

# 24 Arthropod Pests of Australian Canola During Crop Emergence: IPM and Future Directions

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## 24.1 Introduction

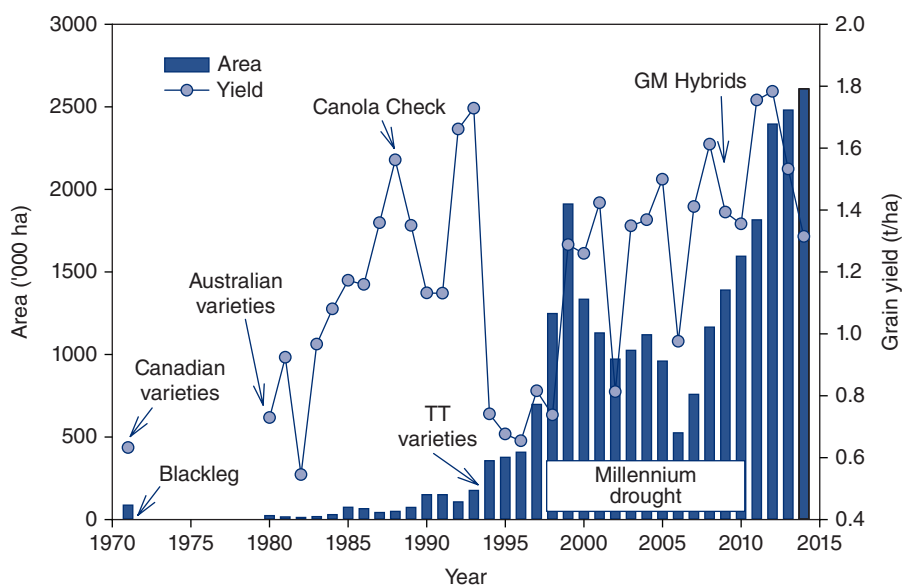
Canola (also known as oilseed rape, mostly spring-type *Brassica napus*) is a common winter oilseed crop grown in a range of soil types across Australia, typically as part of a cereal crop rotation. When *B. napus* was originally introduced and grown in Australia in the 1960s (using Canadian varieties), farmers suffered significant problems with the fungal disease 'blackleg' throughout the 1970s (Van De Wouw *et al.*, 2016). It was not until new varieties were developed for Australian conditions that the crop became attractive to farmers. Although *B. napus* was used as a break crop in the traditional cereal rotation on many farms across southern and western Australia (Australian Government, 2008; Kirkegaard *et al.*, 2016), it is now an important cash crop in its own right. *B. napus* is grown in Mediterranean and temperate climatic regions and, depending on rainfall, is planted in autumn (late April to June) each year. The area of land under *B. napus* in Australia in 2014 was 2.72 million hectares, which represents about 12% of all the area of broad-acre cropping, and this trend has been increased in the past 7–10 years, though productivity has not been improved compared with the mid-1990s (Kirkegaard *et al.*, 2016) (Fig. 24.1).

*B. napus* is especially susceptible to damage from invertebrate pests from emergence to the five-leaf stage (Miles and McDonald, 1999; Gu *et al.*, 2007); consequently pesticide applications in seed dressings and pesticide sprays at the early stages of development are frequent. Today, widespread losses

of *B. napus* crops due to pest damage at crop establishment is a factor that limits productivity and is a continual risk for growers. Furthermore, the increasingly widespread practices of reduced tillage and stubble retention for soil conservation and water-use efficiency may have altered the risks associated with certain pests in recent years (Hoffmann *et al.*, 2008) (Fig. 24.2). There is a limited understanding of the biology and ecology of some of these pest species that attack the plant during the early stages (hereafter referred to as emergence pest species). Due to lack of established economic thresholds, decision making for pest management is not reliable. Additionally, some pest species show a high tolerance (and in some cases resistance) to conventional pesticides. Examples include *Balaustium medicagoense* (Acarina: Erythraeidae) and *Bryobia* sp. (Acarina: Tetranychidae).

There are over 28 invertebrate species that are considered pests of *B. napus* at the crop emergence period (Micic *et al.*, 2008). These include mites (e.g. *B. medicagoense* and *Halotydeus destructor* (Acarina: Pentheleidae)), springtails (lucerne flea *Sminthurus viridis* (Collembola: Sminthuridae)), true and false wireworms (e.g. various species in Coleoptera: Tenebrionidae and Coleoptera: Elateridae families), weevils (e.g. *Listroderes difficilis* (Coleoptera: Curculionidae)) and noctuid caterpillars (e.g. *Agrotis infusa* (Lepidoptera: Noctuidae)). Later in the season, when the crop is flowering and at pod-filling stage, aphids and migratory lepidopterans (e.g. *Plutella xylostella* (Lepidoptera: Plutellidae))

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**Fig. 24.1.** Area and average national grain yield for *Brassica napus* (canola) in Australia highlighting some of the significant events influencing the observed trends. Data compiled from ABARES estimates and Australian Oilseed Federation estimates. Reproduced with permission from Kirkegaard *et al.*, 2016.

can cause sporadic damage (Gu *et al.*, 2007). These pest species are different to the community found attacking *B. napus* (oilseed rape) throughout Europe (Williams, 2010) and North America (Doddall *et al.*, 2012). The Australian pest species are mostly non-native but many have been present in Australian grain production landscapes for many years.

## 24.2 Emergence Arthropod Pest Communities in Australian Agroecosystems

This section focuses on pest species that are economically important during the crop emergence period (Table 24.1): lucerne flea (*Sminthurus viridis*); and the Acari species redlegged earth mite (*H. destructor*), blue oat mites (*Penthaleus* spp.), clover mites (*Bryobia* spp.) and *Balaustium* mite (*B. medicagoense*) (Micic *et al.*, 2008). Whilst *Bryobia* mites are mainly active in warmer conditions closer to crop flowering, they can also be pests of *B. napus* at emergence and are included here (as elsewhere, e.g. Micic *et al.*, 2008). The following sections summarise what is known about these species in Australian cropping systems and what control strategies can be used as a part of integrated pest management (IPM) approaches and discuss new monitoring and

management tools that are being developed for more effective management of these pests.

### 24.2.1 *Sminthurus viridis* (L.) (Sub-Class Collembola: Sminthuridae)

The lucerne flea, *S. viridis*, is a 1–3 mm wingless collembolan that lives in the soil and feeds on living plants, causing skeletonisation of the leaf. It is a commonly occurring pest of pastures and broad-acre grain crops in autumn (March–May) (Wallace and Mahon, 1971b; Bailey, 2007) (Table 24.1). It feeds on a range of plant types (pasture legumes, grain legumes and *B. napus*) but is mostly restricted to heavy (loamy) soils or fine-textured soils that are slightly acidic (Micic *et al.*, 2008). Lucerne flea is regarded as a resident pest that is relatively non-mobile (Table 24.1), though distribution within a field can be highly dynamic and patchy (Wallace, 1967). It is winter active (June–August) and avoids dry summer conditions by producing diapausing eggs that are resistant to desiccation (Wallace, 1968; Roberts *et al.*, 2011a). The genetic data showed significant population structure between regions, suggesting that there is limited gene flow between populations (Roberts and Weeks, 2011). Although human-facilitated long-distance movement events



**Fig. 24.2.** *Brassica napus* (canola) planted into a retained stubble field: (a) at emergence (plants just visible); (b) post-emergence. Quarter-quadrat is shown for scale. Photo credit: CSIRO.

occur to some degree, this has implications for how this resident pest is managed within and between seasons. Currently pesticides are the main control option used by growers; however, this species is known to display high tolerance to a range of pesticides, e.g.  $\alpha$ -cypermethrin, bifenthrin, omethoate, methidathion and phosmetin (Roberts *et al.*, 2009).

#### 24.2.2 *Halotydeus destructor* (Acarina: Pentheleidae)

The redlegged earth mite, *Halotydeus destructor*, is approximately 1 mm in length with a distinctive globular black velvet body and red-orange legs. This species is active in autumn and winter (March–August) and considered a widespread pest in both pastures and emerging field crops, especially *B. napus* (Ridsdill-Smith *et al.*, 2008) (Table 24.1).

Females produce diapausing eggs in spring that are able to withstand the hot and dry summer conditions prevalent across cropping and pastoral regions of the southern Australia (Ridsdill-Smith *et al.*, 2008). *H. destructor* is highly polyphagous and can also exploit alternative broadleaf hosts, such as *Arctotheca calendula* (capeweed), that are common along roadsides, in native vegetation and other areas near crop fields (Fig. 24.3a). On *B. napus*, mite feeding results in a ‘silvering’ pattern (Fig. 24.3b) on the seedlings and can lead to death or slow growth; however, the plant does show some tolerance to feeding at later growth stages (Arthur *et al.*, 2013a).

This species was introduced into Western Australia from South Africa in around 1908 (Halliday, 1991) and has since spread widely across all southern regions. Its distributional limits were previously linked to upper temperatures and a rainfall isohyet (Wallace and Mahon, 1971a), though the species has recently expanded its range in drier and hotter inland regions (Hill *et al.*, 2012a). Genetic analysis suggests that the invasive population that arrived in Australia (likely from soil ballast used on ships) was from a lineage similar to that found near Cape Town today. Populations in Australia remain genetically similar across western and eastern Australia, suggesting ongoing gene flow between these large areas (Hill *et al.*, 2016). This could occur via the movement of diapausing eggs in soil adhering to farm machinery and livestock and through the transportation of plant material. Laboratory studies on the thermal limits of Australian populations and of populations from the native range in South Africa have shown that Australian populations have an increased upper thermal threshold for movement and recover from cold stress more rapidly (Hill *et al.*, 2013). This may explain why this species can persist in drier inland regions of Australia, which experience frosts frequently.

*H. destructor* is active in autumn and winter during the cool and wet months. The adults begin to lay diapausing eggs in spring in response to increased photoperiod (Ridsdill-Smith *et al.*, 2005) and this allows farmers to time control measures (timerite®) (AWI, 2016) that target the adult mites prior to egg laying in the spring (Ridsdill-Smith and Pavri, 2015). However, there continues to be damage to a range of crops caused by this pest each year (Gower *et al.*, 2008). The diapause eggs sit within the cadavers of the dead females over the summer (December–February) (Ridsdill-Smith *et al.*,

**Table 24.1.** Summary of the biological and ecological characteristics of the economically important emergence pest species of *Brassica napus* (canola) in Australia.

Characteristics	<i>Sminthurus viridis</i> (L.) (Collembola: Sminthuridae)	<i>Halotydeus destructor</i> Tucker (Acarina: Penthaleidae)	<i>Penthaleus</i> spp. (Acarina: Penthaleidae) <sup>a</sup>	<i>Bryobia</i> spp. (Acarina: Tetranychidae) <sup>b</sup>	<i>Balaustium medicagoense</i> Meyer and Ryke (Acarina: Erythraeidae)
Common name	Lucerne flea	Redlegged earth mite	Blue oat mite	Clover mite	<i>Balaustium</i> mite
Sexual or asexual reproduction	Sexual	Sexual	Asexual	Asexual (but not confirmed for all species)	Asexual
Diapause	Yes, over-summer as eggs, laid on soil surface	Yes, over-summer as eggs, retained in cadavers of female	Yes, over-summer as eggd, laid on leaves, stems, roots	No, over-wintering eggs laid early–mid winter	Yes, when conditions are unfavourable
Number of generations per year	2–3, active autumn/winter and spring	Multiple, active autumn/winter	2 (on average), active May–November	Multiple, active in warm conditions, spring/autumn	2 per season
Resistance to pesticides <sup>c</sup>	Not confirmed	Confirmed	Not confirmed	Not confirmed	Not confirmed
Tolerance to pesticides <sup>c</sup>	Documented	Not documented	Documented	Documented	Documented
Likely native range	Europe	South Africa	Not sure	Not sure	South Africa
Crops attacked	<i>B. napus</i> , pulses, lucerne, clovers and sometimes annual winter cereals	<i>B. napus</i> , pulses, lucerne, clovers, sometimes annual winter cereals, vegetables	<i>B. napus</i> , cereals, lucerne, pastures	<i>B. napus</i> , lupins, wheat, lucerne, vetch and clovers	<i>B. napus</i> , lupins, cereals, lucerne, pasture legumes, grasses
Potential loss in <i>B. napus</i> if not controlled (AUS\$ million) <sup>d</sup>	29.7	96.6	28.8	19.3	

<sup>a</sup>Three species recognised as pests in Australia (*P. major*, *P. falcatus*, *P. tectus*)

<sup>b</sup>Four species have been recorded in Australia but their taxonomy is complicated

<sup>c</sup>Recorded in Australia

<sup>d</sup>Murray *et al.* (2013a) report (see Table 7.9)

2005). A significant rainfall event and period of cooling temperatures will trigger egg hatch (McDonald *et al.*, 2015). Pesticides are currently the predominant method for controlling this pest but high levels of resistance to synthetic pyrethroids have been documented (Umina *et al.*, 2012).

#### 24.2.3 *Penthaleus* spp. (Acarina: Penthaleidae)

The *Penthaleus* species group (blue oat mites) consists of a morphologically cryptic complex of three

pest species, each approximately 1 mm long: *Penthaleus major*, *Penthaleus falcatus* and *Penthaleus tectus* (Table 24.1) (Qin and Halliday, 1995). These mites are winter-active, with three generations per season. They reproduce parthenogenetically, with populations composed of clones, and produce diapause eggs soon after adult emergence in autumn. Early-sown crops, in years when summer rainfall has supported weed growth, are most at risk from damage. Blue oat mites have been the focus of less prolonged research effort than *H. destructor* but important differences in the





**Fig. 24.3.** (a) Example of a roadside verge that contains grasses and weeds that support emergence pests of *Brassica napus* (canola). (b) Mites and mite damage to *B. napus* (canola), as seen as the silverying on the leaf. Photo credit: CSIRO.

biology and ecology of the species have been reported, with implications for management of the individual species.

Species distribution, host plant preferences, competitive ability on different host plants and pesticide tolerances differ between the *Penthaleus* species (Gu *et al.*, 2007). Historical sampling has shown that *P. major* can tolerate a drier climate than *H. destructor* (Wallace and Mahon, 1971a). More recent species distribution models show that the potential distributions of the three *Penthaleus* species across southern Australia are best described with different sets of climatic variables (Hill *et al.*, 2012b), suggesting differences in physiological tolerances of the species. The most common *Penthaleus* species on *B. napus* in field surveys was *P. falcatus* but it has a limited range of host plants compared with *H. destructor* (Umina and Hoffmann, 2004). In a shade-house study, *B. napus* was a suitable host for *P. falcatus* but *P. major* could not breed successfully on *B. napus* (Umina and Hoffmann, 2004). However, studies have shown that *P. major* can feed on *B. napus*, though it may not be an ideal host. McDonald *et al.* (1995) found that *P. major* caused about 50% less damage than *H. destructor* in a canola variety, Oscar. In the same shade-house study, feeding on *B. napus* by *P. falcatus* led to delayed flowering time in *B. napus* (Umina and Hoffmann, 2004).

#### 24.2.4 *Bryobia* spp. (Acarina: Tetranychidae)

Four species of the genus *Bryobia* (clover mites) have been recorded in Australia but the taxonomy of these species remains unclear (Table 24.1). Adult mites are about 0.75 mm long with pale red or orange legs (Bailey, 2007). *Bryobia praetiosa* has been identified as being involved in outbreaks but other species are also likely to be causing problems (Micic *et al.*, 2008). These species are active from autumn to spring (March–November) and are likely to reproduce parthenogenetically, though there have been no studies in Australia (Micic *et al.*, 2008). Unlike the other mite pests, they produce overwintering eggs that hatch as conditions get warmer in spring, so damage to crops can occur at crop emergence but also later in the season. *Bryobia* species have been found to damage *B. napus*, pasture and lupins and could reproduce successfully on *B. napus* in a shade-house study (Arthur *et al.*, 2010). They are tolerant of a range of commonly used pesticides, e.g. bifenthrin, methidathion and  $\alpha$ -cypermethrin (Arthur *et al.*, 2008). Given the general similarities

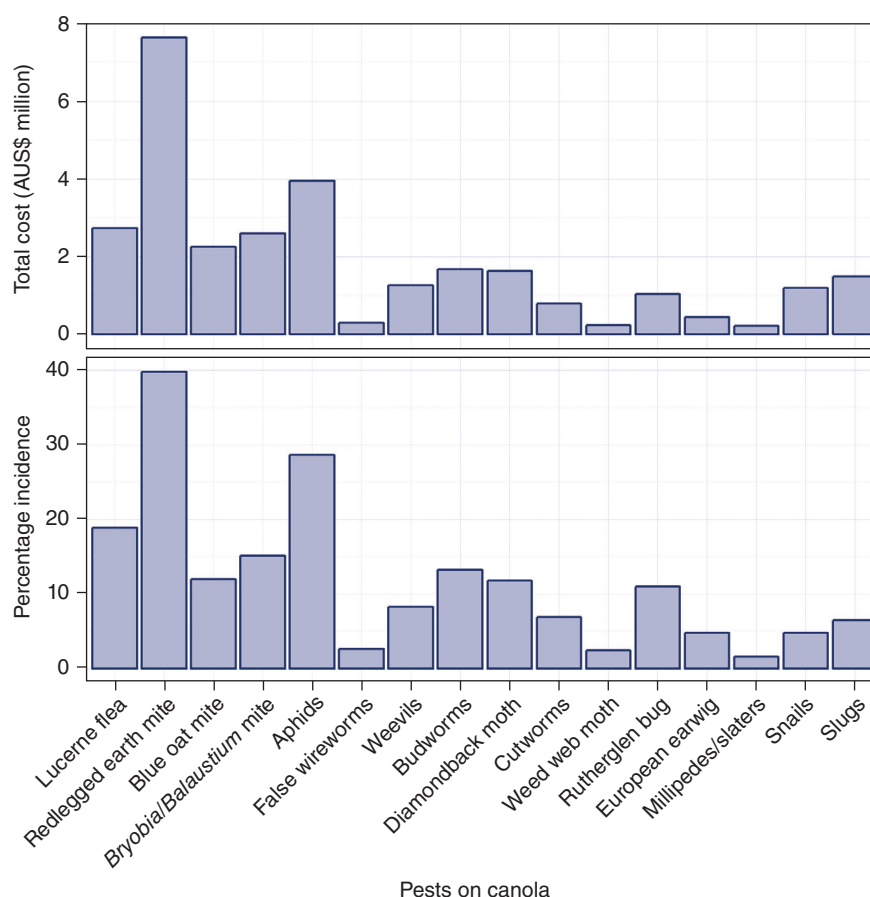
in appearance with other pest mites, and hence the confusion with identification in the field, the economic impact and pest status of *Bryobia* spp. is largely unknown (Arthur *et al.*, 2010).

#### 24.2.5 *Balaustium medicagoense* (Acarina: Erythraeidae)

*Balaustium medicagoense* is the only species of *Balaustium* that has been recorded in Australia to date and it is thought this species was introduced from South Africa through the same pathway as *H. destructor*. It typically undergoes two generations from March until December before entering a summer diapause (Table 24.1). It is a relatively large mite and at 3 mm long is over twice the size of *H. destructor*. It is more commonly found on cereals and grasses but also attacks broadleaf crops such as *B. napus*, lucerne and lupins (Arthur *et al.*, 2010). However, outbreak reports from farmers suggest that *B. napus* is the crop most commonly attacked or damaged by *B. medicagoense* (Arthur *et al.*, 2010). Many common pesticides are ineffective at controlling *B. medicagoense* in a field situation (Arthur *et al.*, 2013b). Furthermore, since the 1980s there has been an increase in the frequency of outbreaks of both *B. medicagoense* and *Penthaleus* spp. reported by growers in grain production regions (Hoffmann *et al.*, 2008).

### 24.3 Impact of Emergence Pests on *B. napus*

The high incidence of *S. viridis* and pest mites, combined with the severity of damage they cause, results in them being the most economically costly pests of *B. napus* (Fig. 24.4). Aphids are the only other pest group that causes large economic losses but not often at crop emergence (Fig. 24.4). The direct economic cost of these pests in *B. napus* is difficult to estimate as other factors, such as frost and competition with weeds, can cause more widespread crop losses within a season than the activities of emergence pests. Seedling death and poor germination due to pests may represent 100% yield loss at the plant level; however, small-scale plant loss at emergence may not reduce yields significantly at the field level (Gu *et al.*, 2007; Umina *et al.*, 2015). Pest damage to *B. napus* has been estimated to cause greater than 10% of crop establishment failures (Miles and McDonald, 1999). The potential loss (if a pest is not controlled) has been



**Fig. 24.4.** Invertebrate pest treatment costs in *Brassica napus* (canola) across Australia (not limited to emergence pests). Top graph: total cost of pesticide treatments for each pest group; bottom graph: percentage incidence of damage from each pest group (= incidence years  $\times$  incidence area). Taken from Table 7.8 in Murray *et al.*, (2013a).

estimated at AUS\$96.6 million for *H. destructor*, AUS\$28.8 million for *Penthaleus* species, AUS\$29.7 million for *S. viridis* and AUS\$19.3 million for *Bryobia* and *Balaustium* species combined (Table 24.1) (Murray *et al.*, 2013a, b).

The total average cost of treatment of invertebrate pests in *B. napus* is AUS\$29.5 million (AUS\$20.18 per ha) (Murray *et al.*, 2013b), with the use of pesticides for the control of emergence pests contributing a significant portion of this total amount. However, most of the insecticide products are relatively cheap to purchase and apply. In small-plot trials of *B. napus* across Australia the cost of insecticide inputs (including application costs) was an average of AUS\$12.67/ha (Macfadyen *et al.*, 2014). At one trial site the economic cost of using pesticides was substantially greater (almost

ten times) due to the late-season application of an expensive selective insecticide against aphid pests (Macfadyen *et al.*, 2014).

Emergence pests and their management present a range of indirect costs to growers, such as increased risk of secondary pest outbreaks and the development of resistance to pesticides. There are anecdotal reports that the application of broad-spectrum pesticides early in the season (as bare-earth sprays) to address *H. destructor* risk can lead to secondary pest outbreaks later in the season from the relatively more tolerant *S. viridis*. There is no quantitative evidence to show how often, and under what circumstances, the risk of secondary pest outbreaks in *B. napus* is increased. In cotton, spider mite *Tetranychus urticae* populations reached higher densities in plots treated with pesticides compared with untreated cotton



(Wilson *et al.*, 1998). A significant negative relationship was found between early-season abundance of predators and the mid-season abundance of *T. urticae*, suggesting that the pesticides reduced predator numbers and released *T. urticae* from control (Wilson *et al.*, 1998). Evidence of resistance in *H. destructor* to synthetic pyrethroids has been documented in Western Australia (Umina *et al.*, 2012) prior to 2010 and is likely to have become more widespread since. For other pests, such as the green peach aphid *Myzus persicae*, widespread and high levels of resistance to carbamates and synthetic pyrethroids have been documented (Umina *et al.*, 2014). The economic impact of resistance is difficult to quantify, especially for emergence pests that may attack a range of crops, including *B. napus*, but is likely to lead to costly and long-term management issues.

#### 24.4 Control Options for Emergence Pests as Part of an Integrated Pest Management Approach

To date, pest management in *B. napus* has been heavily dependent on the use of broad-spectrum pesticides, with the use of some cultural control practices, despite evidence that many pests are highly tolerant to the commonly used products (Arthur *et al.*, 2008, 2013b; Roberts *et al.*, 2009). However, increasing levels of pesticide resistance and scrutiny over the use of certain pesticide groups suggest that farmers must start considering alternative approaches. IPM involves the use of a diversity of biological and cultural control practices, combined with the judicious use of pesticides only after a pest has reached threshold (Dent, 1991; Horne and Page, 2008). Generally, IPM is practised across multiple crops on a farm and across a rotation sequence, and so determining how it can be used specifically for *B. napus* pest management can be challenging. However, a study across Europe demonstrated that an integrated strategy in winter oil-seed rape that was both energy efficient and used less pesticide resulted in similar yields compared with a conventional approach (Nilsson *et al.*, 2015). The following sections summarize how components of an IPM approach are currently being used against emergence pests in *B. napus*.

##### 24.4.1 Cultural controls

Cultural control techniques involve practices such as crop rotation, planting density, weed control and

tillage and stubble management (Horne and Page, 2008). These practices can be effective at controlling emergence pests in *B. napus* by making the environment unsuitable for the growth and development of the pest. Often these practices impact more than one pest species at the same time. For example, *B. napus* crops that follow pastures with grasses and clover are most at risk from pest mite damage at emergence. Growers tend to avoid planting crops that are susceptible to damage into pasture fields, such as *B. napus* (canola), *Lupinus* spp. (lupins), *Vicia sativa* (vetch) and *Medicago sativa* (lucerne). Conversely, when *Triticum aestivum* (wheat) is sown into the rotation, with cultivation, there has been a demonstrated significant decline in *H. destructor* numbers (Merton *et al.*, 1995). The early control of summer and autumn weeds within and around fields, especially broad-leaf weeds such as *Arctotis calendula* (capeweed) and *Trifolium* spp. (clovers), can help to reduce the risk of mite outbreaks (Gu *et al.*, 2007). A greater understanding of the host-plant (both crop and weed species) preferences of emergence pests may lead to better crop rotation sequences (Umina and Hoffmann, 2004; Arthur *et al.*, 2010).

Increased planting density through increased seeding density is another technique for managing pest mite species. Increased planting density reduces the impact of the loss of seedlings to mites at emergence and reduces the abundance of weeds that support pest populations. These techniques have not been well studied in Australia. However, one study demonstrated that, despite higher *H. destructor* densities early in the season (seeding rate 10 kg/ha), the increased plant density meant that the crop was able to survive mite damage and significantly reduce weed biomass (Burnett *et al.*, 2003). This led to improved economic yields.

##### 24.4.2 Natural enemies and other biological control

Natural enemies include both generalist predators and parasitoids that can exert some level of suppression of pest abundance (Dent, 1991; Macfadyen *et al.*, 2015). There is little information available about the pathogens of the emergence pests considered here, despite examples of successful control of mite pests in other agroecosystems using bacterial, viral or fungal pathogens (Christian *et al.*, 1991; Rath, 1991). Whether or not natural enemies have any impact on emergence pest species, and



therefore lowering associated crop damage, is difficult to quantify. In the cooler part of the year, natural enemy populations are usually low in number and may appear to be present in low numbers in a relatively bare crop field. However, sampling studies have shown the presence and activity of a range of generalist predators (e.g. ants, spiders, predatory beetles and predatory mites) that have the potential to reduce pest mite and collembolan abundance. Twenty natural enemies (19 arthropod predators and one microbial pathogen) of *H. destructor* and *P. major* were recorded in pastures in southern New South Wales and it was concluded that natural enemies could play an important role in reducing earth mite populations in unsprayed pastures (James, 1995).

Most research has focused on predatory mite species but their impact on pest reduction and yield protection has not yet been quantified in *B. napus* (but see Tsitsilas *et al.*, 2011, who showed a direct connection in pastures). The predatory mite *Anystis* sp. (later called *Anystis salicinus* (Acarina: Anystidae); Michael *et al.*, 1991) was introduced from France in the 1960s to control *H. destructor* in Western Australia. It was found to be capable of killing large numbers of *H. destructor* under laboratory conditions but was less effective when alternative foods were available (Otto and Halliday, 1991). In later studies, *Anystis wallacei* (Acarina: Anystidae) was found to feed on *H. destructor*; and another introduced predatory mite, *Neomolgus capillatus* (Acarina: Bdellidae), was found to feed on *S. viridis* (Michael, 1995). When these predators were introduced into pasture plots, they reduced pest numbers by two-thirds. *N. capillatus* was investigated in pastures in Tasmania and reduced *S. viridis* density to about 93% (Ireson *et al.*, 2002). *Bdellodes lapidaria* (Acarina: Bdellidae), the predatory snout mite, was found to be tolerant to several of the pesticides used to control *S. viridis* but did not have any impact on *S. viridis* abundance in a semi-field study. In pasture plots, predatory mites were added at different densities (400, 100 or 50) and the numbers of *S. viridis* were compared with plots without predator addition 9 weeks later. At the end of the study there were no difference in *S. viridis* abundance in samples taken from treatment and control plots (Roberts *et al.*, 2011b). *B. lapidaria* is a relatively widespread species, whereas *A. salicinus* and *N. capillatus* have a more restricted distribution (Michael *et al.*, 1991). There have been no natural enemies identified in broad-acre

crops (e.g. *B. napus*, cereals, lupins, faba beans, soybean, cotton) in Australia that are effective in controlling species of *Bryobia*. However, there are a number of predator species known to attack other earth mites such as *H. destructor*, which may potentially prey upon species of *Bryobia*. These include the aforementioned predatory mites (*N. capillatus*, *A. wallacei*, *A. salicinus*, *B. lapidaria*) as well as small beetles (e.g. *Diomus notescens* (Coleoptera: Coccinellidae) and other Coccinellidae) and spiders (e.g. Linyphiidae).

A number of pesticide trials that have included natural enemies as well as pests have shown that natural enemies are relatively more tolerant than the pests. For example, this has been demonstrated for omethoate and dimethoate against *A. wallacei* (Michael, 1995). More generally, *B. napus* field trials using a range of pesticides have shown inconsistent treatment effects on non-target arthropods, including natural enemies (Jenkins *et al.*, 2013). This bodes well for the complementary use of pesticides alongside the activities of natural enemies in an IPM management strategy. However, strategies to increase the abundance of predators in *B. napus* at emergence are few. Besides using more selective pesticides, manipulation of ground cover can have an impact of predator abundances. Tsitsilas *et al.* (2011) found that increasing the height and complexity of ground cover in a windbreak led to greater numbers of natural enemies and the suppression of pests in the adjacent pasture.

#### 24.4.3 Pesticides

Selective pesticides can be an effective means of minimizing yield loss when used based on economic thresholds. However, for many of the emergence pests in *B. napus* there are limited economic thresholds (Arthur *et al.*, 2015), few easy monitoring techniques (Arthur *et al.*, 2014) and high levels of tolerance and resistance to commonly used pesticides (Arthur *et al.*, 2008, 2013b; Roberts *et al.*, 2009; Umina *et al.*, 2012). Furthermore, *B. napus* is planted just prior to the wheat crop on most farms, meaning that it is a critical time for staff and a difficult period to spend time on monitoring emerging *B. napus* fields. This is why seed dressings using neonicotinoid (e.g. imidacloprid) pesticides have become popular on *B. napus*. These seed dressings have both a repellent and anti-feeding effect on *H. destructor* and can provide residual protection for up to 28 days (Seidel, 1999).

However, their role in IPM is debatable as they are applied prior to a pest issue arising. Furthermore, imidacloprid (on the seed or in the soil) can translocate into the pollen and nectar of flowers, as well as move through the soil, potentially impacting non-target species and natural enemies (Krischik *et al.*, 2015). None the less, seed dressings have proved useful for controlling low pest densities and preventing yield loss in *B. napus* (Macfadyen *et al.*, 2014; Umina *et al.*, 2015).

In Australia there are very few selective pesticides registered against crop establishment pests (Umina *et al.*, 2015). Jenkins *et al.* (2013) compared the impact of selective pesticides (e.g. paraffinic oil, spinosad, diafenthiuron) and broad-spectrum pesticides on arthropods in field trials. They found that the selective pesticides had fewer negative impacts on non-target arthropods but a few products did reduce numbers of certain groups. Given the difference in costs associated with some selective products (in comparison with conventional broad-spectrum products), it is not surprising that demand for selective products is currently relatively low amongst growers.

## 24.5 Future Prospects: New Tools for Management

The use of pesticides as the main option for control of emergence pest species (both in seed dressings and as bare-earth or foliar sprays) comes with an increasing risk of resistance. Despite the existence of a diversity of tools and strategies for controlling pests, which have been successful in other agroecosystems around the world, the suite of tools currently used by Australian growers is relatively limited. This is partially due to a lack of research and development into new tools well suited to Australian agroecosystems and partly to complacency caused by cheap and readily available pesticides. The following sections identify some of these new approaches, which, if developed further, may provide a more sustainable approach to the management of emergence pests in *B. napus*.

### 24.5.1 Predictive models

Given the constraints already identified with managing emergence pests, it is critical that growers are able to understand the risk of an outbreak some time before sowing commences. This gives growers time to alter their cultivation practices, manage

weeds, alter planting density and consider alternative crops with lower susceptibility if the risk is great. To date, a simple predictive model has been developed to identify when the median emergence for *H. destructor* will occur in autumn (McDonald *et al.*, 2015). Rainfall and temperature thresholds were evaluated across multiple models and their performance varied between regions. In Western Australia, 5 mm of rain followed by mean day temperatures of below 20.5°C for 10 days were identified as key factors; in south-eastern Australia, a lower temperature threshold of 16°C was employed (McDonald *et al.*, 2015). These models are currently used solely for research purposes but they have the potential to provide useful information to growers if validated further.

### 24.5.2 Monitoring protocols and thresholds for decision making

Economic thresholds are an important component of any IPM strategy. When a pest population reaches this threshold, beyond which the cost of control is less than the cost of the potential yield loss, intervention is warranted (Dent, 1991). For most of the emergence pest species, economic thresholds are not available for *B. napus* and monitoring guidelines to estimate density at the scale of commercial operations are rare. Arthur *et al.* (2015) attempted to develop an economic injury level for *H. destructor*. At the first true leaf stage a threshold of ten mites per plant was proposed but at other crop development stages a relationship between mite numbers and yield could not be established (Arthur *et al.*, 2015). Compounding this problem is the challenge associated with estimating densities of these emergence pest species. Visual assessments are often the easiest for growers and consultants to implement in the field but this technique is heavily influenced by observer bias, sampling date and time of day (Arthur *et al.*, 2014). Further, the method of sampling most of these emergence pests is by blower-vac, which has the potential to get blocked with dirt, especially in wet conditions. Plant densities of below 30–40 plants/m<sup>2</sup> could be used as a proxy for mite damage when densities could not be estimated properly (Arthur *et al.*, 2015). Quantifying the relationship between plant density, plant damage and yield and pest densities is required in order to develop thresholds for the other emergence pest species. There are some nominal thresholds available for certain regions, which

have not been empirically derived but provide some guidelines for growers. For example, in Victoria a threshold of ten holes per leaf has been suggested for *S. viridis* (<http://ipmguidelinesforgrains.com.au/pests/lucerne-flea-in-winter-seedling-crops/>).

### 24.5.3 Impact of natural enemies and other biological control agents

The impact of natural enemies at the critical emergence period in *B. napus* is still unclear. A large diversity of natural enemy species is present in or near *B. napus* fields at this time of the year but their impact on emergence pest populations and the associated reduction in pest outbreak risk has not been quantified (Macfadyen *et al.*, 2015; Zalucki *et al.*, 2015). A significant amount of early research was conducted on the potential of predatory mites to control these pests (Michael *et al.*, 1991; Otto and Halliday, 1991; Michael, 1995) and more recently some work has been conducted on pesticide impacts on predatory mites (Roberts *et al.*, 2011b). However, there are many other predatory groups, including lacewings and ladybird beetles (James, 1995), that might also prove useful for controlling emergence pest populations early in the season. Observation of direct feeding interactions between pests and predators can be difficult but there is a range of new tools for detection of prey DNA in the guts of predators that could be used. For example, Layman and Lundgren (2015) used molecular techniques and gut content analysis to document the complex interactions between pest and non-pest herbivores and shared predators in *B. napus* fields. Furthermore, the use of pathogens for the biological control of emergence pests has not progressed since it was initially identified in the early 1990s (Christian *et al.*, 1991; Rath, 1991). An ecological approach considering the assemblage of natural enemies that are part of the *B. napus* ecological community, and provide a significant reduction in pest numbers, is required. This will allow for determining if highly efficient individual species or a range of different species with different functional roles is required for pest suppression. This could be aided by knowledge generated from co-occurrence studies and predictive models.

### 24.5.4 Host plant resistance

*Brassica* crops display differences in susceptibilities to damage by insect pests and this could perhaps be

exploited to develop varieties that are more tolerant of emergence pests (Gu *et al.*, 2008; Shaw *et al.*, 2009; Karimi *et al.*, 2012). There is a large number of potential *B. napus* varieties that could be used for screening in Australia but to date little research has been conducted in this area (Gu *et al.*, 2008). McDonald *et al.* (1995) screened some Northern hemisphere *B. napus* varieties and found that they were more prone to cotyledon damage from *H. destructor*, in comparison with local varieties. Furthermore, other pests, such as cotton bollworm *Helicoverpa armigera* (Karimi *et al.*, 2012) and diamondback moth *Plutella xylostella* (Fathi *et al.*, 2010), display differences in development time and fecundity across different *B. napus* varieties documented in overseas studies. It is known that competitive interactions between earth mite species occur and vary by the host plant. Umina and Hoffmann (2005) showed that, on pasture, the competitive advantage swayed between *P. major*, *H. destructor* and *P. falcatus* but that *P. falcatus* and *H. destructor* were consistently superior competitors on *B. napus*. A better understanding of the impact of host-plant and varietal differences on population dynamics of emergence pests could underpin management strategies for novel ways of controlling these species.

## 24.6 Conclusions

Whilst the focus of this chapter has been on *B. napus* as an isolated crop, *B. napus* often sits in a farming landscape that contains many crop types, pastures and semi-natural vegetation patches. The spatial and temporal spread of host plant resources for pest mite and collembolan species varies across the year. Bottom-up processes related to host plant preferences can be used for better management of these pests. Likewise, top-down processes associated with natural enemies and other biological control agents hold much promise for more effective and sustainable pest control. Importantly, thinking about how pesticides can be combined with cultural and biological control options is the key to better management of these pests in the future.

There has been some research conducted on the basic biology and ecology of these pests but there is still a lack of key information that is useful for developing more sustainable control practices. We have highlighted that our understanding of the impact of natural enemies on emergence pests in *B. napus* is unclear. Both the tolerance of natural enemy species to commonly used pesticides and

their role in the frequency or likelihood of secondary pest outbreaks need to be further quantified. We have shown that new tools such as predictive models, simple monitoring protocols and better use of host plant specificities could be used to improve management in an IPM context. Currently, only a very small suite of pesticides is being used to manage these pests and their efficacy is being challenged by the development of resistance.

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