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Final Report

Review of Issues and Options for Preventing and Removing Redback Spiders in Broccoli

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Review of Issues and Options for Preventing and Removing Redback Spiders in Broccoli – VG17014

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Content

Summary

Since 2016 there have been numerous customer complaints about redback spiders (*Latrodectus hasselti*) in broccoli. Complaints have come from customers in all Australian states, suggesting that this is not an issue for a single production area, but can occur anywhere that broccoli is grown. Redback spiders are clearly unacceptable to consumers, and also pose risks to growers, pickers and packers.

Most finds have occurred between January and June, with peaks in April and May. This is when redback populations are highest, as the spiders mainly produce egg sacs over the summer months.

Despite their fearsome reputation, redback spiders are generally timid. They are nocturnal ground dwellers which need protection from wind, rain and extremes of temperatures. Broccoli crops are not their usual habitat.

This review has examined factors that may be contributing to redback spiders entering broccoli crops and / or contaminating broccoli after harvest. Key findings include:

- Female redback spiders can mature in 6 to 8 weeks at around 25°C. Spiderlings that enter a broccoli crop at planting can therefore potentially mature by harvest.
- Pheromones are produced by females on their webs to attract and signal to males; they do not attract mature female spiders into crops.
- Female spiders commonly lay 4–7 egg sacs over summer, each of which produces an average of around 110 spiderlings, so a single egg sac can cause a significant infestation.
- Long distance dispersal of redbacks occurs through hitchhiking on equipment and machinery, so spiders are most likely to enter crops with human assistance.
- Redback spiders are occasionally found in crops such as cotton, table grapes and pumpkins, but there are no records of them in brassicas.
- The webs of redbacks have a number of key distinguishing features that make them relatively easy to distinguish from those of other spiders.
- Key prey of redbacks includes beetles, millipedes and other ground dwelling insects that are not usually regarded as pests.
- The shift to Integrated Pest Management (IPM) using selective insecticides is likely to have increased survival of both spiders and non-target prey organisms.
- Redback spiders can survive long periods without food and extremes of heat and cold, so can easily tolerate the times and temperatures in broccoli supply chains.
- Social media photos appear to show newly mature female spiders, which is consistent with them having emerged from egg sacs laid in mid summer.
- Social media photos do not show any webbing within the broccoli heads, which may indicate that the spiders have not been living in the broccoli in the field but actually entered at or soon after harvest.

Peaks of redbacks being found in broccoli appear to correspond with hot, dry summer conditions. Risk appears to be increased when an autumn crop of broccoli follows a summer crop of cucurbits such as pumpkin. It is unclear whether this is because significant redback populations remain in the field, or whether redbacks sheltering on equipment and harvest bins enter broccoli after harvest. However, it is noted that the major outbreak of redback spiders in broccoli occurred after a dry summer when pumpkins were in major oversupply, resulting in abandoned crops and extended storage of harvested fruit.

Thoroughly cleaning equipment and machinery used to grow and harvest broccoli is the best way to reduce risk. If spiders have been found in the field, then destroying crop residues they could use as harborages will effectively kill them.

Pesticides may be used if an infestation is found. However, it is not recommended to spray broccoli in the field as there is no evidence (at this stage) that spiders are actually present in the crop. Moreover, no products are registered for this purpose. If using a pesticide to clean infested equipment, then a product formulated in oil is more likely to penetrate egg sacs and webbing than a product formulated in water. Chlorine and detergents may also be effective, but this requires further investigation.

There is no information on the effect of different postharvest practices on redback spiders already in broccoli heads.

Keywords

Redback; Spider; Broccoli; Consumer; IPM; Contamination

Introduction

Since 2016, there have been numerous customer complaints regarding redback spiders (*Latrodectus hasselti*) being found in broccoli. Most of the complaints have been from consumers in Queensland. However, complaints have also come from NSW, Victoria, WA SA and ACT, with the greatest number of them being made between March and June.

The major concern for the industry is that redback spiders in broccoli have the potential to shock and even harm customers. Spiders are also a risk for growers, pickers, packers and transporters.

Redback spiders thrive in warm dry weather, which may have contributed to the outbreak of redback spiders in Queensland in 2016. It is likely that mild winters and warm dry summers allow increased breeding of redback spiders, contributing to them being found in broccoli heads from January to June. Redback spiders are found in all states of Australia, so it seems likely that this problem can occur anywhere broccoli is grown.

Despite their fearsome reputation, redback spiders are generally timid. They are nocturnal, travel only short distances and need protection from wind, rain and extremes of temperatures. Broccoli crops are not their natural habitat.

Initial consideration suggests that the increase in the use of Integrated Pest Management (IPM) methods, including “soft”, targeted chemicals to control insect pests in broccoli, has contributed to the increase in spider populations in the crop. However, IPM has been used by broccoli growers for more than a decade, but significant detections of redback spiders have only been reported within the last three years.

This review therefore focuses on the various factors that could be leading to redback spiders being found in harvested broccoli. This includes examination of their environmental requirements, lifecycle, diet and dispersal. The aim is to provide growers with tools to identify potential sources of contamination and reduce the risk that redback spiders will contaminate crops.

Lifecycle

Development to maturity

Key points relating to broccoli

- Female redback spiders can mature in 6 to 8 weeks at around 25°C. Spiderlings that have entered a broccoli crop at planting can therefore mature by harvest
- Redbacks need a warm summer with at least 3 months at 15 to 25°C to reproduce
- It is only female spiders that represent a threat to consumers, as males are tiny, short-lived and virtually non-venomous

If food supply is not limiting, then the development rate of redback spiders directly relates to temperature. The optimum temperature for redback development is from 25°C to 30°C. Males mature after their fourth moult, referred to as their fifth instar or 'lifestage'. Under warm conditions they can reach this stage in only 28 days. In contrast, females take longer to mature, being able to reproduce once they reach their seventh or eighth instar. This can take as little as 45 days, but also up to 74 days with an average of around 62 days[i].

As temperature falls development slows significantly, so that at 15°C to 25°C females require 2–3 months to reach maturity. Once temperature falls to 10°C or less, development effectively stops. The requirement for a warm summer, in order to allow the female spider to reproduce, has slowed their expansion into some areas of Australia, as well as within New Zealand[ii].

Figure 1. Juvenile female (left) – Ed Nieuwenhuys, Sydney; mature female – Greg Anderson, Stirling Ranges WA and mature male (rightº – Beth Shaw, Perth.

Even though females take more time to mature than males, they grow much faster. While many female spiders dwarf the male of the same species, in redbacks this is taken to an extreme level. A mature male may be only 1–2% of the weight of a large, mature female[iii].

The rapid growth of females gives them a competitive edge over males as well as smaller siblings[iv]. Dominant females may kill smaller females, or at least thieve prey from their webs. They will also establish their webs in the optimum locations. Once established, the female redback will generally stay where she is rather than risk roaming further[v].

The smaller, lighter coloured males may be reduced to foraging at the edges of the female web, or establishing much more limited webbing. Males also have a much shorter lifespan; females can live for over one year whereas most males perish within 4 to 6 months[vi]. Even mature males appear relatively inconspicuous. Males are also believed to be mostly non–venomous to humans. Although they can cause a painful bite, the effects are localised and short-lived[vii].

Use of pheromones

Key points relating to broccoli

- Pheromones are produced by females on their webs to attract and signal to males; they **do not** attract mature female spiders into crops

Once mature, male redback spiders are likely to begin the search for a mate. This means leaving the relative safety of their web and refuge, and venturing out into a dangerous world. However, they are helped by their small size and brown colouration, which makes them far less conspicuous than the female[iv].

The primary cue for males to search for females are pheromones released from the female's web. These pheromones not only help males to locate female spiders, but also to assess whether they are mature, have previously produced egg sacs, and even whether they have recently mated[viii].

It is thought that only a relatively small percentage of males have the opportunity to pass on their genes. Choosing the right female is therefore extremely important to the male spiders' reproductive success, especially as the first male to mate with a female is likely to father most of her offspring[ix].

Mating

The mating process in redback spiders has long been a source of fascination among spider researchers. It is believed to be unique, and has fostered a significant number of research papers exploring the evolutionary advantages of this system.

Key points relating to broccoli

- Males allow themselves to be cannibalized by females during mating, a sacrifice which increases the number and fitness of their offspring

Males become alert to sub-adult females several days before they have their final moult and reach maturity. Typically, they will remain on the outskirts of her web, subsisting on leftover prey. Once she has moulted, courtship can commence. This often takes several hours, the male using a variety of moves that include abseiling, jerking, web-cutting and web bouncing.

Initially it was thought that these activities were designed to convince the female that he was not prey, but a potential mate. However, as female redbacks do not usually respond to such tiny prey as the male represents, it seems more likely that these moves are actually designed to attract her attention[iv]. She may initially reject these advances, flicking her legs at her suitor. However, persistence can win her over, and eventually the female will assume a docile position within the web.

The male will then approach on her ventral side. He explores using his palps – a short pair of appendages in front of the first pair of legs. These have already been loaded with sperm, ready to transfer to the female. At the same time the tip of his abdomen shrinks and constricts, changing from an oval into a more cone-like shape. Once in position, he inserts a palp into the female external reproductive organ (epigyne).

Cannibalisation of the male after mating has been recorded in many groups of insects, including insectivorous flies, praying mantis and scorpions. The American spider *Latrodectus mactans* is renowned for killing and eating the male after mating, hence her common name of 'black widow'.

However, only in redbacks is this not left to chance. Having inserted and inflated the first palp, the male somersaults 180°, placing the tip of his abdomen against the females fangs. She immediately squirts digestive juices onto him, and starts to gnaw against his abdomen.

Timing is now essential, as he needs to transfer a full packet of sperm before she fully penetrates his abdomen. After some 5–20 minutes he starts to jerk himself free, injured but not yet fatally.

Usually the female will permit this, allowing him to briefly retreat as she 'spits out' the fragments of inedible chitin from his outer skin.

After around 10 minutes he returns, inserting his second palp and again somersaulting against the female mouthparts. This time the move is fatal, as the female soon starts to feed on his internal organs[iv]. However, inserting both palps guarantees that 90% of the offspring will be his, even if she mates again. If he only manages one palp, he will father 50% of the offspring[x]. This is more likely to occur if several males are competing for the same female; she may prematurely attack and kill after the first copulation, then allow a second male to mate[xi].

Females who cannibilise the male during sex have been shown to produce more and healthier spiderlings. This is not just due to simple nutrition, as even well nourished females show some benefit. Instead it is thought to be related to interactions between the contents of the male's body and changes in the female's physiology after mating[xii].

Egg sac production

Key points relating to broccoli

- Redback spiders breed prolifically, commonly laying 4–7 egg sacs over summer
- On average, each egg sac produces approximately 110 spiderlings, which emerge after approximately a month at 25°C
- Just a few egg sacs accidentally dropped into a broccoli field from machinery or equipment can introduce many hundreds of young spiders into the crop

The female redback produces an egg sac soon after mating. The egg sacs are spherical, pea sized, and hang inside the main part of the web. Most egg sacs are produced during summer and into early autumn.

Figure 2. Female with egg sac and smaller male (left) – E Nieuwenhuys; mass of egg sacs and debris (right) – B. Thompson.

In the laboratory, a single female spider has been known to produce as many as 16 egg sacs, although this appears to be somewhat unusual[xiii]. Females produce at least 3–4 egg sacs, with many producing 7–8 over a season[v]. The closely related brown widow spider *Latrodectus geometricus* can produce an egg sac every four days during the early period of her maturity[xiv], a figure which may well be matched by a well fed redback female.

The egg sac itself is protected by a thick layer of hydrophobic silk. This protects the eggs from the effects of temperature and humidity, as well as sheltering them from predators.

Each sac contains around 150 eggs, of which around 70–75% hatch into live spiderlings. It takes around 12 days at 25°C for the eggs to hatch, although this may vary within quite a wide range[xv]. At 30°C development can be 1–2 days faster, but the number of live spiderlings is greatly reduced. If temperature falls to 20°C development takes more than twice as long (34 days), while at 15°C eggs

fail to hatch even after several months incubation[xvi].

The young spiderlings do not immediately leave the egg sac, but remain inside until after their first moult. Unhatched eggs are eaten as well as – possibly – smaller and weaker spiderlings[xiii]. In all, it takes between 20–30 days[xvii] between oviposition and the emergence of 40 to 180 tiny spiderlings (average 109), which start to spread out from their mothers web[xvi].

Mature female redbacks often die at the end of summer after producing their egg sacs, although they can survive until the following season if conditions are favourable[v].

Dispersal

Key points relating to broccoli

- There is little evidence to support 'ballooning' as a means of dispersal of redback spiderlings
- Natural long-distance dispersal of young spiders is rare, with most populations expanding less than 0.3km from the original infestation point per season
- Unsuitable habitats such as roads, open fields and watercourses are significant barriers to dispersal
- It seems clear that young redback spiders travel larger distances by hitchhiking on equipment, machinery, freight and other human-transported items

Most true young spiders disperse by "ballooning". The spiderling walks towards the light, climbing up nearby plants or objects then clinging to the top while releasing a strand of silk. Eventually the webbing catches the air current, carrying away the tiny spiderling. They can potentially drift great distances in this way, travelling considerable distances from their birthplace[v].

However, the mechanism of dispersal of redback spiderlings remains unclear. There are occasional references to newly emerged redbacks ballooning [v,xviii]. However, it seems clear that any climbing behaviour associated with ballooning is lost soon after emergence[iv]. Greenstone[xix] failed to find any redback spiderlings during aerial surveys for different spider species in Trangie, NSW during late November, although this may reflect local weather and seasonal abundance.

It seems likely that redback spiderlings disperse primarily through walking. Long distance dispersal is extremely rare, occurring mainly when assisted by human activity. This conclusion is supported by extensive studies of dispersal in countries to which it has been introduced, especially Japan and New Zealand.

For example, a comprehensive study of dispersal of redbacks from several original infestation points in Osaka, Japan[xx] found that more than half of all measured expansion distances were less than 0.3km, with many less than 0.1km. Redbacks did not disperse over natural barriers, such as train lines or rivers, in coastal areas. Although expansions of >5km were more common in settled areas further inland, the researchers suggest that these long distance movements were likely due to redbacks travelling on construction materials or cars.

This is further supported through studies in New Zealand. Although many parts of New Zealand are climatically suitable for redbacks, the spider has so far only colonised limited areas in Central Otago (South Island) and New Plymouth (North Island). These often occur as dense groupings, rather than widely dispersed populations[xxi].

Both the NZ and Japanese researchers conclude that redbacks do not disperse by ballooning, but move simply by walking.

Lifestyle

Habitat

Key points relating to broccoli

- Redbacks prefer well sheltered sites with minimal disturbance, protected from temperature extremes, as well as wind and rain
- There is a strong association between redback spiders and humans, with the majority of spiders found in urban areas
- Cropping areas can be suitable for redbacks, if they include dry, sheltered sites
- The spiders are occasionally found in crops such as cotton, table grapes and pumpkins
- No records could be found of redbacks in brassica crops, which supports the observation that broccoli crops are not their natural environment
- Redbacks are likely to die if their shelters are destroyed, and no alternate sheltered sites are available

Redback spiders are legendary for being found living in outdoor toilets, a habit long popularised in Australian folklore (Figure 3).

The traditional outdoor toilet does indeed provide an ideal habitat for the redback spider, being protected from wind and rain, sheltered from extremes of heat and cold and well supplied with prey. It is notable that the number of redback spider bites in Australia declined significantly with the advent of indoor plumbing[v] in the 1940's. There have been no confirmed deaths from redback spider bites since 1955, which was a year before the introduction of an antivenom for redbacks[xxii].

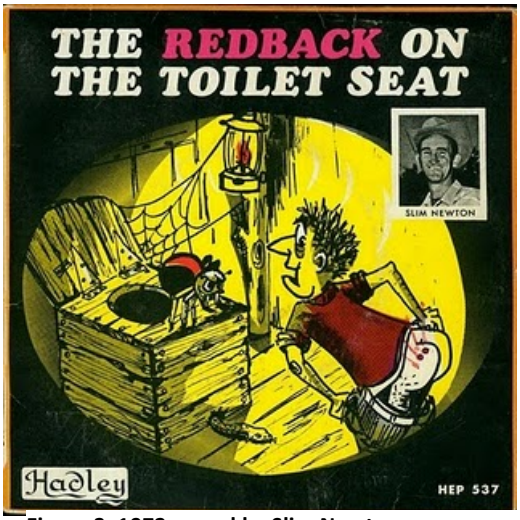

Figure 3. 1972 record by Slim Newton

Redbacks in urban areas

Redbacks originated in warm, arid conditions. It is believed by some to have originated in Western Australia, although the first description of the species was in South Australia[i]. The lack of earlier records led some to suggest it may not be an Australian species at all, but actually introduced[v]. It seems more likely that it was previously uncommon, but that European settlement provided it with dry conditions and plentiful prey, as well as protection from wind and temperature extremes[iv]. This has enabled the species to colonize areas that would previously have been unsuitable.

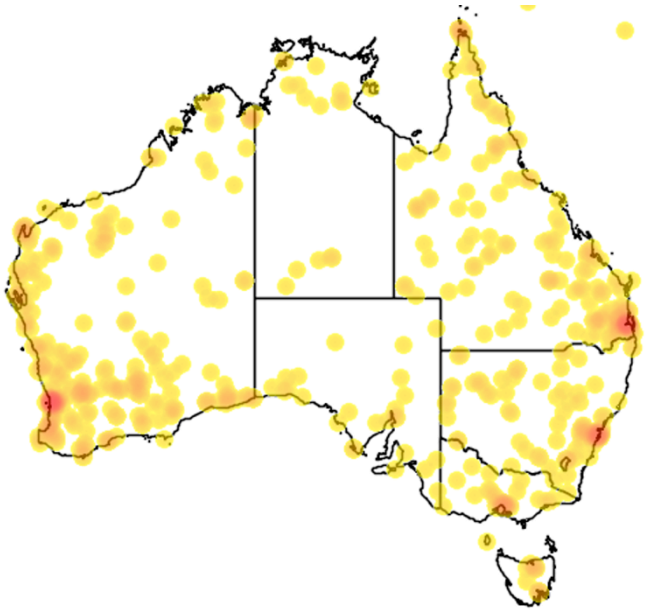

Figure 4. Distribution map for redback spider records. From the Atlas of Living Australia.

There is extremely strong association between redbacks and built environments. As shown in Figure 4, the majority of records are from urban areas, with fewer in outback regions. In Osaka, Japan, extensive searching found redbacks in residential areas, newly constructed facilities, fences, rainwater conduits, drainage ditches, parking lots, schools, cemeteries, public facilities and other human modified areas[xx]. The spiders were also found in dune areas but mainly around seawalls and pipes[xxiii], all essentially human modified habitats.

Fortunately, despite their close association with humans, redbacks virtually never enter houses. Instead they prefer outdoor sheltered areas such as sheds, verandas, plant pots and equipment.

Redbacks in the natural environment

Clearly, redbacks can survive in natural environments, even though the conditions may be less favorable to them. In Japan, they have been found sheltering inside dense patches of invasive yucca plants[xxiv]. They have also been observed on yucca plants in Sydney. Presumably the large, waxy leaves and ridged structure of these plants, which tend to grow in dry areas, provides the type of sheltered environment they prefer.

The related New Zealand native *Latrodectus katipo* is also found in dune plants, such as pingao (*Desmoschorensus spiralis*) and other sedges. Webs may also be established under driftwood, stones or other debris, generally close to the ground and nearly always in coastal areas[xxv].

In India, redback spiders were found under stones and logs and inside soil crevices[xxviii]. Similarly, rabbit holes were found to be a highly suitable habitat for redbacks in New Zealand; a study inside a nature reserve in Central Otago found 455 spiders in old rabbit holes, compared to three under plants and one inside a tin can[xxvi]. In this study, destroying the shelters used by the spiders by filling in the old rabbit holes, was effective at eliminating them from the treated area.

Redbacks in crop areas

Latrodectus species are rarely found in cropping areas. For example, an extensive study of brown widow and black widow spiders in California found 1.2 spiders/hour/collector in avocado orchards, 0.0 spiders/collector/hour in citrus orchards, but 10.9, 9.0 and 7.7 spiders/hour/collector in landscaped parks, urban homes, and playgrounds respectively[xxvii].

Redback spiders are most likely to enter fields and orchards if they are dry and sheltered. Cotton is one of the few crops where redbacks have been repeatedly sighted. The Australian cotton industry

manual “Pests and Beneficials in Australian Cotton Landscapes” lists redbacks as one of the more common spiders found in cotton fields. In Western India, seven redbacks were found in cotton fields, two in castor plantations and one in lucerne. None were found in other crops. In comparison, more than 20 were found in nearby wasteland[xxviii].

Latrodectus spiders have also been found in vineyards, including those producing table grapes. Rain covers installed over the vines can create the warm, dry, sheltered environment that the spiders prefer. In Chile, *Latrodectus* species are relatively common in the grape growing region area of Vicuna, north of Santiago. Conditions here are hot and dry, and the spiders can be found in both vineyard and rangeland areas[xxix]. USA table grapes exported to several countries, including Australia, must be fumigated as a phytosanitary measure against *Latrodectus hesperus* (black widow)[xxx]. A 2002 report by New Zealand Biosecurity noted that 12 adult *Latrodectus* spiders had been intercepted in Californian grapes, and two adult redbacks had been found on Australian grapes (although one was intercepted before leaving Australia). However, the same report also notes that black widow spiders are rare in Californian vineyards, comprising <1% of all species[xxxv].

Figure 5. Redback spiders are occasionally found in bunches of table grapes.

In addition, there are several unofficial reports of redback spiders being found in crops of “large leafed vegetables” such as pumpkins[xxxi], particularly those growing large varieties such as Kent and Queensland Blue. Cucurbit crops such as pumpkins and melons, especially those grown on plastic with drip irrigation, may also provide the type of warm, dry, sheltered environment that suits redback spiders.

Webs

Key points relating to broccoli

- Redback webs have specific features that make them relatively easy to distinguish from those of spiders such as house spiders and daddy long-legs
- Understanding what webs to look for is a good way to detect redbacks, as the spiders themselves are not usually visible in their webs during the day

Redbacks are primarily ground-dwelling spiders, so their web often contacts the ground, or close to it. As they are nocturnal, the spiders themselves spend much of their time in a "retreat" connected to the web. Occasionally this can be high above the web itself[v], whereas in others it may be only a dense mass of webbing within the web itself.

Redbacks make "tangle webs". These consist of a few sticky strands at the base, and a tangled mass of non-sticky webbing above. They can often contain leaves, sticks, and dried out cadavers of prey; whereas other spiders will remove contaminants from their webs, redbacks do not, and the web can develop a very messy appearance as a result.

Figure 6. Typical structure of a redback spider web, from B York Main (left) and the retreat (top) and tangle web (below) typical of a redback living inside an electrical box on farm.

Another characteristic of redback webs is their strength. Whereas the webs of many other spiders break easily when touched, breaking redback webbing requires much greater pressure.

These factors make it relatively easy to distinguish redback webs from those of other spiders, especially as the spider itself is often not visible during the day.

Figure 7. Redback webs often contain leaves and debris, as well as old insect cadavers, as they do not clean their webs.

Other spiders that are also found in the sheltered, indoor spaces preferred by redbacks include house spiders (*Badumna longinquus*; *Badumna insignis*.) and daddy long-legs (*Pholcus* spp.).

House spider webs are untidy lacy sheets, with funnel like retreats formed somewhere inside the web (Figure 8).

Figure 8. Typical structure of a house spider web, from B York Main (left) and webbing on farm equipment (centre) and inside a farm shed (right).

Daddy long-legs make fragile, untidy webs in sheltered positions. They are usually found within the web, which they shake violently as a form of protection if disturbed. Daddy long-leg spiders will kill redbacks, so if large numbers are found there are unlikely to be redbacks in the same, sheltered spot. It may be this habit that has led to the widespread urban myth that, although daddy long-legs are extremely venomous, their fangs cannot pierce human skin. In fact, their fangs can pierce human skin, but they themselves are only very slightly venomous.

Preferred prey

Key points relating to broccoli

- Beetles, particularly ground-dwelling species, are the key prey eaten by redbacks
- Beetles, millipedes and other insects are not generally considered significant horticultural pests, so may not be controlled by normal crop protection programs
- Environmental conditions that favour development of prey species also suit redbacks

While redbacks will attack a wide range of prey, the majority of their diet (60–70%) usually consists of ground-dwelling beetles[iv]. One New Zealand study found that nearly 90% of prey in redback webs were various types of beetle, including the endangered, ground-dwelling chafer beetle[xxvi].

Redbacks will also attack flies, millipedes, other spiders, slaters, small skinks and even tiny mice or small snakes that blunder into the web's sticky trap lines. Once prey becomes tangled, the spider approaches cautiously, then immobilises it by squirting it with sticky "glue". It will then repeatedly bite its victim, simultaneously injecting venom and digestive enzymes. The dead prey is further wrapped in silk, before being taken back to the spiders refuge to be sucked dry.

Figure 9. Redback spider web containing millipedes, beetles, a bush cockroach and even another spider (left) and spider wrapping a weevil (right)

As it is with spiders, the rate of development of insects is also highly temperature dependent. Growth and development increases as temperature rises, up until a maximum point. For example, growth rate of the tenebrionid beetles *Aphitobius diaperinus* and *Tenebrio molitor* is maximised at around 31°C[xxxii]. This means that the rate of growth of both spiders and their prey increases under warm, summer conditions.

Distribution

Key points relating to broccoli

- Trade and movement of people have allowed redback spider populations to become established in a number of other countries.

As previously noted, although redbacks are believed to have originated in Australia, they are now found in many different parts of the world. This is due to their ability to "hitchhike" on equipment and machinery, inside shipping containers, and even potentially on personal luggage. For example:

Redback spiders were introduced to the Island of Tristan da Cunha on satellite tracking equipment previously stationed in Narrabri, NSW[v]

Redback spiders have been found near the port of Bandar Abbas in the south of Iran; the authors suggest that they may have arrived on trans-shipped goods, which travel through this port from many parts of the world[xxxiii]

The species is now found in greenhouses in Belgium[xxxiv], presumably through movement of

equipment

New Zealand biosecurity found at least 36 redbacks between 1966 and 1982 on goods imported from or via Australia[xxxv]

None of this expansion of range is thought to have occurred through natural movement of spiders, but rather has been human mediated. There is no evidence for spread through wind dispersal, carriage by birds, floating on debris, etc.

Survival

Key points relating to broccoli

- Redbacks are able to survive extremes of heat, cold, starvation and even exposure to radiation
- The storage conditions used in broccoli supply chains will not kill redback spiders

The redbacks' ability to survive transport has been a key factor allowing them to spread to different parts of the world.

Sub-adult and adult females have been shown to survive an average of 120 days without food, with some adults surviving more than 300 days without food, when kept at 10°C. Survival was markedly shorter at 25°C, averaging around 50 days. Once fed, spiders recovered quickly, sometimes within hours[xxxvi]. Such time periods without food are clearly enough for them to survive even prolonged periods trapped inside cargo.

They can also survive extremes of temperature. In Osaka, redback spiders have established and continue to breed and expand despite normal temperatures ranging from -0.5 to 46.1°C[xxxvii]. Members of all development stages were found to survive a Japanese winter where temperatures fell to -3°C[xxxviii], while 50% of adults survived 30 minutes below -10°C in a laboratory study[xxxix] . They survive in parts of New Zealand which get occasional snowfall[iv]. At the other end of the scale, they have been seen fully active in the open in Australia at 41°C[xl].

A small trial some years ago found that exposure to 500 gray radiation killed approximately 50% of adult females but had less effect on sub-adults and juveniles (J. Ekman pers. com.). For comparison, 150 to 400 gray is used as a quarantine treatment against a range of insect pests, while exposure to only 5 grays will kill a human.

Redback spiders are comparatively difficult to kill.

Redbacks in Broccoli Crops

Detections in crops

Key points relating to broccoli

- There are no official records of redbacks in broccoli crops, and growers who have searched for redbacks have failed to find any in the crop itself
- Redbacks are occasionally found in broccoli heads after harvest, usually either during packing or by consumers when they are preparing vegetables for a meal
- Consumers have reported redbacks in broccoli from January through to June, with the peak months being April and May
- Reports of redback spiders in broccoli have come from all states at various times, suggesting that this issue can occur wherever broccoli is grown
- Social media photos appear to show newly mature female spiders, which is consistent with them having emerged from egg sacs laid in mid summer
- Social media photos do not show any webbing within the heads, which may indicate that the spiders have not been living in the broccoli heads in the field, but have entered at or soon after harvest

No official or unofficial reports of redback spiders in broccoli crops could be located for this study. Growers have reported searching for the spiders extensively, but failing to find a single one. This doesn't mean that they aren't there, but does suggest that they are not present in large numbers.

Spiders are sometimes detected in broccoli crops after harvest. Sometimes this has occurred at the packing shed, especially when staff have been trained to look for spiders hiding inside the broccoli heads. Unfortunately, some interceptions are made by consumers, the spider being found while preparing broccoli for a meal.

The sensational nature of such relatively rare events has resulted in numerous news reports (>50 Google hits), both local and international, as well as significant social media discussion. Virtually all of these reports date from either April 2016 or April 2017. In many cases the consumer has loaded their pictures onto the web, encouraging further negative publicity.

Figure 10. Images of spiders in broccoli, taken by consumers, April 2016 (left and centre) and April 2017.

Reported consumer detections of redbacks in broccoli show a clear increase in risk during April and May. This is when the redback population is likely to be greatest, with both juvenile and adult females present that have matured over summer. In contrast, no detections have been recorded between July and December. Populations are lowest in winter, while the juveniles active in spring may be less noticeable than the adults shown in Figure 10. It is interesting to note that all three of the spiders shown here appear to be newly mature females, which is consistent with their having emerged from egg sacs laid in January – February in the Lockyer Valley.

Another noticeable element in the social media photos is that **no webbing is visible** within the

broccoli head itself. While it is possible that the spider has moved from its original position, it still seems surprising that no pictures of webbing have been uploaded. If the spider had been present and active within the sheltered environment of the broccoli head before harvest then it would have built some sort of protective retreat. While it is difficult to make conclusions based on incomplete information, this suggests that the spider may have entered the broccoli **at or after harvest**, rather than before.

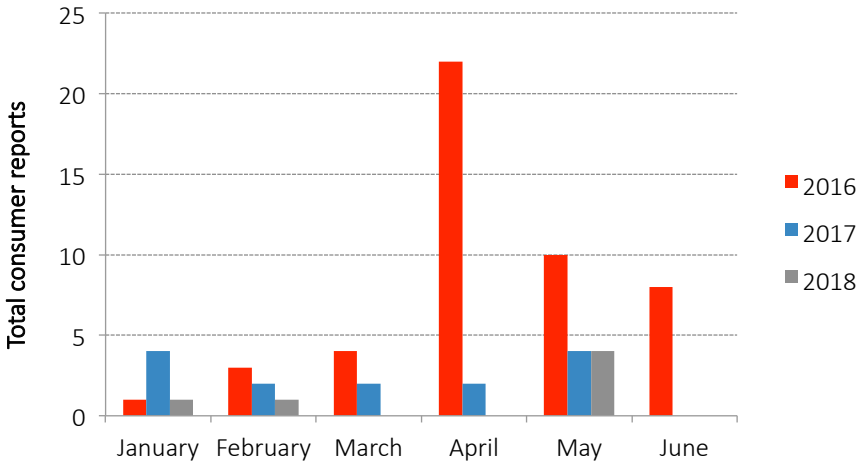

Figure 11. Total consumer reports of redback spiders in broccoli between 2016 to 2018.

Unfortunately, even though the location of the complainant is known, it has not been possible to trace the broccoli back to a specific production region. This limits the inferences that can be made regarding environmental factors leading to contamination. Moreover, while there are seasonal patterns in broccoli supply, some areas produce broccoli virtually year round.

Despite these limitations, some probable connections can be drawn from the data:

Broccoli purchased in WA during January to March is very likely to have been grown in Manjimup

Broccoli purchased in Queensland during April to June is likely to have been grown in the Lockyer valley

Broccoli purchased in Victoria or NSW during January to March is most likely to have been grown in Werribee

Broccoli purchased in South Australia could be from a variety of locations, including local suppliers in the Adelaide Hills or Murray Bridge

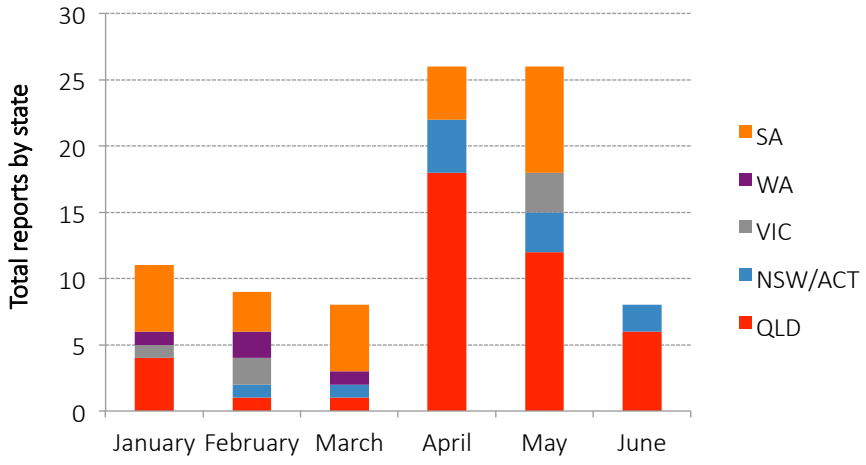

Figure 12. Total reports of redback spiders in broccoli between 2016 to 2018 by consumer location.

The presence of redbacks in broccoli clearly raises a number of risks, as shown in Table 1.

Table 1. Potential risks from redback spiders in broccoli

Risk	Impacts	Likelihood
Worker bitten by redback spider during harvest / packing	Variable and potentially severe effects lasting 1 to 7 days, worker time off and compensation.	Moderate to Low – workers wear gloves and boots
Redback spider found in broccoli displayed at retail	Possible product withdrawal, loss of reputation and sales.	Low
Redback spider found by customer when taking broccoli out of the fridge	Major loss of reputation and sales due to wide negative reporting on social media and news services.	Low
Redback spider bites customer when taking broccoli out of the fridge	Variable effects ranging from increasing localised pain for approx. 24 hours to nausea, severe sweating, intense referred pain in other parts of the body, hospitalisation and other effects lasting up to a week.	**Very** low – Spider inactive while cold so unlikely to bite
Redback spider bites customer during preparation of broccoli		Low
Redback spider accidentally ingested by customer	Negligible; the proteins in venom are denatured by heating and/or destroyed by low pH in the stomach.	**Very** low

Possible contributory factors

Climate

Key points relating to broccoli

- Redback populations peak during late summer and autumn, and this is when most detections occur
- Hot, dry weather appear likely to increase the likelihood of finding redback spiders in broccoli

The largest known outbreak of redbacks in broccoli crops occurred in April 2016, with the majority of consumer reports in Queensland.

The previous few months had been unusually dry in the Lockyer Valley. Only 265mm of rain fell between December and April, compared to a usual average closer to 450mm. Over this period the daily maximum temperature in the Lockyer averages 30 to 32°C, with minimums around 18°C. These conditions are ideal for redbacks, and could well have contributed to an increased population.

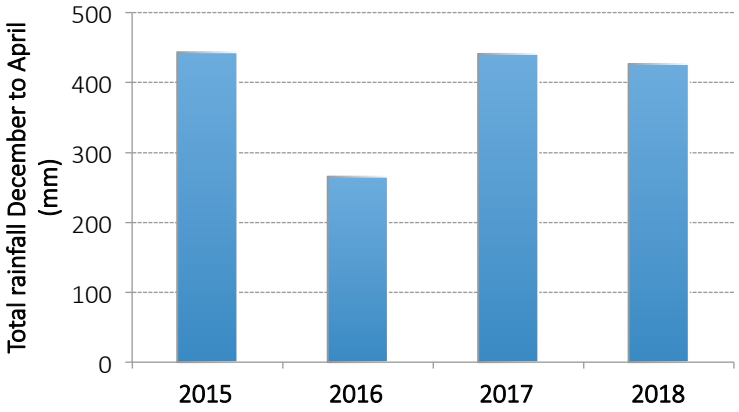

Figure 13. Total summer rainfall in Gatton, Queensland between December and April, from 2014 to 2018.

Werribee, in Victoria, produces broccoli year-round, with peak production during the warmer months. Summer rainfall in Werribee is usually less than half that experienced in Gatton, averaging 150 to 220mm total for the December to April period. However, as well as being dryer, it is also cooler. Daily maximums are 5 to 7°C less in Werribee than in Gatton. Under these conditions redback reproduction will still occur, but be slower than in Queensland. These climatic factors may help explain the lower rate of detections for broccoli that was likely sourced from Victorian production areas.

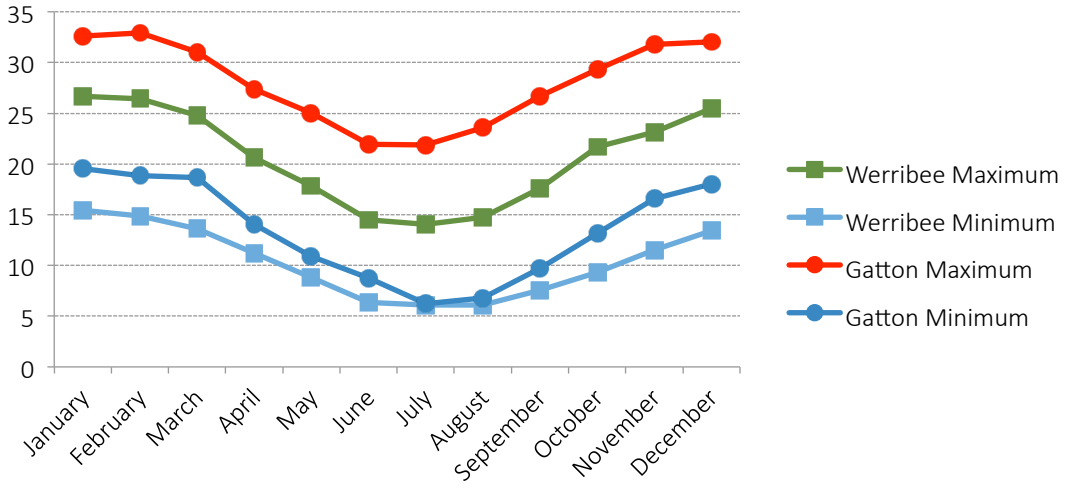

Figure 14. Mean monthly maximum and minimum temperatures in two major broccoli production areas.

Other crops grown

Key points relating to broccoli

- Redback spiders have been detected in cucurbits, grapes and cotton, suggesting that these crops can provide a suitable habitat for the spiders
- Growing crops that provide harborages for redback spiders near to, or immediately prior to, broccoli may increase the risk of redback spiders transferring to broccoli crops on crop residues, farm equipment or harvest bins
- There appears to be a correlation between abandonment of pumpkin crops and redbacks in the succeeding crop of broccoli
- Removing crop residues and/or spraying a broad spectrum insecticide before planting, may help to reduce the risk of contamination of broccoli crops

It was previously noted that redbacks have been reported in cucurbit crops. The sheltered conditions inside the closed canopy of a dense crop of pumpkins or melons, especially if grown on plastic mulch with drip irrigation, could well provide a suitable environment for redback spiders.

Spiders have been found sheltering under Kent pumpkins, much as they might shelter under a stone in the natural environment. Moreover, the ground-dwelling beetles that are the key prey of redbacks are not considered cucurbit pests, so would usually not be specifically controlled within pest management programs. A suitable habitat plus a plentiful food supply could allow relatively high populations to develop during summer months.

Pumpkins are generally harvested into large plastic bins. These may be stored for several weeks before the pumpkins are repacked into hat bins, cartons or crates. Plastic bins can provide a suitable habitat for redback spiders, having numerous cut-outs and cavities within the moulded plastic.

Pumpkins and other cucurbits are not widely commercially grown in Werribee, but are produced in large volumes in the Lockyer Valley. Summer production of Kent pumpkins may be followed by winter production of broccoli.

Cross-contamination between these crops appears possible if planters, harvest bins, irrigation equipment and other machinery used for growing and harvesting pumpkins is subsequently used when planting broccoli. It is easy to imagine a scenario where egg sacs or spiderlings clinging to such equipment become dislodged during planting operations, or are accidentally transferred into the crop on irrigation pipes. Alternatively, redbacks that have made their homes on plastic bins used to store pumpkins could move into the picked product once it is transferred to the cold room.

Figure 15. Irrigation equipment (left) and plastic bins used during harvesting (right) could introduce redback spiders into the crop or picked product respectively.

The major peak in reports of redbacks in broccoli occurred in April – June 2016. This followed a

major oversupply period for pumpkins. Hot, dry summer weather meant that production was high, but demand was slow and prices plummeted. As a result, many growers abandoned crops of Kent and Grey pumpkins, which were not worth harvesting (J. Kappas, pers. com.). It seems possible that leaving the residues of these crops in the field contributed to high numbers of redback spiders in succeeding crops of broccoli.

Adoption of integrated pest management (IPM)

Key points relating to broccoli

- Redback spiders and their prey (ground-dwelling beetles, millipedes, etc) are killed by contact with the broad spectrum insecticides that were once widely applied during crop production.
- The shift to Integrated Pest Management (IPM) using selective insecticides is likely to have increased survival of both spiders and non-target prey organisms

Broccoli crops are certainly not the natural habitat of redback spiders. Up until 2016, they were not a significant issue for broccoli producers or consumers.

It seems probable that the broad-spectrum insecticides once widely used by vegetable producers were effective against both spiders and their prey. However, many growers have now changed to IPM programs. Minimal sprays of "soft", selective pesticides have replaced many of the old synthetic pyrethroids and organophosphates. Populations of non-target insects, including beneficial insects and the ground dwelling beetles and millipedes that form much of the diet of redback spiders, are likely to have increased as a result.

One study in Switzerland examined populations of non-target insects and spiders in cabbages treated with a broad spectrum insecticide program (dimethoate, cypermethrin), a selective insecticide program (pirimicarb, *Bacillus thuringiensis*) or left unsprayed. Unsurprisingly, populations of both spiders and carabid beetles were reduced under the broad-spectrum insecticides compared to the selective options[xli]. The "soft" insecticide spinosad has also been shown to have little effect on spiders[xlii].

It therefore appears probable that adoption of sustainable pest management practices has significantly contributed to increased spider populations in crops generally, including redbacks.

Control strategies

Physical

Key points relating to broccoli

- It is likely that redbacks mainly enter broccoli crops on equipment and machinery
- Ensuring equipment used to grow broccoli is free of spiders and egg sacs is key to preventing contamination
- Removing or cleaning sites that provide habitat for redback spiders will prevent local populations increasing and spreading

According to Queensland Museum spider expert Dr Robert Raven, redbacks primarily move into cropping areas on farm equipment. This may include seedling planters, irrigation pipes, tractors, farm vehicles and harvest bins. Spiders can drop off machinery as adults or enter in greater numbers through dislodged egg sacs or as newly emerged spiderlings. Possibly the most important strategy to reduce risk of contamination is ensuring that all equipment is spider-free before it enters the cropping area. This could include high pressure washes and/or inspection for webbing.

As noted previously, removing protected sites where redbacks can make their webs can be an effective control strategy[xxvi]. In agricultural areas, these sites can include piles of building materials,

old equipment, disused vehicles, old storage sheds, etc. Removing unnecessary materials from around crops and packing areas eliminates redback harborage sites.

Some protected sites are permanent – such as pump houses, electrical boxes and storage sheds. Ensuring these are kept clean and clear of debris may also help to reduce the redback population.

Figure 16. Keeping piles of building materials separated from farm equipment (left) and keeping pump houses and other structures clean, removes harborages that could be used by redback spiders.

Chemical - pesticides

Key points relating to broccoli

- Most research relating to the effect of crop pesticides on spiders has focused on minimising, rather than maximising, spider mortality
- There is limited information on the effects of various insecticides on redbacks
- Redback webbing is likely to partially protect spiders from the effects of pesticides
- In general, products containing a pyrethroid, organophosphate or fipronil active ingredient are the most likely to be effective against adult redback spiders
- Egg sacs are protected by waterproof silk; pesticides are more effective against eggs when formulated in oil
- Although there are a number of broad spectrum insecticides registered for use on broccoli crops with active ingredients that *may* control redback spiders, they are not registered for this purpose; use to control spiders would therefore be off-label (illegal)
- Application of a broad spectrum insecticide in broccoli is not recommended as it is likely to kill very few spiders but will strongly disrupt existing IPM programs
- The best use of insecticide/miticide is to control redback spiders in potential harborages and on equipment and machinery used to grow broccoli

There is little information on whether the registered pesticides commonly applied to broccoli affect redback spiders. Pesticides with modes of action that target specific insect pests, or which have to be ingested, are less likely to affect spiders. This is why such chemicals are used in IPM programs. Spiders are generally perceived as beneficial in crops, so most research has focused on identifying insecticides with minimal impacts[xliii].

For example, even though the insecticides pyridalyl, indoxacarb, chlorfenapyr and chlorpyrifos were active against diamondback moth on cabbage, they were not recommended for IPM programs as they reduced spider populations by 25 to 75%, with chlorpyrifos having the greatest effect[xliv]. A study testing the effects of various pesticides on the beneficial spider *Theridion impressum* found that a mixture of cypermethrin and chlorpyrifos resulted in 80% mortality, while @-cypermethrin and deltamethrin caused approximately 60% and 30% mortality respectively. Spiders are more closely related to mites than insects, and a number of miticides also resulted in high mortality[xlv].

Despite the beneficial effects of spiders in crops generally, most would make an exception for *Latrodectus* species. A study developing methods to control black widow spiders (*L. hesperus*) tested applications of fipronil (broad spectrum phenylpyrazole), cyfluthrin (a synthetic pyrethroid) and imidacloprid (a neonicotinoid) to spiders and their webbing. Fipronil was the most effective, killing 96% of spiders within 8 days. Cyfluthrin controlled 70% of spiders after 5 days while imidacloprid resulted in only 18% mortality after 14 days[xlvi].

Laboratory trials against redback spiders in Japan confirm that sprays of synthetic pyrethroids (permethrin and phenothrin) can be effective control measures[xlvii]. The organophosphate diazinon and the carbamate insecticide fenobucarb also resulted in 100% mortality, but relatively higher doses were required. Carbaryl was less effective, while imidacloprid provided little control. It should be noted that these trials were conducted with the spiders continuously exposed in glass tubes. Spraying spiders through their web reduced the effectiveness of some insecticides, but still resulted in acceptable mortality.

In general, pyrethroids, cyclodienes, organophosphates and carbamates are most toxic to spiders, whereas products such as neonicotinoids, organochlorides, benzylurea, oils and insect growth regulators are not effective. However, mortality varies according to spider species, sex and web type; the three dimensional webs of *Latrodectus*, together with their use of a retreat, make them less susceptible to pesticides than some other species[Error! Bookmark not defined.].

However, insecticides that kill adult spiders do not necessarily affect egg sacs. Egg sacs are covered with a protective layer of water-repellent silk, which can stop chemical sprays from contacting the eggs or young spiderlings inside.

A Californian study on brown widow (*L. geometricus*) egg sacs found that water based sprays containing active ingredients such as cyfluthrin or deltamethrin resulted in 28 to 44% of egg sacs failing to produce spiderlings. When the same products were mixed with an oil based carrier they were 94 to 100% effective[xvii]. The authors suggest that results are likely to be similar for other *Latrodectus* species, and recommend use of oil based sprays when egg sacs are present.

The effects of a number of pesticides on spiders in general, and *Latrodectus* species specifically, are summarised in Table 2.

Table 2. Pesticide efficacy against spiders. NB. list only includes active ingredients where there is a formulation registered for use on broccoli.

	Chemical group	Active ingredient	Approx. mort (%)	Tested on *Latrodectus*?	Source
Adults	1B Organophosphate	Chlorpyrifos	70	No	Patra *et al*, 2017
		Diazinon	100	Yes	Nagata *et al*, 1997
	2B Phenylpyrazole	Fipronil	96	Yes	Gaver & Hansen, 2005
	3A Pyrethroid	a-Cypermethrin	60	No	Pekar, 2002
		Bifenthrin	68	No	Pekar, 2002
		Cyfluthrin	70	Yes	Gaver & Hansen, 2005
		Deltamethrin	30	No	Pekar, 2002
		Permethrin	100	Yes	Nagata *et al*, 1997
		Tau-fluvalinate	70	No	Pekar, 2002
	4A Neonicotinoid	Imidacloprid	18	Yes	Gaver and Hansen, 200
	13 Chlorfenapyr	Chlorfenapyr	70	No	Patra *et al*, 2017
	22A Oxadiazine	Indoxacarb	45	No	Patra *et al*, 2017
Eggs	3A Pyrethroid	Cyfluthrin	44	No (but related	Vetter *et al*, 2016
		Deltamethrin	33		
		Cyfluthrin + oil	100		
		Deltamethrin + oil	100		
	13 Chlorfenapyr	Chlorfenapyr + oil	100		

It should be emphasised that the products listed in Table 2 for use on crops are not necessarily registered for use against redback spiders. Moreover, applying broad spectrum chemicals in the field will kill beneficial insects that are present in the crop, severely disrupting any IPM program that is in place. Redback spiders are unlikely to be present in broccoli crops in large numbers, so application of a broad spectrum insecticide in the field would seem an inefficient control strategy.

Using an effective insecticide or miticide on potentially contaminated machinery or equipment, so as to ensure that spiders are not transferred into the field, would be a better application of such products. There are a range of products registered for control of spiders on hard surfaces, including ones with the active ingredients noted in Table 2.

Chemical - other

Key points relating to broccoli

- While herbicides are generally harmless, the surfactants they contain can kill a significant percentage of spiders
- Chlorine compounds are thought to reduce the viability of egg sacs, but no supporting data could be found for this report

In recent years, there has been considerable concern about the impact of herbicides on spiders. In general, most studies have demonstrated that the herbicides themselves are non-toxic to spiders, even though they may alter aspects of behaviour[xlviii], either increasing or reducing overall activity[xlix].

Other researchers have suggested that, while herbicides themselves are relatively benign, the surfactants that are used to improve their effectiveness can be toxic. In New Zealand, researchers are concerned that herbicides used to control lupins could kill endangered *L. katipo* spiders. Tests on brown house spiders (*Steotoda capensis*, Theridiidae) showed that application of the surfactant Boost® (900g/L Dimethicone copolyol) resulted in 35% mortality within 7 days[l]. It is thought that surfactants kill spiders by breaking down their cuticle, resulting in dehydration[li].

Unfortunately, no information could be found on the effectiveness of detergents against spiders when used for washing equipment or vehicles.

Another control strategy may involve the use of chlorine compounds to destroy egg sacs (R. Raven, pers. com.). As chlorine compounds such as bleach react with organic molecules, it seems plausible that these products can dissolve the protective silk layer, exposing fragile eggs and spiderlings to the environment. This could not be confirmed for the current study, although sprays of strong bleach (approx. 1% chlorine) are recommended by some pest control agencies to destroy webbing. However, it should be noted that a small laboratory study by the author found that spraying spiders with 10,000ppm (1%) chlorine solution did not cause significant mortality of adult redbacks.

Postharvest controls

Key points relating to broccoli

- Various fumigants have been shown to be effective against redback spiders in table grapes, but the cost of applying such treatment to broccoli would likely be prohibitive
- The effects of existing postharvest practices on redbacks are unknown

While it is clearly preferable to stop spiders from entering broccoli crops in the first place, postharvest treatments may provide an extra level of security against live infestation.

Californian table grapes exported to Australia are fumigated with a mixture of 1% SO_2 + 6% CO_2 as a quarantine treatment against black widow spiders[lii]. More recent work has proposed fumigation with ozone, as this can be performed without increasing the temperature of the fruit and has additional benefits in terms of disease control[liii]. In Australia, a trial involving nearly 4,800 redback spiders demonstrated that fumigation with 31g.m^3 ethyl formate plus 21.6% CO_2 resulted in 100% mortality[liv].

While redbacks can survive low temperatures and extended periods without food, it is possible that other existing practices may reduce risk. One example is hydrocooling, which could potentially wash spiders out of broccoli heads. It is also possible that the low pressures used during vacuum cooling could kill spiders; creatures such as lizards and frogs are killed during vacuum cooling. However, these techniques remain untested.

Summary

While much is not known about redback spiders in vegetable production areas, enough information is available to make a number of informed guesses as to ways to reduce the potential for contamination in broccoli crops. Some of these measures have already been implemented by growers, which may explain the reduction in customer interceptions of redbacks in broccoli crops in the last two years. Actions that may help to reduce risk are summarised in Table 3.

Table 3. Strategies to reduce risk of redback spider contamination during broccoli production.

Step	Input / Hazard	Risk reduction
Climate	• Weather	• Contamination less likely during cool, wet weather
Site history	• Previous crops grown eg cucurbits • Adjacent crops	• Clean site thoroughly if previous crop provided potential harborages for spiders • Apply broad spectrum pesticide pre-planting if spiders present
Site preparation	• Nearby habitat, shelters • Crop residues • Pre-planting herbicides • Irrigation type	• Keep crop edges clear • Till to eliminate protected sites in-field • Apply product that includes surfactant • Overhead (not drip) irrigation; clean irrigation pipes before transfer to crop area
Planting	• Equipment • Seedling trays	• Vehicles and planters cleaned before use • Check for spiderlings under seedling trays
Spraying	• Equipment • Chemicals used	• Vehicles and equipment kept physically clean • Application of broad spectrum insecticide / miticide (eg a synthetic pyrethroid or organophosphate) to equipment, machinery and harborages
Harvest	• Bins • Machinery	• Plastic harvest bins pressure cleaned inside and out • Machinery cleaned before use
Cooling	• Cooling method • Other stored products	• Hydro-cooling / vacuum cooling MAY reduce risk • Broccoli bins not stored alongside potentially contaminated products
Packing	• Packing materials • Packing line and equipment • Product inspection	• Packing materials exclude spiders • Facilities well managed and clean • Staff trained to look for redbacks during packing

Further Research and Recommendations

This review has been undertaken during winter months, when spider populations are at their lowest and those remaining are less active. Understanding how and why redbacks enter broccoli crops clearly requires field work during summer and autumn, when spider populations are highest and contamination is most likely.

Questions for an applied project:

Where are redbacks found in vegetable production areas? This will require scouting of different vegetable crops, areas adjacent to production areas, equipment, machinery and harvest bins to examine where redbacks are most commonly found. The study should include consideration of prey species found in webs, as this may provide further clues as to control strategies.

Are there crop combinations or cultural practices that increase the risk of contamination? While it has been observed that there appears to be a correlation between pumpkin production and redbacks in broccoli, this link is purely speculative. Other crops, such as melons or corn, may similarly increase spider populations and therefore risk to a later crop of broccoli. Factors such as irrigation through sub-surface drippers instead of overhead sprinklers, and leaving crop residues in the field before replanting, may also be risk factors, but are currently untested.

How can pesticides contribute to reducing risk from redback spiders, and what products would be most effective? Some growers have proposed using an early spray of a registered class 1B or 3A registered chemical to ensure that no redbacks are present in the crop. As these products are not registered for control of spiders, this is an off-label use pattern. Moreover, destroying any existing IPM program in order to kill a relatively small population of spiders would seem an inefficient use of these products. Broad-spectrum pesticides could be used to control spiders more efficiently if applied to crop residues before broccoli is planted, machinery and equipment before use, and potential harborages to prevent infestation. Recommendations on the most effective chemicals for these purposes would provide growers with a reduced risk pesticide program that leaves their IPM program intact.

Are physical control methods such as washing and habitat destruction effective for controlling redback spiders? Some growers already use high-pressure washing to clean equipment and vehicles used in broccoli crops. It is possible that effectiveness could be significantly increased by adding a surfactant / detergent to the water used. This could be particularly useful against egg sacs, which are unlikely to be destroyed by washing alone. Alternatively, the use of chlorine products should be investigated, to determine what concentrations are needed to destroy webbing and denature egg sacs.

Is there a role for postharvest treatments that kill/remove spiders from broccoli? While it is clearly preferable to avoid spiders entering the crop in the first place, postharvest tools that further reduce risk could be useful in some circumstances. For example:

- Vacuum cooling can cause some small creatures (lizards, frogs) to explode due to the rapid change in pressure; the effects of this cooling method on redback spiders should be investigated.
- Hydrocooling with pressurized water could potentially help remove spiders from broccoli heads.
- To further reduce risk, it may be possible to detect spiders by scanning with near infrared (NIR). NIR units are already installed on packing lines for other products. The application of these units to detect contaminants including spiders could be investigated.

Can research be conducted jointly to benefit the vegetable and table grape industries? Redback spiders are regularly an issue for table grape producers. Control strategies are likely to be similar for both crops, suggesting that conducting research jointly would benefit both industries.

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Appendices

Fact sheet on managing redback spiders in broccoli crops

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AUGUST 2018

MANAGING THE RISK OF REDBACK SPIDERS IN BROCCOLI CROPS

INTRODUCTION

Since 2016 there have been numerous customer complaints about redback spiders (*Latrodectus hasselti*) in broccoli. Complaints have mainly come between January and June, and from customers in all Australian states. This suggests that this is not an issue for a single production area, but can occur anywhere that broccoli is grown.

Redback spiders are clearly unacceptable to consumers, and also pose risks to growers, pickers and packers.

Despite their fearsome reputation, redback spiders are generally timid. They are nocturnal, travel only short distances and need protection from wind, rain and extremes of temperatures. Broccoli crops are not their usual habitat.

This Fact Sheet summarises what we know about the risk of redback spiders contaminating broccoli.

LIFE OF A REDBACK SPIDER

Developing to maturity

Redbacks can reproduce anywhere where daily temperatures are >15°C for three months or more. Temperatures of 25°C to 30°C are optimal. Under these conditions tiny spiderlings can grow into mature females within **6 to 8 weeks**. Maturation is slower at 15 to 25°C and effectively stops at 10°C or less.

In redback spiders the differences between the sexes are extreme. Females can be 50 times larger than the tiny, brownish coloured males.

Males usually only live a few months, whereas female spiders can live for 12 months or more if conditions are good. The population peaks at the end of summer, after which many of the mature females die.

Juvenile female – Ed Nieuwenhuys, Sydney.

Mature female – Greg Anderson, Stirling Ranges WA.

Mature male – Beth Shaw, Perth.

Reproduction

Redback populations can increase rapidly. Females are able to lay up to 16 egg sacs during a season, although most will produce 4–7. Each egg sac contains around 150 eggs, of which ~75% emerge as spiderlings. **A well-fed female redback can therefore produce 430–800 spiderlings over summer.**

Female with egg sac and smaller male – E. Nieuwenhuys.

The eggs are surrounded by a thick layer of water-repellent silk, which protects them from changes in temperature and humidity and keeps them dry.

Dispersal

Many species of spider initially disperse by "ballooning", where young spiderlings are carried to new areas on the wind.

Redback spiders do not commonly spread through ballooning. Without human help, redback colonies expand by 0.1–0.3km/year. Spiders cover these distances simply by walking. Roads, rivers and cleared areas can therefore act as natural barriers to spread of redback spiders.

The majority of long-distance spread occurs due to human movement. Redbacks readily hitchhike on vehicles, construction materials, equipment or other goods.

Habitat

Redback spiders prefer undisturbed and well-sheltered sites, protected from temperature extremes as well as wind and rain. They are legendary for being found in outdoor toilets, a habit long popularised in Australian folklore.

There is a strong association between redbacks and humans. The expansion in built environments has allowed them to increase their range and population. Redbacks are mostly found places like drains, parking lots, cemeteries, public facilities, sheds, electrical boxes etc.

They are less common in natural areas, although they can be found hiding under rocks and logs, or sheltering inside disused rabbit holes. Dense patches of plants such as yucca can also provide the dry, sheltered environment they need.

Redbacks are occasionally found in crops such as cotton. Related black widow spiders have been found in Californian table grapes, with the result grapes must be fumigated before export to Australia. Redbacks are also sometimes found in table grapes, probably because rain covers provide the hot, dry environment they prefer.

There are several reports of redbacks living under pumpkins. It's possible they can also colonise other cucurbits, such as watermelons. The combination of dense foliage and under-fruit protection effectively provides redbacks with dry, sheltered spots to live.

Webs

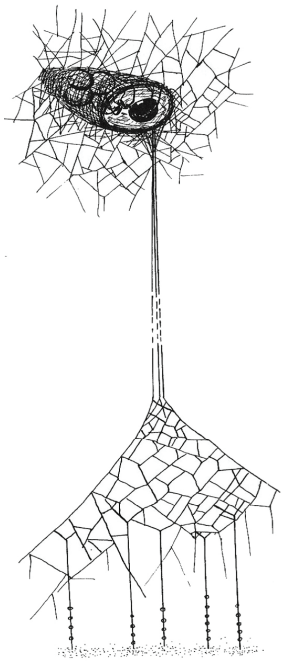
The webs of redbacks have specific features that make them relatively easy to distinguish from those of other types of spiders:

- Redbacks are ground dwellers, so the web often contacts the ground
- As they are nocturnal, they spend the daytime in a "retreat" connected to and above the main web
- Redbacks make "tangle webs", which have a few sticky strands at the base, and tangled mass above
- Webs often contain leaves, sticks and dried cadavers of prey, as redback spiders don't clean their webs (unlike most other species)
- Their webbing is relatively strong, so does not break easily when touched

Redback webs should not be confused with those of house spiders or daddy long legs, both of which are also found in sheltered locations. House spiders make untidy, lacy sheets, with funnel like retreats formed inside the web. Daddy long legs make untidy, fragile webs. They are often found within the web, which they shake violently if disturbed. Daddy long legs will kill and eat redbacks, so they are not usually found together.

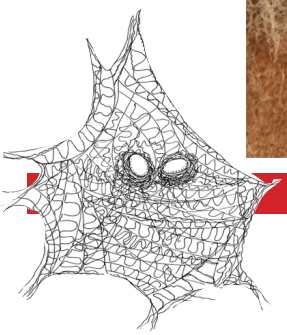
Redback webs often contain leaves and debris, as well as old insect cadavers, as they do not clean their webs.

The retreat of a redback living inside an electrical box, complete with egg sacs.



REDBACK SPIDER WEB

Structure (left, from B. York Main) and tangle web (above) of a redback spider.



HOUSE SPIDER WEB

Structure (left, from B. York Main) and web (above) of a house spider.

Prey

The majority of the diet of redbacks is ground-dwelling beetles. They will also attack millipedes, slaters, flies and even tiny lizards and mice that become snared in their webs.

Beetles, millipedes and other ground dwellers are not usually considered significant horticultural pests, so may not be controlled by pest management programs. Moreover, the warm, dry conditions that favour growth of redbacks also increase insect populations.

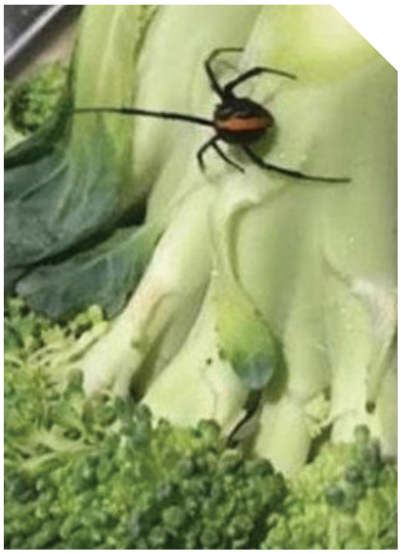
Redback spider web containing millipedes, beetles, a bush cockroach and even another spider.

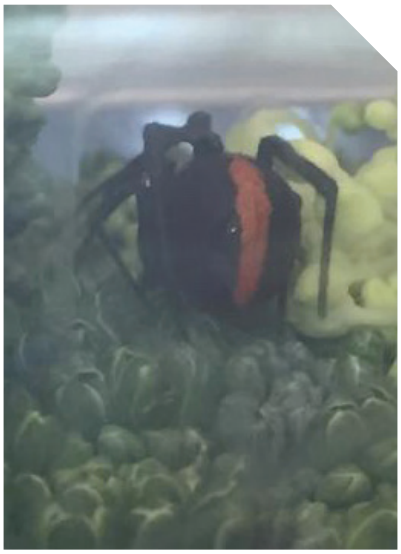
Distribution and survival

Redback spiders are now found in New Zealand, Iran, Japan and even Belgian greenhouses. This is thought to be due to their ability to hitchhike on and inside shipping containers and exported goods. Most outbreaks are associated with ports.

This spread is partly due to redbacks' ability to survive extremes of temperature as well as long periods without food or water. They can live without food for four months at 10°C, or six weeks at 25°C. Provided with shelter, redbacks can also survive winter temperatures falling to -3°C, and remain active at 40°C during summer.

Redbacks can easily survive the times and temperatures involved in broccoli supply chains.





Images of spiders in broccoli, taken by consumers in April 2016 and 2017.

REDBACKS IN BROCCOLI

Detections

There are no official records of redback spiders in broccoli crops, and growers who have searched for them have failed to find any. This doesn't mean they are not there, but does suggest they are very uncommon.

Redbacks are occasionally found in broccoli heads after harvest, either during packing or by consumers preparing them for a meal. Most finds have been between January and June, with peak months in April and May. This is unsurprising, as this is when redback populations are highest.

Quite apart from negative media, redback spiders in broccoli pose a number of risks, as detailed in the table **below.**

RISK	IMPACTS	LIKELIHOOD
Worker bitten by redback spider during harvest / packing	Variable and potentially severe effects lasting 1 to 7 days, worker time off and compensation.	Moderate to low – workers wear gloves and boots
Redback spider found in broccoli displayed at retail	Possible product withdrawal, loss of reputation and sales.	Low
Redback spider found by customer when taking broccoli out of the fridge	Major loss of reputation and sales due to wide negative reporting on social media and news services.	Low
Redback spider bites customer when taking broccoli out of the fridge	Variable effects ranging from increasing localised pain for approx. 24 hours to nausea, severe sweating, intense referred pain in other parts of the body and other effects lasting up to a week.	**Very** low – Spider inactive while cold so unlikely to bite
Redback spider bites customer during preparation of broccoli		Low
Redback spider accidentally eaten by customer	Negligible; the proteins in venom are denatured by heating and/or destroyed by low pH in the stomach.	**Very** low

Spiders can potentially move around the farm on irrigation equipment.

Plastic bins used during harvesting could introduce redback spiders into the crop or directly onto picked product.

Risk factors

It is not known how or why redbacks get into broccoli, only that they are occasionally found in broccoli heads after harvest.

- Redback spiders can enter broccoli crops by being carried in on equipment such as irrigation pipes, machinery, seedling trays or harvest bins.
- Cross-contamination may be more likely if equipment used for broccoli was previously used for growing and harvesting cucurbits.
- Bins and equipment that have been sitting undisturbed for several weeks are more likely to have been colonised by spiders.
- High populations of potential prey (e.g. millipedes, ground beetles) could support redback spider survival and breeding in cropping areas.
- Spider discoveries appear to correspond with hot, dry summers, which are likely to lead to spikes in population.

Pictures of redback spiders in broccoli posted on social media appear to show newly mature females, perhaps 2–4 months old. However, no webbing is visible in these photos. This suggests that the spider was not living in the broccoli head in the field, but entered at or after harvest. For example, it is easy to imagine a scenario where a spider living on the bottom of a plastic harvest bin crawls into picked broccoli after it is moved into a cold room.

REDBACK SPIDERS LIVING ON HARVEST BINS COULD POTENTIALLY CONTAMINATE BROCCOLI AT HARVEST

Control strategies

Chemical

There are a number of broad-spectrum insecticides registered for use on broccoli crops with active ingredients that *may* control redback spiders. However, they are not registered for this purpose. Application of these products to control spiders would be an off-label use pattern and therefore illegal.

In any case, application of a broad-spectrum insecticide to kill redback spiders in broccoli is not recommended. There are likely to be extremely few, if any, spiders within the crop. Moreover, such sprays will strongly disrupt existing IPM programs. This therefore appears an inefficient control strategy.

The best use of insecticide/miticide is to control redback spiders in potential harbourages and on equipment and machinery for growing broccoli.

There is very limited information on the effects of various pesticides on redback spiders. However, products registered for controlling spiders which contain a synthetic pyrethroid (e.g. permethrin), organophosphate (e.g. diazinon) or fipronil as the active ingredient are most likely to be effective against adult spiders. Efficacy generally ranges from 70–100%.

The effects of pesticides are likely to be reduced if spiders are protected by their webbing. This effect is strongest for egg sacs, which are protected by a thick layer of waterproof silk. Pesticides formulated in oil are far more effective against eggs than the same products formulated in water.

Webbing may also be dissolved using chlorine compounds (e.g. bleach), but care needs to be taken not to damage equipment with the strong concentrations required.

Physical

The best way to avoid contamination of broccoli by redback spiders is to stop them entering the crop in the first place. Ensuring equipment, machinery and bins used for broccoli are free of spiders and egg sacs is key to preventing contamination.

Electrical boxes, piles of disused materials, and irrigation pipes can make good habitat for redbacks.

THE BEST WAY TO KEEP SPIDERS OUT OF AN AREA IS NOT TO BRING THEM IN.

Removing or cleaning sites that provide habitat for redback spiders – such as piles of building equipment, disused machinery, pump houses and farm sheds – will help prevent local populations from increasing and spreading.

If redback spiders were present in the crop grown prior to broccoli, such as a summer planting of pumpkins before autumn broccoli, then crop residues should be thoroughly ploughed in before re-planting. Redback spiders will die if their shelter is destroyed and they are left exposed.

MANAGING THE RISK OF REDBACK SPIDERS IN BROCCOLI CROPS
August 2018

Strategies to reduce the risk of redback spider contamination of broccoli

STEP	INPUT / HAZARD	RISK REDUCTION
CLIMATE	■ Weather	■ Contamination less likely during cool, wet weather
SITE HISTORY	■ Previous crops grown e.g. cucurbits ■ Adjacent crops	■ Clean site thoroughly if previous crop provided potential harbourages for spiders ■ Apply broad spectrum pesticide pre-planting if spiders present
SITE PREPARATION	■ Nearby habitat, shelters ■ Crop residues ■ Pre-planting herbicides ■ Irrigation type	■ Keep crop edges clear ■ Till to eliminate protected sites in-field ■ Apply product that includes surfactant ■ Overhead (not drip) irrigation; clean irrigation pipes before transfer to crop area
PLANTING	■ Equipment ■ Seedling trays	■ Vehicles and planters cleaned before use ■ Check for spiderlings under seedling trays
SPRAYING	■ Equipment ■ Chemicals used	■ Vehicles and equipment kept physically clean ■ Application of broad spectrum insecticide / miticide (e.g. a synthetic pyrethroid or organophosphate) to equipment, machinery and harbourages
HARVEST	■ Bins ■ Machinery	■ Plastic harvest bins pressure cleaned inside and out ■ Machinery cleaned before use
COOLING	■ Cooling method ■ Other stored products	■ Hydro-cooling / vacuum cooling MAY reduce risk ■ Broccoli bins not stored alongside potentially contaminated products
PACKING	■ Packing materials ■ Packing line and equipment ■ Product inspection	■ Packing materials exclude spiders ■ Facilities well managed and clean ■ Staff trained to look for redbacks during packing

Hort Innovation Strategic levy investment | VEGETABLE FUND

This project has been funded by Hort Innovation using the vegetable research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

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