment advice would be provided by Commonwealth agencies in the areas of environment, human health and occupational health and safety.

When the NRS was introduced in 1995, the Australian Pesticides and Veterinary Medicines Authority (APVMA) assumed responsibility for over 5,000 chemical registrations granted under earlier arrangements by Australia's states and territories.

Pesticide fact – Chemical labels vs safety data sheet

Chemical label – the technical information about an agricultural chemical product in the form of printed material provided by the manufacturer or its agent, including the label, flyers, handouts, leaflets and brochures. Labels also include advisory statements – used to clarify the circumstances under which product use may be ineffective or hazardous due to extraneous factors not otherwise specified (or described) on the label. General advisory statements also endeavour to provide important information related to controlled use.

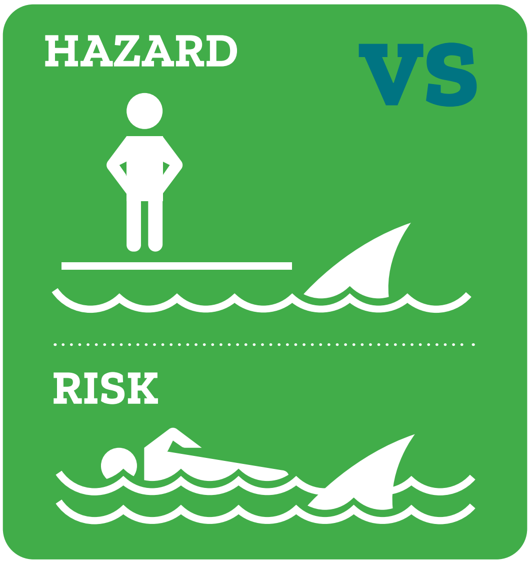
Safety data sheet (SDS) – an important information source for eliminating or minimising the risks associated with the use of hazardous chemicals (hazardous substances and/or dangerous goods) in workplaces.[91]

The APVMA in its role as an independent statutory authority under the Agvet Code has national authority to undertake evaluation, registration and control of agricultural and veterinary chemical products.

The APVMA is a world-class regulator that has the trust and confidence of producers and consumers.

The APVMA is responsible for the regulation and control of agvet chemicals in Australia up to the point of retail sale. The states and territories of Australia retain responsibility for control-of-use activities by producers and other pesticide users, such as licensing of pest control, operators and aerial spraying. Some states have also enacted legislation relating to the enforcement of the Code.

91 https://www.worksafe.qld.gov.au/injury-prevention-safety/hazardous-chemicals/managing-hazchem-risks/labelling-and-safety-data-sheets



Hazard vs risk – What is the difference?

Every day we are exposed to risks and hazards. While it may sound preferable to avoid them, it is simply not possible to avoid risks and hazards as they are present in nearly every action in our lives. That is why mitigating and managing risk is the most effective approach to safety. Understanding the difference between hazard and risk is essential when it comes to effective regulation.

A hazard is something that has the potential to harm people, including objects and processes. A risk is the probability that a hazard will harm an individual. Hazard does not change, but the risk changes enormously depending on how a hazard is mitigated.

Coming into contact with 240 volts of electricity represents a substantial hazard however, the humble power point switch, with earthing and a residual current device on circuits, reduces the risk of exposure to negligible levels. This risk mitigation method allows the safe use of many of life's creature comforts, despite the hazard.

With agricultural chemicals, the risk of hazard is effectively mitigated by formulation, packaging and the prescribed label use of the product with appropriate personal protective equipment.

A risk-based assessment by expert technical regulators is a superior and more appropriate approach to regulation than a hazard-based assessment. Information provided to users should be clear, specific and relevant to users to ensure compliance and the health and safety of workers.

Case study: The critical facts and need for regulator independence

Recent media reporting on the use of crop protection products containing the active ingredient glyphosate has been marred by serious factual inaccuracies and is misleading in regard to the context of the International Agency for Research on Cancer's (IARC) classification. Understanding the difference between a hazard and risk is essential when it comes to reporting on a complex and important issue such as this.

The IARC report is not a risk assessment. It very narrowly determines the potential for a specific compound to cause cancer under some circumstances, even if those circumstances are unlikely to occur in the real world. Coffee and aloe vera are 'possible' carcinogens according to the IARC's classifications.

All agricultural chemical products are subject to a chemical risk assessment that involves years of data collection and an exposure assessment to ensure their safety for human health and the environment. This process assesses in detail the likely exposure contact users, members of the public and the environment have and takes into account how the chemical product is to be used, the type and formulation of the product and the crop or animal to be treated.

The misrepresentation of the IARC report findings on glyphosate has been misleading and irresponsible.

It is critical that a science-based approach is taken for technical assessment and communication with the public. Unfortunately, pseudo-science is often used to misrepresent the facts, or sometimes the focus is on hazard rather than actual risk, which leads to misplaced political agendas by activists.

Pesticide fact – Glyphosate is safe to use according to regulators globally

All glyphosate products have been extensively and independently risk assessed by regulators including in the United States, Canada, Australia and Europe and found to be safe. Recent findings of the European Food Safety Authority have concluded that glyphosate is unlikely to pose even a carcinogenic hazard, let alone an actual risk.[92,93] In Australia, the APVMA regulates glyphosate and has concluded that the chemical can continue to be used safely according to label directions.[94] Glyphosate is degraded by soil microbes in a matter of days and does not accumulate in the environment.[95]

The impact of delayed regulatory decisions can significantly delay access to the innovation that our farming sectors desperately need to remain internationally competitive and become even more sustainable. An efficient, science-based regulator is essential to underpinning commercial delivery and producer access to these much-needed new crop protection technologies, which are safe to use and environmentally friendly.

Managing the threat of illegal pesticides

The global demand for productivity as well as higher-quality, healthier food has driven demand for agricultural chemicals. Unfortunately, this has been criminally exploited with illegal and counterfeit pesticides.

In Europe, illegal and counterfeit pesticides have been estimated to make up 10 per cent of the overall market. In India and China illegal pesticides are estimated to be around 30 per cent of the pesticide market. The counterfeit and illegal pesticide business is valued globally at approximately US$6.5 billion.

The global trade in illegal pesticides is an increasing risk for Australian agriculture and such products are a threat to human health, the environment and the nation's economy. Australia is fortunate to have an effective, robust, rigorous and science-based agricultural chemical registration system that requires all pesticide products to demonstrate their human health and environmental safety before they can be registered for use in Australia. Illegal (unregistered or counterfeit) pesticides are poor in quality and may contain dangerous contaminants.

CropLife Australia provides farmers with advice about how to identify and avoid buying illegal or counterfeit pesticides. Recent legislation changes have provided the APVMA with a comprehensive suite of new enforcement and compliance powers to counter the illegal sale of pesticides in Australia.

The Australian Government adheres to the Organisation for Economic Co-operation and Development Recommendation on Countering the Illegal Trade of Pesticides. The Recommendation promotes greater cooperation between countries, border force authorities and regulatory and compliance agencies to facilitate more rapid identification of and response to illegal trade of pesticides.

92 EFSA (2015) Conclusion on the peer review of the pesticide risk assessment of the active substance glyphosate. EFSA Journal;13(11):4302 www.efsa.europa.eu/en/efsajournal/pub/4302

93 www.efsa.europa.eu/sites/default/files/corporate_publications/files/efsaexplainsglyphosate151112en.pdf

94 https://apvma.gov.au/node/13891

95 la Cecilia, D. and Maggi, F. (2018) Analysis of glyphosate degradation in a soil microcosm. Environmental Pollution Volume 233, pp 201-207 h ttps://doi.org/10.1016/j.envpol.2017.10.017

Ensuring human health

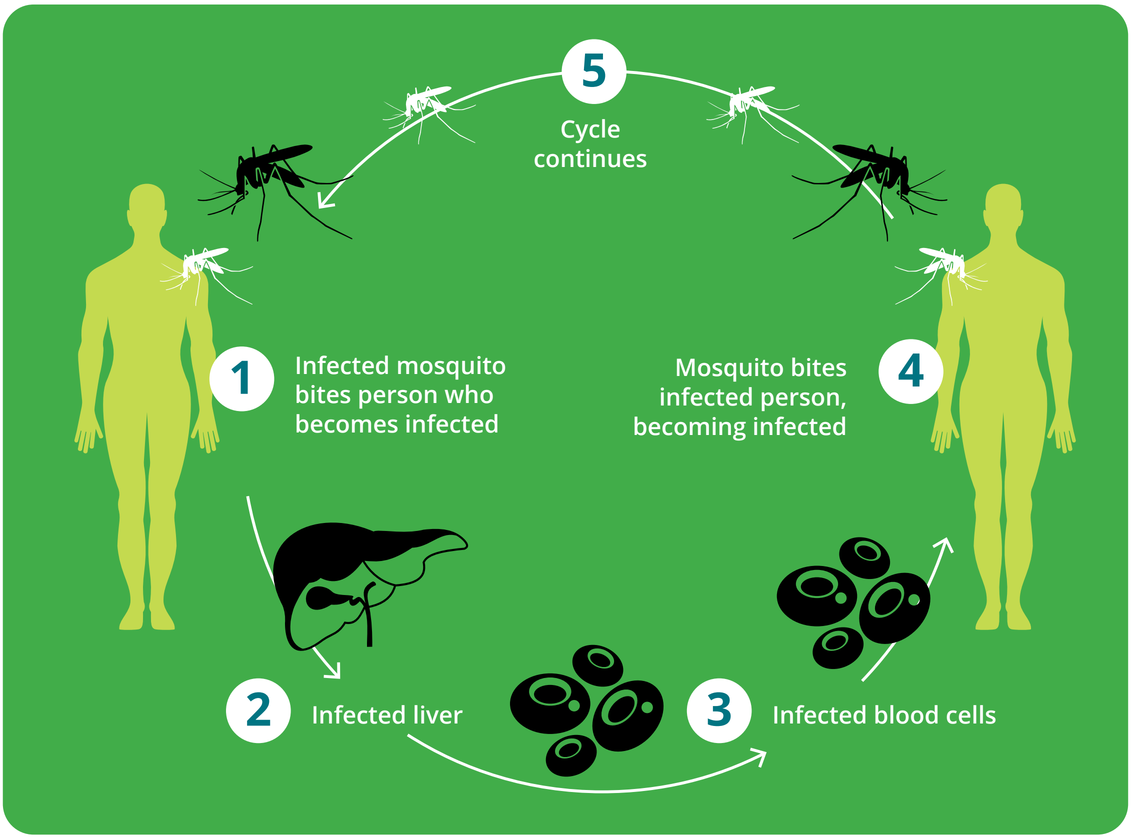
Pesticides for human disease vector management

Globally, pesticides have a major role in delivering human health outcomes including control of parasites that infect animals and humans, plus controlling the vectors involved with the transmission of parasites, viruses and other infectious diseases. The WHO states that vector-borne diseases account for more than 17 per cent of all infectious diseases, causing more than 700,000 deaths annually.

Vectors are living organisms that can transmit infectious diseases between humans or from animals to humans. Many of these vectors are bloodsucking insects, which ingest disease-producing microorganisms during a blood meal from an infected host (human or animal) and later inject it into a new host during their subsequent blood meal.

Mosquitoes are the most widely known disease vector. Others include ticks, flies, sandflies, fleas, triatomine bugs and some freshwater aquatic snails.

The world's most serious vector transmitted disease is malaria. Malaria is a life-threatening disease caused by *Plasmodium* parasites that are transmitted to people through the vector of bites from infected female *Anopheles* mosquitoes.[96] In 2017, there were an estimated 219 million cases of malaria in 87 countries with 435,000 malaria deaths. Children under five years of age are the most vulnerable group affected by malaria, accounting for 61 per cent of all malaria deaths worldwide, while Africa alone accounts for 92 per cent of malaria cases and 93 per cent of malaria deaths.[97] It is, however, preventable and curable.



96 www.who.int/news-room/fact-sheets/detail/malaria

97 www.who.int/malaria/publications/world-malaria-report-2018/en

Case study: Targeted pesticide use for malaria control

Since the *Anopheles* mosquito bites between dusk and dawn, sleeping under mosquito nets treated with insecticides provides critical protection against the spread of malaria. Insecticide treated nets can prevent around 50 per cent of malaria cases and has reduced child deaths by 18 per cent. Long-lasting insecticidal nets (LLINs) are the most cost effective and sustainable method for protection against malaria. LLINs are treated in factories with insecticide and last for approximately three years. While protecting people from infected mosquitoes, LLINs help reduce the overall number of mosquitoes by killing those that come into contact with the treated net.

Indoor residual spraying (IRS) is considered an effective means of mosquito (vector) control. IRS involves spraying internal walls and ceilings of dwellings using insecticides with residual action (i.e. insecticides that remain on the surface for a long time). Most vectors in Africa do prefer to rest indoors. The aim of IRS is to kill potentially infected *Anopheles* mosquitoes before the parasite they carry develops into an infective stage. There is a high probability that the mosquito will rest on a sprayed wall during the time that the Plasmodium parasite is developing to become infectious.

The IRS chemicals usually last between three and six months, preventing seasonal increases in malaria transmission, or may help to prevent and control epidemics. One of the main advantages of IRS is the ability to use a wide range of insecticide products. IRS can however be expensive due to the high operational costs and the precautions that need to be followed to ensure its effectiveness and that it meets environmental and safety compliance requirements.

Other diseases such as Chagas disease, leishmaniasis and schistosomiasis affect hundreds of millions of people worldwide. Many of these diseases are preventable through informed protective measures including the targeted use of pesticides.

Targeted pesticide use for dengue in Far North Queensland

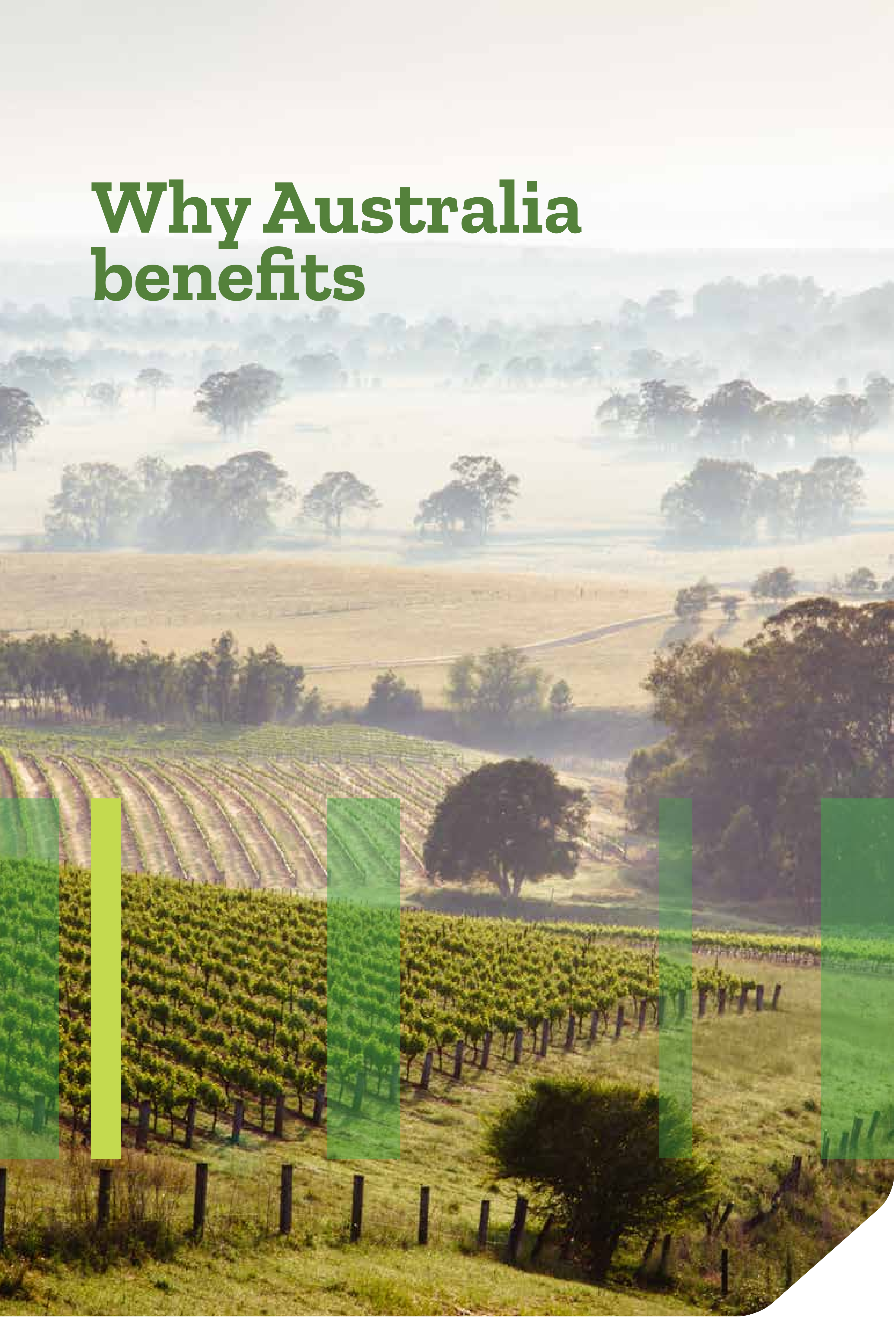
More than 3.9 billion people in over 128 countries are at risk of contracting dengue, with 96 million cases estimated per year.[98] During the 2019 dengue outbreak in Cairns, public health officials traced recent contacts of people with a confirmed infection. Using mobility data from the known cases, they targeted residences for indoor residual spraying, which involved spraying the walls of homes and dark, humid places where *Aedes* mosquitoes might rest, with an insecticide that lasts for months.

The new approach of using contact tracing to identify houses for targeted insecticide spraying was between 86 and 96 per cent effective in controlling dengue fever during the Cairns outbreak, while in comparison, vaccines for the dengue virus are only 30 to 70 per cent effective, depending on the type of virus involved.[99]

98 www.who.int/en/news-room/fact-sheets/detail/vector-borne-diseases

99 Ferguson, N.M. et al. (2015) Modeling the impact on virus transmission of Wolbachia-mediated blocking of dengue virus infection of Aedes aegypti. Science Translational Medicine 18 Mar 2015: Vol. 7, Issue 279, pp. 279ra37. DOI: 10.1126/scitranslmed.3010370

Why Australia benefits



The Australian Government has a crucial role in determining the future role of pesticides in agriculture through maintaining the confidence and support of the community.

Demand for pesticide-based solutions to manage pest problems and food security risks will continue, if not accelerate, into the future as the world's population continues to grow. Concern and confidence in adequately managing human and environmental health effects of pesticides also need to be addressed. The benefits of pesticides as a viable and safe solution need to be pragmatically considered using a scientific, risk-based approach, while considering the ethical and environmental challenges that come with delivering food to a growing and hungry world.

Contributing globally

The reduction of current yield losses caused by pests is a major challenge to agricultural production. Worldwide crop losses due to pests is significant and famine would be common if pesticides were not available. While there are costs from pesticide use, there are significant benefits of reduced yield losses through integrated pest management programs, which utilise chemical, biological and recombinant genetically engineered methods of pest control.[100]

Community confidence

Profitable farm production is the lifeblood of a rural community. Growers and the community must have confidence in having access to suitable crop protection tools to ensure agricultural industries avoid catastrophic loss of production or trade restrictions. It is also essential that communities are confident that chemical products are being used appropriately and applied to the intended target with no environmental impacts. The agricultural industry requires confidence in delivering an increasing diversity of high-quality food products to local and international markets.

Supporting a multicultural Australian society

Growers value the investment in development of crop protection product labels in delivering market confidence for an increasing diversity of agricultural produce. Australian agriculture, while being a relatively small producer in a global context, is a major global exporter of food produce, while domestic market demand is increasing for a greater diversity of foods to meet the needs of our increasingly multicultural society.

Confidence in the future of agriculture is demonstrated by the significant investment made by crop protection companies in new pesticide products, for organic and traditional farming systems.

100 Popp, J., Pető, K. and Nagy, J. (2013) Pesticide productivity and food security. A review. Agronomy for Sustainable Development 33: 243. https://doi.org/10.1007/s13593-012-0105-x

Pesticides deliver:

- Sustainable production
- Environmental conservation
- Food and nutritional security
- Safe food
- Human health

Frequently asked questions

What is the difference between hazard and risk?
A hazard is something that has the potential to harm people, including objects and processes. A risk is the probability that a hazard will harm an individual. Hazard does not change, but the risk changes enormously depending on how a hazard is mitigated.

Are pesticides important in managing the environment?
Invasive weeds and other pests can have major negative impacts on Australia's natural environments as they can damage the diversity and balance of ecosystems. These changes threaten the survival of many native plants and animals because weeds compete for space, moisture, nutrients and sunlight. The plant science industry provides Australia's land managers with the innovative tools that are crucial to controlling invasive weeds and insects throughout Australia's national parks, in public parks, golf courses, gardens and to control weeds alongside roads, buildings, pathways and other public infrastructure.

How much does it cost to develop a new pesticide?
Today it costs over US$286 million to bring a new crop protection product from discovery to commercial sale for growers. This investment addresses all aspects associated with the operator, the environment and food safety at a global level and includes the delivery of new registrations. It ensures that crop protection products can be used on produce destined for export markets. Growers can then transfer this investment and confidence to improved productivity in growing their produce.

What is the global benefit of pesticides?
Food lost due to pests and diseases can average as high as 40 per cent. The worldwide universal adoption of pesticides for controlling weeds, insects and disease pathogens has delivered production gains of between 18-26 per cent. A loss of pesticides globally would result in a potential loss of over 20 per cent in global food production.

What is the Australian benefit of pesticides?
It is estimated that 73 per cent of the total value of Australian crop production can be attributed to the use of chemical crop protection products. In 2015-16, the value of Australian agricultural output attributed to crop protection products was $20.6 billion. Australian production of many crucial food crops would be commercially unviable without access to effective crop protection products.

Is glyphosate safe to use?
All glyphosate products have been extensively and independently risk assessed by regulators including in the United States, Canada, Australia and Europe and found to be safe. Recent findings of the European Food safety Authority have concluded that glyphosate is unlikely to pose even a carcinogenic hazard, let alone an actual risk. In Australia the APVMA regulates glyphosate and has concluded that the chemical can continue to be used safely according to label directions. Glyphosate is degraded by soil microbes in a matter of days and does not accumulate in the environment.

Have neonicotinoid insecticides reduced bee populations in Australia?
No, registered beekeepers in Australia have increased from 13,000 in 2014-15 to over 30,000 today, operating approximately 669,000 hives, providing pollination services worth $4-6 billion per year. The APVMA's Overview Report: Neonicotinoids and the Health of Honey Bees in Australia reports, "The introduction of neonicotinoids in Australia has led to an overall reduction in the risks to the agricultural environment from the application of insecticides."

Are pesticides important for human disease control?
Yes, particularly in targeted pesticide use for malaria control. The World Health Organization (WHO) states that vector-borne diseases account for more than 17 per cent of all infectious diseases, causing more than 700,000 deaths annually. More than 3.9 billion people in over 128 countries are at risk of contracting dengue, with 96 million cases estimated per year. The WHO reports that malaria causes more than 400,000 deaths every year globally, most of them children under five years of age. Insecticide treated nets can prevent around 50 per cent of malaria cases and has reduced child deaths by 18 per cent. Indoor residual spraying (IRS) is also considered an effective means of mosquito (vector) control. IRS involves spraying internal walls and ceilings of dwellings using insecticides with residual action (i.e. insecticides that remain on the surface for a long time). Most vectors in Africa do prefer to rest indoors.

Glossary

Active constituent – Ingredients or substances or just 'actives' are the chemicals or micro-organisms, in a pesticide that enable the product to do its job. The pesticide is the final product sold to users. Apart from one or more actives, a pesticide commonly contains other ingredients that help the product achieve its objective. These may help to reduce environmental effects or improve safety to users.

Biological pesticides – A growing class of crop protection products, which make use of living organisms like microbes found in nature. Microbes are tiny micro-organisms like viruses, bacteria or fungi, some of which can have pesticide-like qualities that can be used by all farmers. In nature, populations of beneficial insects and organisms that are naturally occurring enemies of unwanted pests and pathogens assist plants. Many naturally occurring organisms have been developed into commercial biological pesticides for crop protection.

Chemical label – The technical information about a agricultural chemical product in the form of printed material provided by the manufacturer or its agent, including the label, flyers, handouts, leaflets and brochures. Labels also include advisory statements - used to clarify the circumstances under which product use may be ineffective or hazardous due to extraneous factors not otherwise specified (or described) on the label. General advisory statements also endeavour to provide important information related to controlled use.

Codex Alimentarius Commission (Codex) – The intergovernmental standards-setting body for food, which delivers international food standards, guidelines and codes of practice, including maximum residue limits (MRLs) for pesticides in food. that contribute to the safety, quality and fairness of this international food trade.

Crop protection products – Commonly referred to as pesticides, these are essential to Australian farming. Without these tools, Australian farmers would not be able to commercially produce food crops prone to pests and diseases. Pesticides that include chemical and non-chemical naturally derived technology including biologicals are essential for food production.

Food toxins – Natural toxins including mycotoxins that are toxic compounds naturally produced by living organisms. These toxins are not harmful to the organisms themselves but they may be toxic to other creatures, including humans, when eaten. These chemical compounds have diverse structures and differ in biological function and toxicity.

Formulation and enabling chemistry – What gets added to the active ingredient to improve its effectiveness and safety. In other words, its 'delivery system'. Plant scientists are working on 'microencapsulation', a type of formulation that can trigger an active ingredient into action in specific ways, for example by temperature or by exposure to sunlight. Companies are focused on developing technologies that enable improved active function. These technologies can include natural and synthetic synergists, adjuvants and delivery design platforms.

Fungicides – Protect plants from disease-causing organisms called fungi, like the one that caused the infamous Irish potato famine of the 1800s. In people's home gardens, roses, tomatoes and peppers are particularly susceptible to fungi. On a farm, a fungus can spread quickly from one plant to destroy an entire field.

Herbicides – A pesticide that kills unwanted plants, weeds, so crops can flourish. Weeds and other invasive plants are actually the most damaging pests for many agricultural crops because they compete for vital nutrients, space, water and sunlight.

Insecticides – A pesticide that controls insects that could damage crops by eating them or infecting them with diseases. Fighting these pests is difficult in part because of the wide variety of insects and because new invasive species are continually being introduced as a result of globalisation. Insecticides protect against insects like locusts, lawn-devouring grubs, tree-smothering caterpillars, maggots that tunnel through fruit crops and moths/aphids that can devastate grain crops.

Integrated Pest Management (IPM) – Farm management systems which combine effective pest monitoring and the use of all effective pest control technologies. IPM has reduced the incidence of catastrophic pest populations and has reduced the volume of agrochemicals used in production of higher yielding crops.

Microencapsulated pesticides – Where the active ingredient is encapsulated by a protective coating and when mixed with water applied as a spray. The coating of the microencapsulated pesticide breaks down and can potentially provide slow release of the active ingredient contained inside the capsule, which can offer safety and environmental benefits.

Mode of action – Indicated by a number or letter code on the product label. The mode of action labelling is based on the resistance risk of each group of pesticides. Australia was the first country to introduce compulsory mode of action labelling on products.

Organic pesticides – Derived from 'natural' compounds rather than new synthetic compounds. It is important to understand that some of the most toxic substances that exist are in fact 'natural'. For example, cyanide is a natural substance, as is spider venom and plant poison.

Pesticide – Pesticides are products used to kill pests, including insects, weeds, fungi, bacteria and rodents. Pesticides are used in agriculture to kill pests that damage crops and in public health to kill vectors of disease, such as mosquitoes. Pesticides are the final product placed on the market. Apart from one or more active substances, a pesticide usually contains other ingredients that help increase its efficacy and better protect the plant on which it is applied.

Pesticide label – In Australia, as in other parts of the world, information is written on the pesticide product label. The Australian national regulator, the APVMA, individually assesses these instructions for each product and approves the label to ensure that the product, when used in accordance with its instructions, is safe for use.

Pesticide resistance – The genetic capacity of a crop pest – a weed, insect or fungus – to survive the use of a herbicide, insecticide or fungicide treatment that would effectively control it under normal conditions.

Plant growth regulators – Also called plant hormones, used in agriculture, are numerous chemical substances that profoundly influence the growth and differentiation of plant cells, tissues and organs. Plant growth regulators function as chemical messengers for intercellular communication. They are used in agriculture for managing plant growth, particularly for managing lodging of crops or for crop flower management for crop thinning.

RNAi (or dsRNA) pesticides – New generation crop protection technology that interferes with protein expression in targeted pest insects by a cellular mechanism called RNA interference (RNAi). This new generation of pesticides can be used to control invertebrate pests by compromising the insects ability to create essential proteins. When the pest eats this pesticide, it prevents the insect from making essential proteins, leading either to stunted growth or to death.

Safety data sheet (SDS) – Previously known as a material safety data sheet, an important information source for eliminating or minimising the risks associated with the use of hazardous chemicals (hazardous substances and/or dangerous goods) in workplaces.

Seed treatments – Coatings for seeds that can be applied prior to planting to help protect them from pests and diseases. They help farmers to plant early and boost their yields, while also enabling cover crops to reduce soil erosion. The seed treatments use a bright colour such as red, purple, blue or bright green so that it's very obvious if a seed has been treated.

Synthetic chemistry – Products that are derived from actives manufactured using traditional chemical-based production processes.

Tillage – Mechanical manipulation of the soil for the purpose of crop production. Traditionally, this involved ploughing, however, advancements in machinery and crop protection products now allow for reduced or 'ploughless' tillage and direct drilling, which utilises a seed drill to plant the seed without otherwise disturbing the soil.

Useful links

CropLife Australia website
croplife.org.au

StewardshipFirst

Find out more at
croplife.org.au/resources/stewardship-programs

Pollinator Protection Initiative
Find out more at
croplife.org.au/resources/programs/pollinator-protection-initiative

BeeConnected
Find out more at
croplife.org.au/beeconnected

Seed Treatment Stewardship Strategy
Find out more at
croplife.org.au/seed-treatment-stewardship-strategy.

MyAgCHEMuse
Find out more at
croplife.org.au/resources/programs/myagchemuse

SprayBest
Find out more at
croplife.org.au/resources/programs/spraybest

Resistance Management
Find out more at
croplife.org.au/resistance

Illegal agricultural chemicals
Find out more at
croplife.org.au/resources/fact-sheets/illegal-agricultural-chemicals

Recycling – Agsafe programs, *drum*MUSTER and ChemClear®
Find out more at
agsafe.org.au

Training – Agsafe accredited premises and handler training
Find out more at
agsafe.org.au/premisesaccred/accreditation-training

CropLife Australia

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