Earwigs - an appetite for destruction or are they beneficial?

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Keywords

- earwig, canola, lifecycle.

Take home messages

- Adult European earwigs are present all year, but eggs and juvenile earwigs are only present from April to November.
- European earwigs can cause significant damage to canola, lucerne, lupins and in some cases, lentils.
- The potential for damage to emerging crop seedlings by adult European earwigs exists, although it is dependent upon the timing of germination and egg laying. During mid-late season, earwigs can act as a predator of aphids, potentially contributing to their control.
- Multiple earwig species have been detected in grain crops, most of which are not associated with crop damage. It is therefore important to correctly identify which species is present in a paddock before taking any action.

Background

There are at least 80 species of earwigs (Dermaptera) present in Australia (Haas 2018). Recent work using a combination of morphological and molecular data has identified ten different species of earwigs in grain crops (Stuart et al. 2019). These species are comprised of introduced and native earwigs, and there is limited information on the native earwigs. Many of the native species are potentially beneficial species and appear to be region specific (Stuart et al. 2019). However, reports of earwig outbreaks and damage to canola, cereals and pulse crops, have been increasingly recorded in Victoria (Vic), New South Wales (NSW), South Australia (SA), and southern Western Australia (WA). Factors that influence the risk of earwig outbreaks and crop damage are not well documented.

The most dominant and widespread species in Australian crops is the European earwig (*Forficula auricularia*) (Hill et al. 2019) which consumes a variety of foods (plants, invertebrates, fungus, detritus), acting beneficially through the consumption of crop pests in some fruit orchards (Quarrell et al. 2017). However, the European earwig has been observed as an irregular pest of grain crops in Australia (Murray et al. 2013). Despite being introduced into Australia over a century ago (Quarrell et al. 2018), there has been little research conducted on crop damage from European earwigs in Australia. Furthermore, the potential beneficial activities of the European earwig in grain crops have not been explored.

The two dominant native earwig species found in grain crops are *Labidura truncata* and *Nala lividipes* (unpublished data). Research has shown *L. truncata* to be predatory (Horne and Edward 1995), although its importance as a beneficial in grain crops has not been explored. *Nala lividipes* is a pest of Queensland cereals (Hargreaves 1970), although it is unclear if this is also the case in southern Australia, or if it feeds on canola. Increased stubble retention and the associated increase in organic matter within the soil may be linked to increase in-field earwig populations. However, studies that examine the factors affecting the risk of crop damage from pest earwigs, as well as management options to minimise crop damage, are limited.

Methods

Lifecycle monitoring of the European earwig

To establish the life cycle of European earwigs within a grains production context, grain crops (canola, wheat, oats) at five commercial farms were examined, two in Vic and three in SA. Sampling at these sites was undertaken over a period of seven days each month from September 2016 to December 2018. During each sampling period two types of traps were used; shelter traps in the form of cardboard rolls inserted into PVC pipe, and pitfall traps containing 100% propylene glycol. Three pitfall traps were installed two meters apart at four sampling locations (>30m apart) per site, with at least one sampling location being placed at the paddock edge for a total of 12 pitfall traps. Pitfall traps were used to capture earwigs during times of activity (i.e. foraging for food at night).

At each of the four sampling locations within the field, three cardboard rolls were placed complementary to the pitfalls to determine abundance (12 rolls in total). The cardboard roll traps were placed within an inter-row parallel to the stubble row, two meters from the pitfall traps. Roll traps were collected after seven days. Additionally, to establish movement of earwigs into vegetation adjacent to field sites, two rolls were placed in the canopy of four trees per site (eight tree rolls) using wire to tie the rolls to branches. The use of cardboard rolls allowed the collection of live earwigs during times of inactivity (being nocturnal, earwigs use the rolls for shelter during the day).

European earwigs (*F. auricularia*) comprised 75% of earwigs collected (unpublished data), and so laboratory processing first involved separating them from the other earwig species that were captured. Part of the species separation process involved confirmation via molecular work with comparisons to published sequence data (Stuart et al. 2019). Adult and nymphal stages of F. auricularia were identified using head width, the number of antennal segments and wing bud development as described in Crumb et al. (1941). As earwigs are sexually dimorphic, sex was identified using the shape of the cerci (Crumb et al. 1941) and earwigs were categorised as male, female or gynandromorph.

Damage and management of the European earwig in canola

On 23 April 2019, 8m by 1.8m plots of canola were sown into wheat stubble on a 0.5ha paddock on the Ginninderra research station near Canberra ACT (latitude -35.203571, longitude 149.083316). The plots were randomly allocated to different seed treatments; fipronil, imidacloprid or untreated. All seed was planted at the rate of 2.7kg/ha, and all seed was treated with Jockey® Stayer® for blackleg control. The plots around the edges of the paddock were assigned as a buffer, roughly 10m in width. Every second 1.8m row was also assigned as an internal buffer.

On 23 May 2019, seedling establishment was measured in the fipronil/imidacloprid/untreated plots by counting the number of seedlings. At this time the European earwigs had either laid eggs or were preparing to lay eggs, but no juveniles had yet hatched. By mid-June, second instar earwig nymph activity was detected using a modified wildlife camera (Spartan SR1 IR) and damage was seen over the next couple of weeks. On 24 June 2019 the damage to the plots of canola was assessed by estimating biomass loss in each experimental plot by measuring the area of plant damage.

Exclusion/inclusion cages

Following sowing on 23 April 2019, 100 enclosures were constructed to keep earwigs out or in, depending on the treatment. These open-top enclosures were 1m x 1.2m in area, made from corflute sheets buried 30cm into the ground, which was affixed to wooden stakes (driven 50cm into the ground) by screws and liquid nails. Both the inside and outsides of each corner was sealed using Selleys® silicon sealer. Tanglefoot was applied to the top 10cm of the corflute around the enclosure to prevent crawling insects getting in or out. This method of using tanglefoot barriers was previously used to successfully exclude/include European earwigs on tree branches to study aphid predation (Mueller et al. 1988).

Inside each enclosure, before earwig introduction, the existing wheat stubble in the paddock was manipulated so that there were three stubble loads: bare, 2t/ha (2T) and 5t/ha (5T). In addition to this, three water treatments were assigned: Low (exclusion of direct rainfall), Medium (natural rainfall) and High (additional artificial rainfall applied throughout the season).

Earwig manipulation occurred after all enclosures were constructed, whereby any earwigs within the plots were removed and added to a population of earwigs collected from the 1ha area. In total, 3000 *Forficula auricularia* were collected and sorted, after which forty second-instar juveniles were added to each of the 50 plots assigned to have earwigs the following morning and given a cardboard roll trap as shelter.

Laboratory trial – effects of crop growth stage and earwig life-stage on the damage done to a range of crops by European earwigs

Microcosm containers (600ml BioPak® Biocups) were used to which 250ml of soil was added. The soil mix used was 3 parts sandy loam soil: 2 parts sand: 1 part potting mix. The top layer of soil over the seeds is sandy loam soil only, sieved to create a 1cm topsoil layer. Each microcosm was watered on Monday, Wednesday and Friday ensuring a moist surface. Each cup contained four crop seedlings which were grown at 18°C, 12:12 L:D from untreated seed.

This experiment was run four times to capture multiple earwig life-stages. The earwigs used for this experiment were captured from a property near Elmore (latitude -36.4863, longitude 144.5513) which were acclimatised at 18°C for three nights. On day 0, the earwigs were introduced following the treatments in Table 1. All treatment combinations were used with 5 replicates each. The experiment was run for 14 days at 18°C 12:12 L:D.

Table 1. Treatments used for European earwig crop feeding experiment.

Earwig life-stages	2nd instar juvenile, 4th instar juvenile, summer adults, winter adults
Crop types	Lucerne, canola, lupin, lentil, wheat, oat, chickpea
Crop growth stages	1st and 2nd as defined by Lancashire et al. (1991)

Laboratory trial – effects of aphid presence and density on the damage done to canola by European earwigs

Forty microcosm containers (Biocups) were set up using the same methods as for the crop feeding trial described previously. Each cup contained four canola seedlings which were grown to the third growth stage as defined by Lancashire et al. (1991), at which point the experiment was started. The earwigs used for this experiment were 4th instar juvenile European earwigs collected from Ginniderra experimental station on the 25 October 2019. Cabbage aphids were also collected at this time. These earwigs were acclimatised at 18°C and starved for three nights, though they were provided with moisture. On day 0 (28 October 2019), the earwigs and aphids were introduced following the treatments in Table 2 each replicated five times. Aphids were added first and allowed three hours to establish themselves on the seedlings, only apterous aphids were used. In addition to this, a small (3cm x 3cm) piece of moist paper towel was placed onto the soil surface as shelter for the earwigs. The experiment was run for 14 days at 18°C 12:12 L:D.

Table 2. All treatment combinations used for European earwig aphid feeding experiment

4th instar European Earwigs	Cabbage aphids
Two individuals present	0
Two individuals present	50
Two individuals present	250
Two individuals present	500
Absent	0
Absent	50
Absent	250
Absent	500

Scoring was done at day 1, 3, 7 and 14. On each occasion, treatments were scored for the number of earwigs, number of aphids, earwig plant damage (1-10, 10 being stem snipped), aphid plant damage (% curled/discoloured leaves), number of canola seedlings, and photographed from 20cm above the soil surface.

Laboratory pilot trial – feeding preferences of the two major native earwig species (Labidura truncata and Nala lividipes)

Twenty-four microcosm containers (Biocups) were used and set up using the same methods as for the crop feeding trial described previously. The crop seedlings were grown to the third growth stage as defined by Lancashire et al. (1991), at which point the experiment was started. The earwigs used for this experiment were adult black field (*Nala lividipes*) and common brown (*Labidura truncata*) earwigs collected from Ginniderra experimental station on the 6 November 2019. Green peach aphids (GPA) were also collected at this time. These earwigs were acclimatised at 18°C and starved for three nights, and again provided moisture. On day 0 (9 November 2019), earwigs and aphids were added following the treatments described in Table 3 and each replicated three times. Aphids were added first and allowed three hours to establish themselves on the seedlings, only apterous aphids were used. In addition to this, a small piece of moist paper towel was placed onto the soil surface as shelter for the earwigs. The experiment was planned to run for 14 days at 18°C 12:12 L:D but extended to 42 days when no plant feeding was observed. Scoring was done as in the previously described experiment.

Table 3. All treatment combinations used for native earwig feeding experiment.

Adult Earwigs	Crop type	Green Peach Aphids
Two Nala lividipes	Canola	0
Two Labidura truncata	Canola	0
Two Nala lividipes	Canola	250
Two Labidura truncata	Canola	250
Absent	Canola	0
Two Labidura truncata	Wheat	0
Two Nala lividipes	Wheat	0
Absent	Wheat	0

Results and discussion

Lifecycle

The lifecycle of the European earwig *(F. auricularia)* was investigated over the course of two years, with 25 000 specimens captured from five sites.

The timing of the peak abundance of each lifestage was relatively consistent across each of the five sites, for which the data was combined to determine the proportion of each lifestage expected to be observed for each month of the year (Figure 1). The initial brood of eggs was observed in nests during April to July, with peak numbers of first and second instar nymphs observed in July. Third instar numbers peaked in October, while fourth instar numbers peaked before this in September. This is potentially due to earwigs moving out of the paddocks and into nearby trees when they reached fourth instar in September and October. Adult earwig numbers were shown to peak in November/December and remain abundant until the following March.

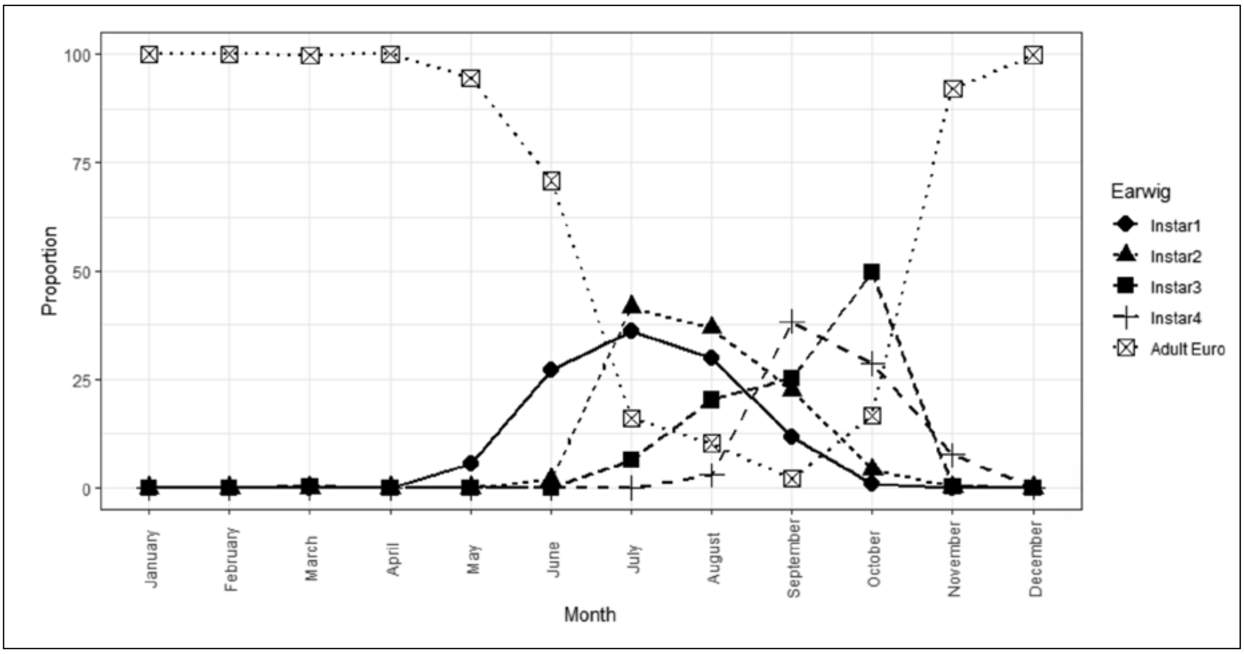

Figure 1. The lifecycle of the European earwig in grain crops. This figure shows the combined proportion (%) data of each *F. auricularia* lifestage from two years of sampling at five sites across Victoria and South Australia. Adults are present all year, but juveniles are only present from April to November.

Detailed lifecycle data for *F. auricularia* has enabled orchard growers worldwide to preserve or increase earwig numbers and thereby take advantage of their beneficial behaviors to protect orchards from pest insects (Nicholas et al. 2005; Quarrell 2013). Conversely, using this lifecycle data for grain crops may allow better prediction of the risk of crop seedlings to earwig attack, and if necessary, optimise timing of management tactics to reduce earwig numbers by targeting the appropriate life stages.

Damage and management

Early season

No significant difference was found in seedling establishment a month after sowing between seed treatments (p=0.25). Generally, canola is sown and starts growing several weeks before the European earwig eggs hatch. As such, the severe damage caused by juveniles may be avoided during the plant's most vulnerable stage unless sowing occurs late. However, adults will be present at this time and have the capacity to cause seedling damage (**cesar**, unpublished data), though there is a window of a few weeks where the adult female is underground caring for her eggs and not feeding. For this particular trial, the canola germinated as the females stopped feeding and started laying eggs. Thus, only very mild and occasional earwig damage was seen, not enough to have much effect on seedling establishment. Of course, there are many cases when earwigs can be damaging in autumn months. Although preliminary, these trials point to a complexity of factors at play that influence timing of events and thus impact the likely damage caused to emerging crop seedlings by European earwigs.

Once the earwig juveniles had hatched and reached second instar, significant damage started to occur to the canola (Figure 2). The damage caused by earwig nests at the 4 to 5 true leaf stage was significant ($p<0.05$) depending on the seed treatment used (Figure 3). Fipronil provided significantly more protection over untreated and imidacloprid treated seed, while imidacloprid seemed to result in no significant improvement over untreated seed in terms of earwig damage. In laboratory studies, both imidacloprid and fipronil prevented earwig damage during the time in which the treatment remained active (**cesar**, unpublished data). However, fipronil caused significant mortality in earwigs whereas imidacloprid did not (imidacloprid only acted as a feeding repellant). Potentially, fipronil is more effective in the long term due to the initial reduction in earwig numbers. Thus, as seen in this field trial, damage occurred after the imidacloprid seed treatment had worn off and there were significantly fewer ($p<0.05$) earwig nests found in the fipronil treated areas.

In this experiment, the overall average biomass loss per plot at this stage was 0.17% for fipronil and about 1% for untreated/imidacloprid. This is with an average of eight 'nesting spots' for the untreated/imidacloprid treatment compared to 1.6 'nesting spots' for fipronil; each 'nesting spot' represents

Figure 2. Damage to canola by second instar earwig juveniles. This is typical for canola that is in very close proximity to a European earwig nest, the white arrow (left) points to where the nest was found. The black arrow (right) points to an image of second instar earwigs feeding observed from about 11:00pm to 2:00am.

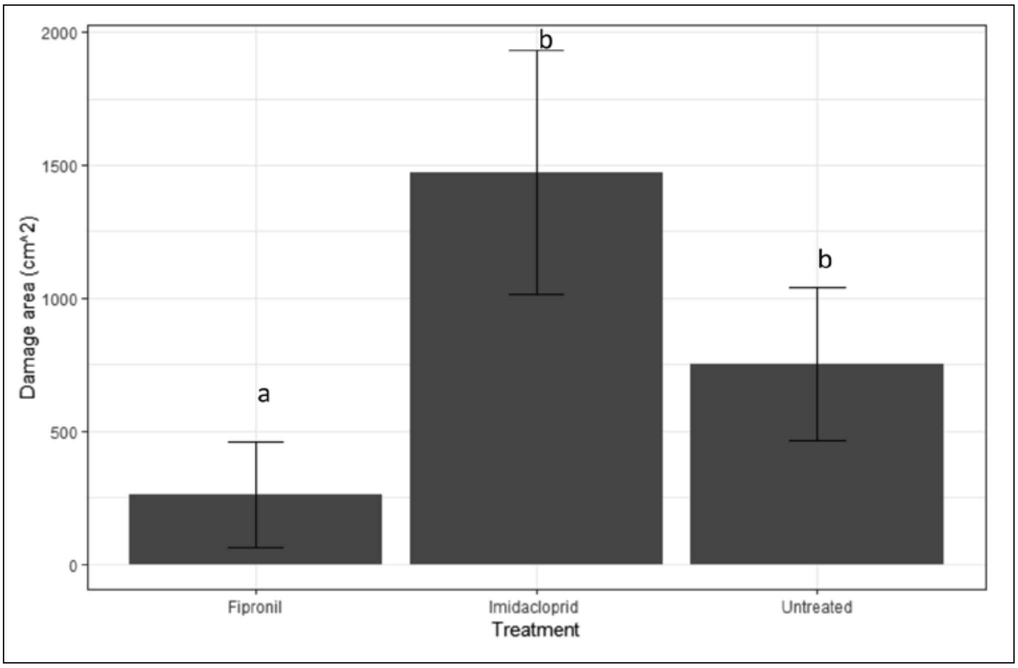

Figure 3. Total area of earwig damage measured in each 8m x 1.8m plot at the 4- to 5-true leaf canola growth stage. Bars represent the means with +- standard error. Letters represent similar means at $p<0.05$ based on an ANOVA.

either one earwig nesting location (Figure 2) or several in close proximity. The damage does not seem to spread much further than 30cm from an earwig nest during the pre-bolting growth stage of canola. This suggests that while the damage to the plant is apparent, it won't necessarily impact overall biomass or yield. This result is from one paddock only, and so additional data is required to assess how damage and biomass/yield loss scales with increased earwig nest densities in order to establish economic thresholds.

Mid-season – aphids

By late August, aphids started to colonise the canola plants. Green peach aphids were observed low on the plant and cabbage aphids were observed higher, mostly on the buds and spreading down the stems. Aphids were counted at four time points, and a negative binomial regression model was fitted to the data at each time point, testing the effects of earwig presence, water treatment, stubble load and seed treatment on aphid abundance (Figure 4). For 9 September 2019 and 6 October 2019 the results show a significant earwig presence and water interaction ($p < 0.05$). There were significantly more aphids in the non-earwig plots than the earwig plots, although this was only the case for the low water treatments ($p < 0.05$). For the third time point, 18 October 2019, aphid numbers were significantly higher ($p < 0.05$) where earwigs were absent, and there was no significant water effect. Stubble load and seed treatment had no significant effects on aphid numbers ($p > 0.1$) at any of these time points. The final time point, 1 November 2019, had too many aphid zero values for model convergence, and could not be reliably assessed. These results suggest that European earwigs may help control aphids.

Late season – pod damage

Non-aphid pod damage only occurred from 1 November 2019 when the aphid populations had declined. No significant difference ($p = 0.37$) in pod damage was found between earwig treatments. Earwig pod damage (Figure 5) is very similar to diamondback moth damage, of which there were moderate numbers present. This makes it difficult to assign damage directly to the earwigs; however given the fact that less than 0.5% of pods had this damage, and given the damage was only superficial, it is unlikely that European earwigs in the density that was used will cause much damage when present at this point in the season.

Harvest

The harvest biomass is the total dry weight of the entire canola biomass within an experimental plot. Seed weight is the weight of all seed produced within a plot after cleaning. This seed will be processed further during 2020 to look for differences in oil content. An ANOVA was used to look at all experimental treatment combinations and

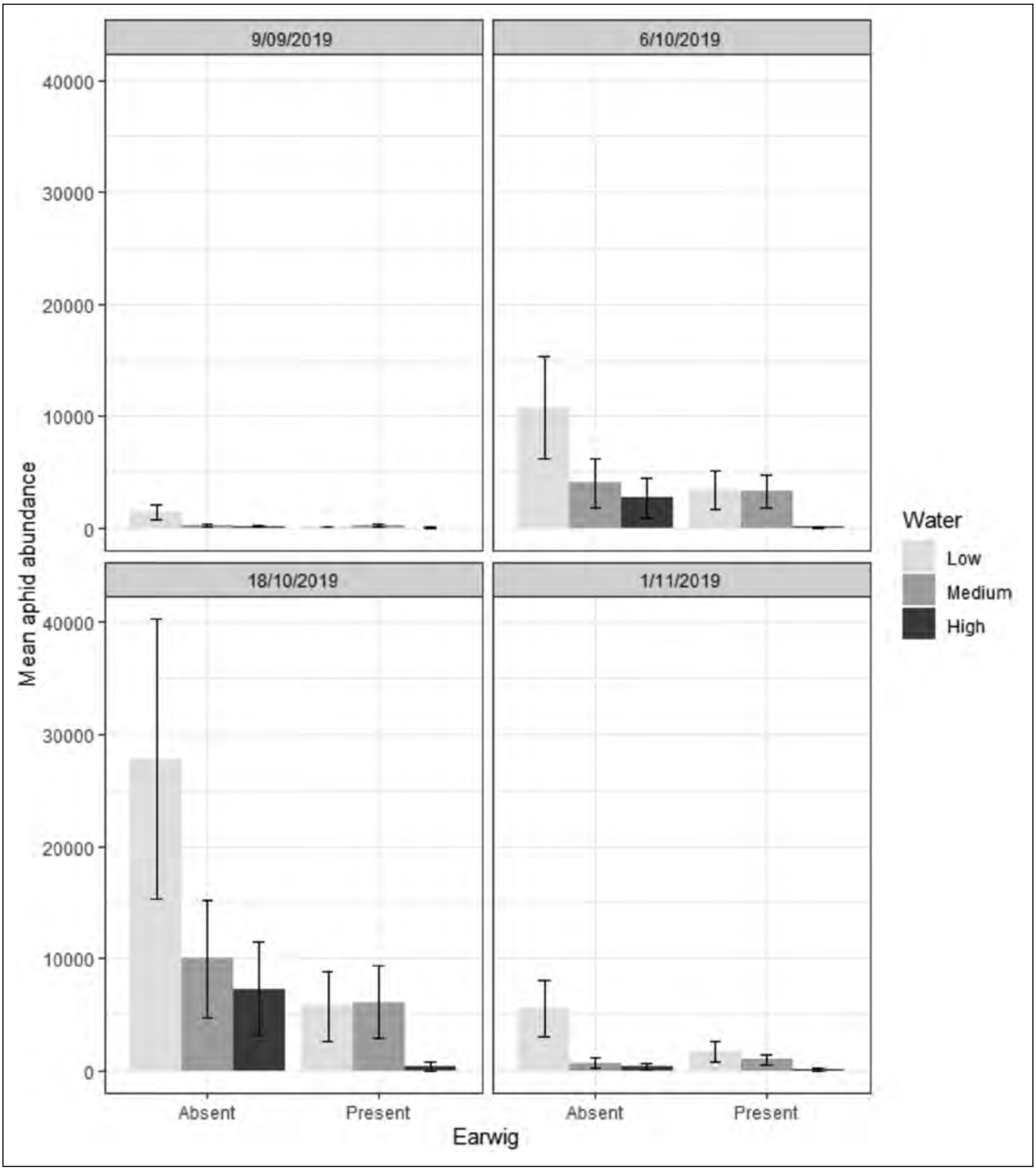

Figure 4. Aphid abundance over time, showing the interaction between water treatments and European earwig presence/absence treatments.

associated interactions. Interactions were tested but none were significant ($p > 0.1$). Significantly higher biomass was found in the plots containing earwigs than those without earwigs ($p < 0.05$). This was not what was expected early in the season, as the earwigs caused obvious damage to the plants. However, it may reflect earwig effects on other crop pests such as aphids when they arrive later in the season. As expected, the highest biomass was obtained from the plots that received a 'high' water treatment (Figure 6). The highest biomass was also found in plots that received a 'bare' stubble treatment, no difference was found between 5T and 2T treatments (Figure 7).

The differences in plant biomass did not appear to translate to total seed weight in this experiment (Figure 6; Figure 7). No significant differences were found in seed weights across any of the treatments ($p > 0.05$), further processing will be done in 2020 to obtain seed oil content.

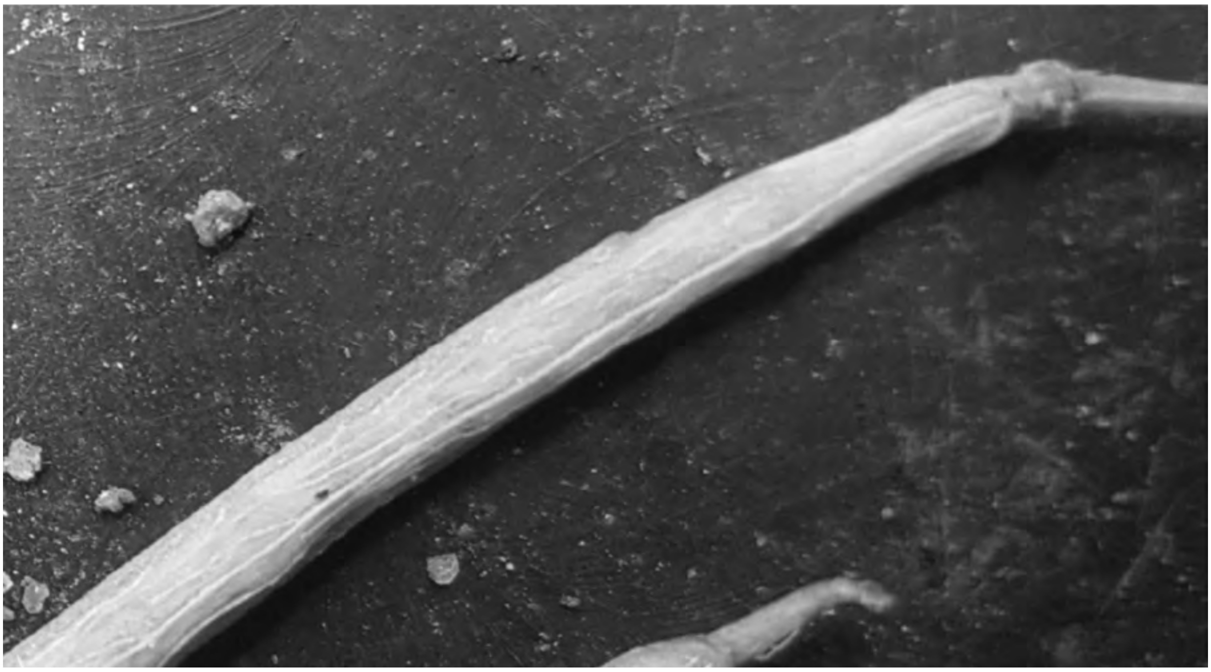

Figure 5. Example of the chewing damage done by European earwigs to canola pods.

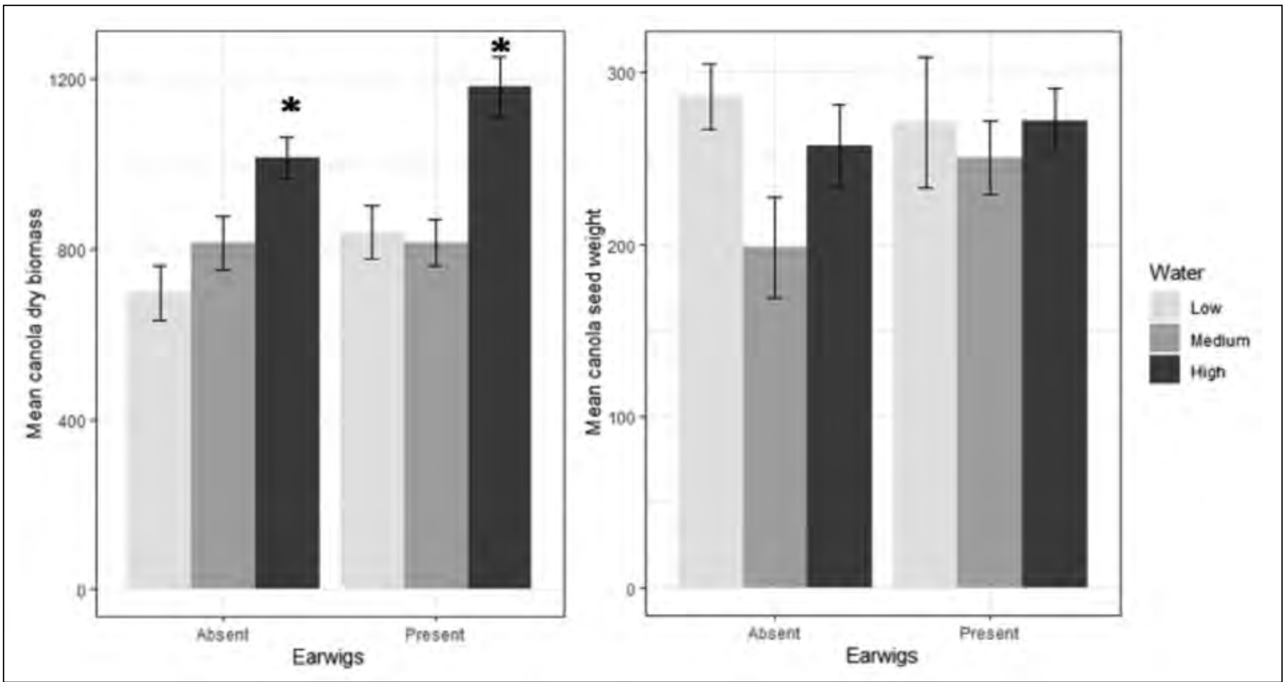

Figure 6. The effects of earwig presence and water treatment on total canola biomass (left) and total seed weight (right) measured in grams. Asterisks indicate significant ($p < 0.05$) differences within the earwig groups.

The effect of seed treatment on harvest biomass was significant ($p < 0.05$). The effect is consistent with what was recorded early in the season, greater biomass was measured from Fipronil treated seeds than both untreated and imidacloprid (Figure 8). The biomass of untreated and imidacloprid treated seed was not significantly different. Fipronil and imidacloprid treated plots all received 2T/ha stubble and medium water, so the interactions with stubble/ water could not be assessed. This was done to reduce the number of treatment combinations, making construction more feasible.

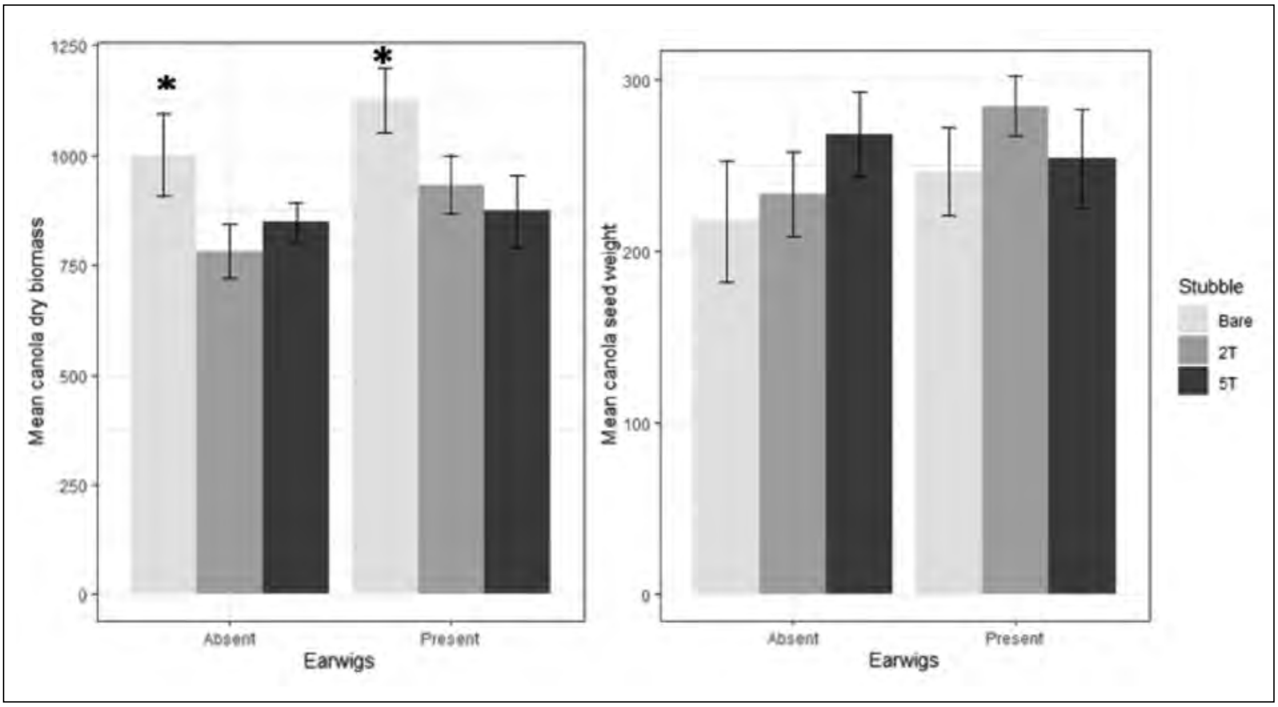

Figure 7. The effects of earwig presence and stubble treatment on total canola biomass (left) and total seed weight (right) measured in grams. Asterisks indicate significant ($p < 0.05$) differences within the earwig groups.

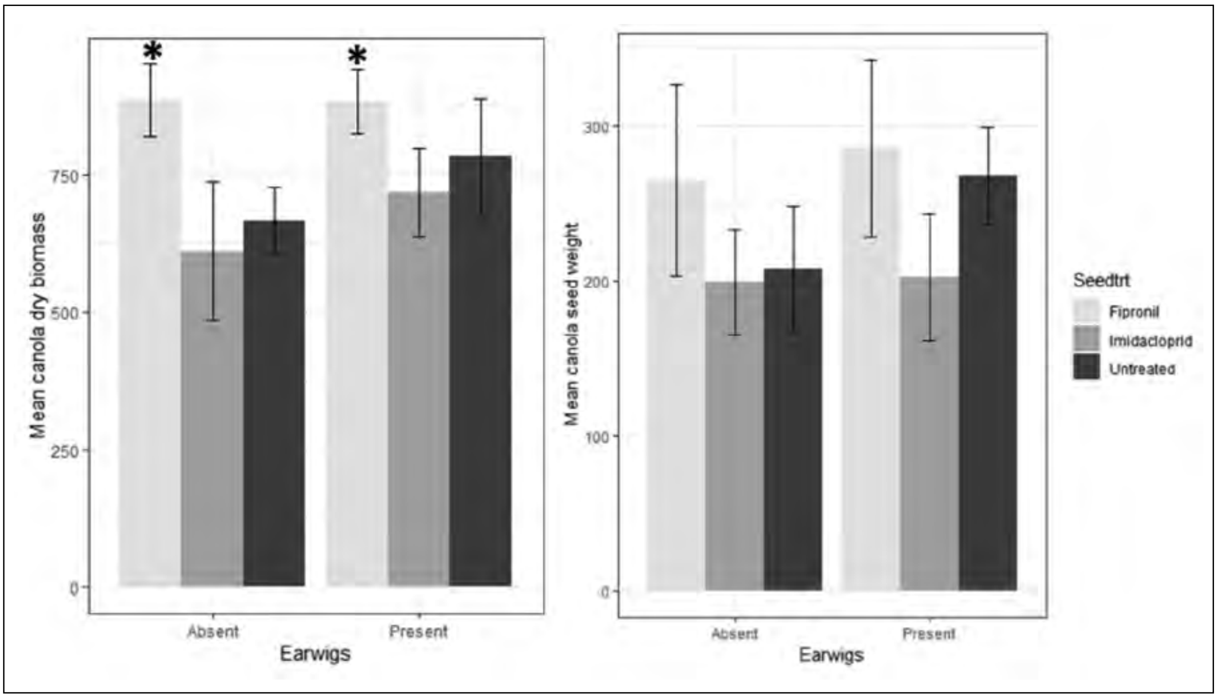

Figure 8. The effects of earwig presence and seed treatment on total canola biomass (left) and total seed weight (right) measured in grams. Asterisks indicate significant ($p < 0.05$) differences within the earwig groups.

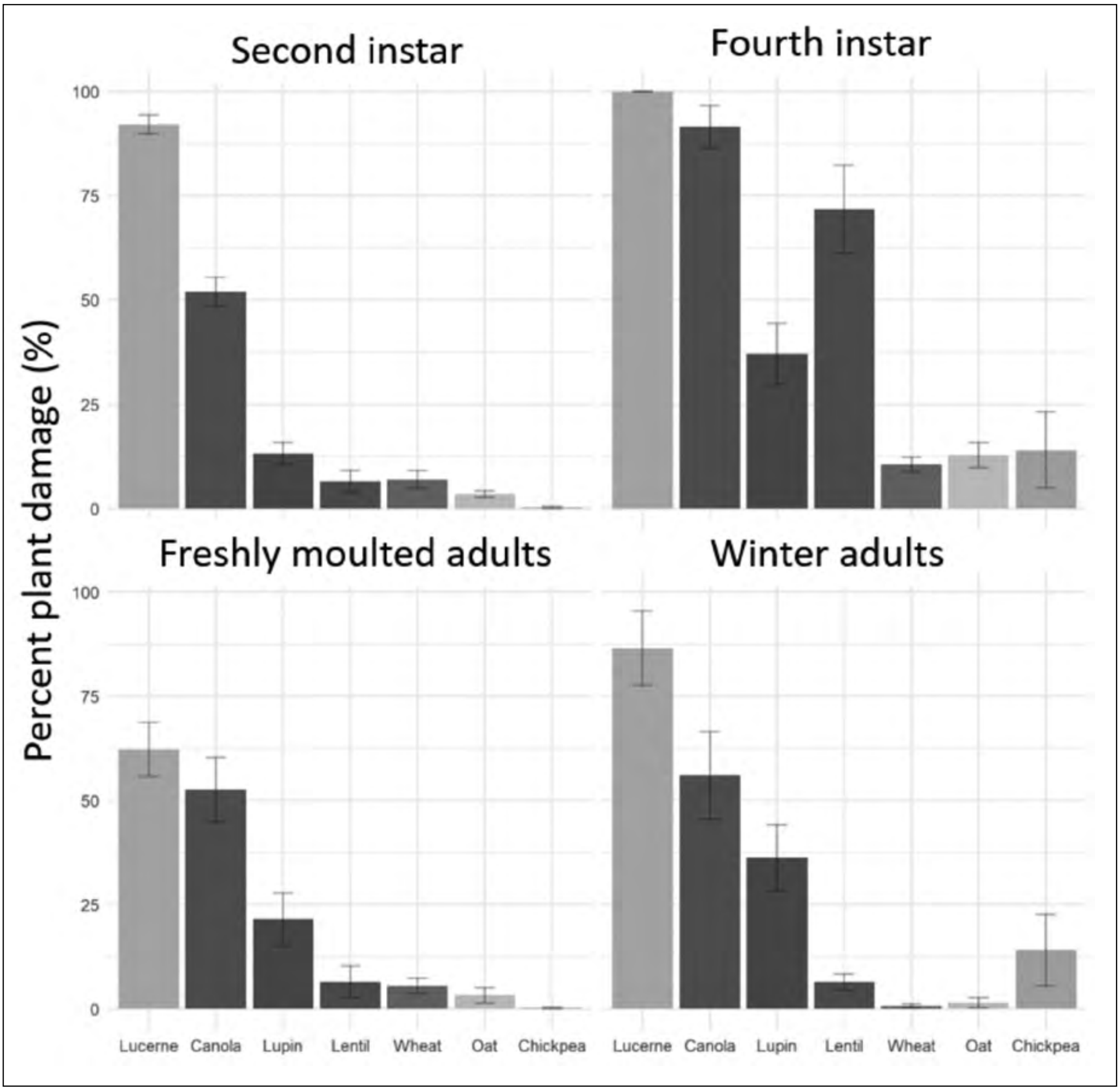

Figure 9. Mean damage by treatment and life stage for days after treatment (DAT) 14 and 1st growth stage with standard errors shown.

Again, the biomass results did not carry over to the seed mass. The effect of seed treatment on seed weight was not significant ($p > 0.05$).

Laboratory trial – effects of crop growth stage and earwig life-stage on the damage done to a range of crops by European earwigs

European earwigs caused the most damage to lucerne, canola, lupins, and lentils. The most damaging earwig life-stage appears to be fourth instar juveniles, this was also the only life-stage that caused significant damage to lentils (Figure 9; Figure 10). The difference in percentage damage to plants between plant growth stages was expected, a lower percentage of damage was scored on the mature plants (Figure 10).

Laboratory trial – effects of aphid presence and density on the damage done to canola by European earwigs

Earwigs started damaging the canola in the no-aphid and 50 aphid treatments from Day 1 (Figure 11). The aphids in the 50 treatment were entirely consumed by Day 1 (Figure 12). The canola in the 250 and 500 aphid treatments was not damaged until Day 7 (Figure 11). The aphids in the 250 and 500 treatments were entirely consumed by Day 7 (Figure 12).

These results show that European earwigs will readily feed on canola when no other food is available. However, if there are large enough numbers of aphids present, the earwigs will not damage the canola at all until the aphids have been consumed.

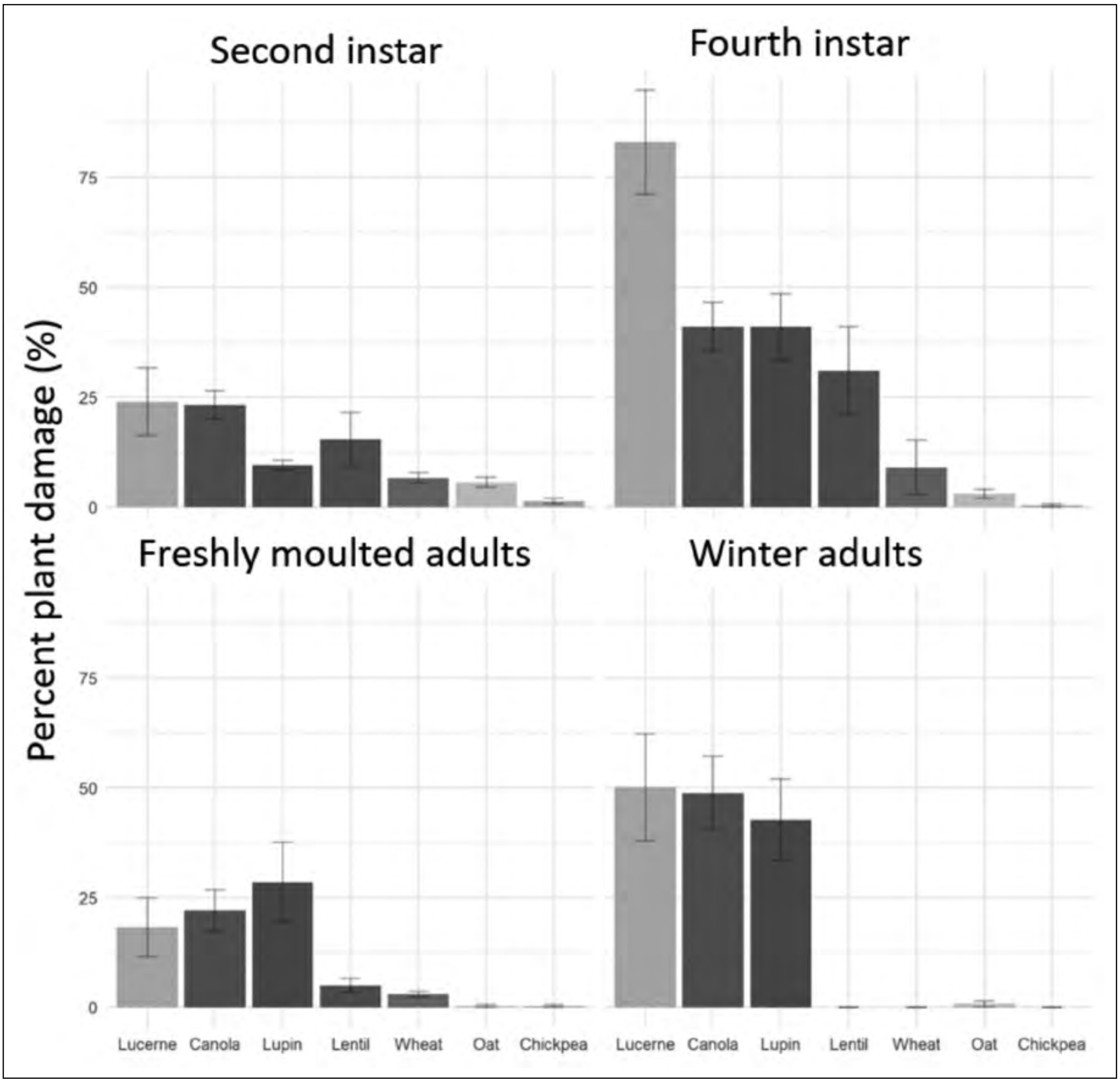

Figure 10. Mean damage by treatment and life stage for days after treatment (DAT) 14 and 2nd growth stage with standard errors shown.

Laboratory pilot trial – Feeding preferences of the two major native earwig species: Labidura truncata and Nala lividipes

After running the experiment for 42 days, there was no damage by native earwigs to any of the canola or wheat plants. The earwigs remained alive throughout this duration but did not appear to feed on plant material. The aphids were consumed entirely over one night by the *L. truncata* and over two nights by the *N. lividipes*.

Conclusion

European earwigs are generally not regarded as a pest in grain crops internationally (other than occasional harvest contamination), and potentially play a beneficial role in pest management (Sunderland and Vickerman 1980). However, it is clear from damage reports that they can cause damage in Australian crops, particularly in canola. European earwigs have the capacity to cause damage throughout the entire season. The nesting phase begins around April, which is often when canola is sown. Prior to nest establishment, adult earwigs are actively feeding, and can cause damage to emerging seedlings if the crop starts germinating at that time. However, there is a period of several weeks where the female earwig is confined underground caring for her eggs and crop feeding is less likely to happen. After the eggs have hatched and the juveniles start developing, significant damage to canola can occur which can be particularly harmful if the plant is still small and vulnerable. Hence, the timing of earwig feeding activity and crop vulnerability is likely to be an important predictor of crop damage.

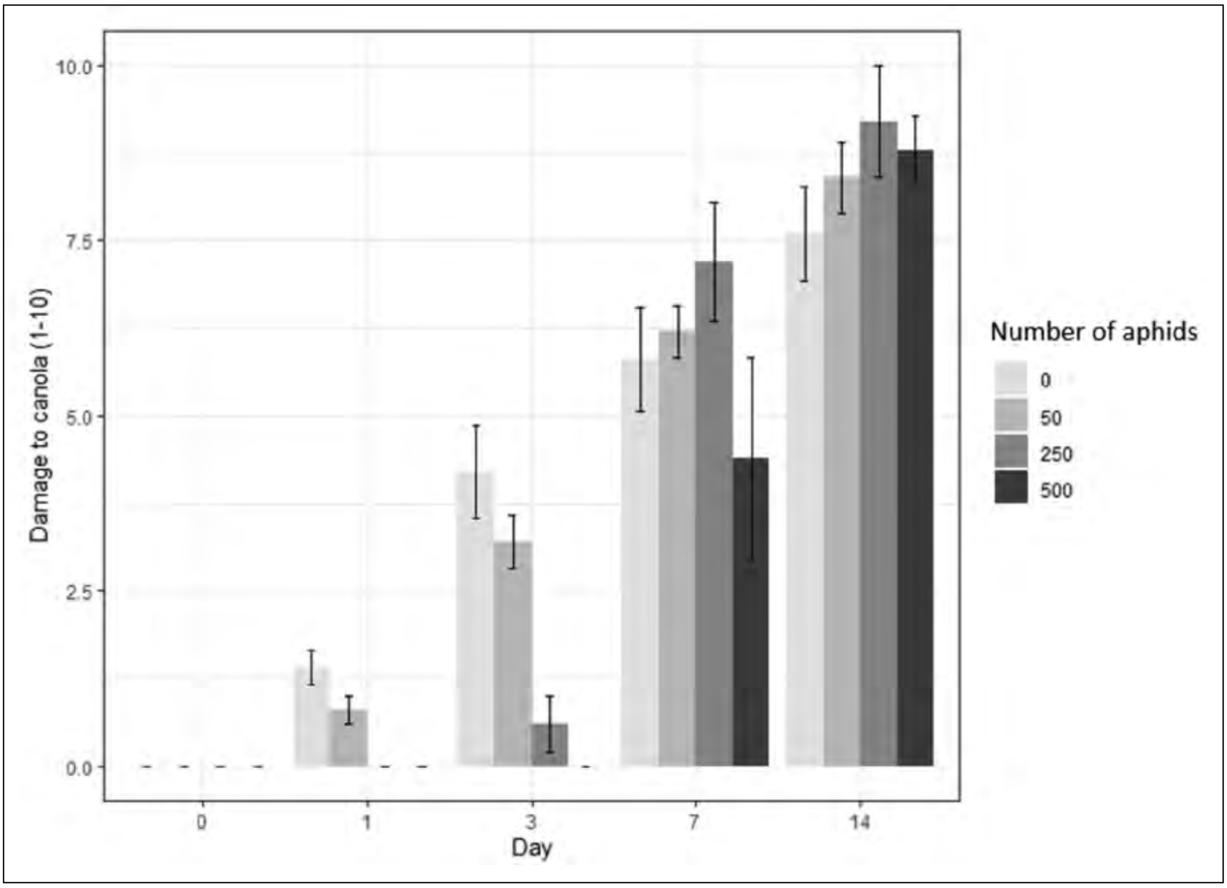

Figure 11. Damage done to canola by European earwigs when varying numbers of aphids are present (1-10 scale). Day refers to the number of days after the earwigs were introduced to the microcosm.

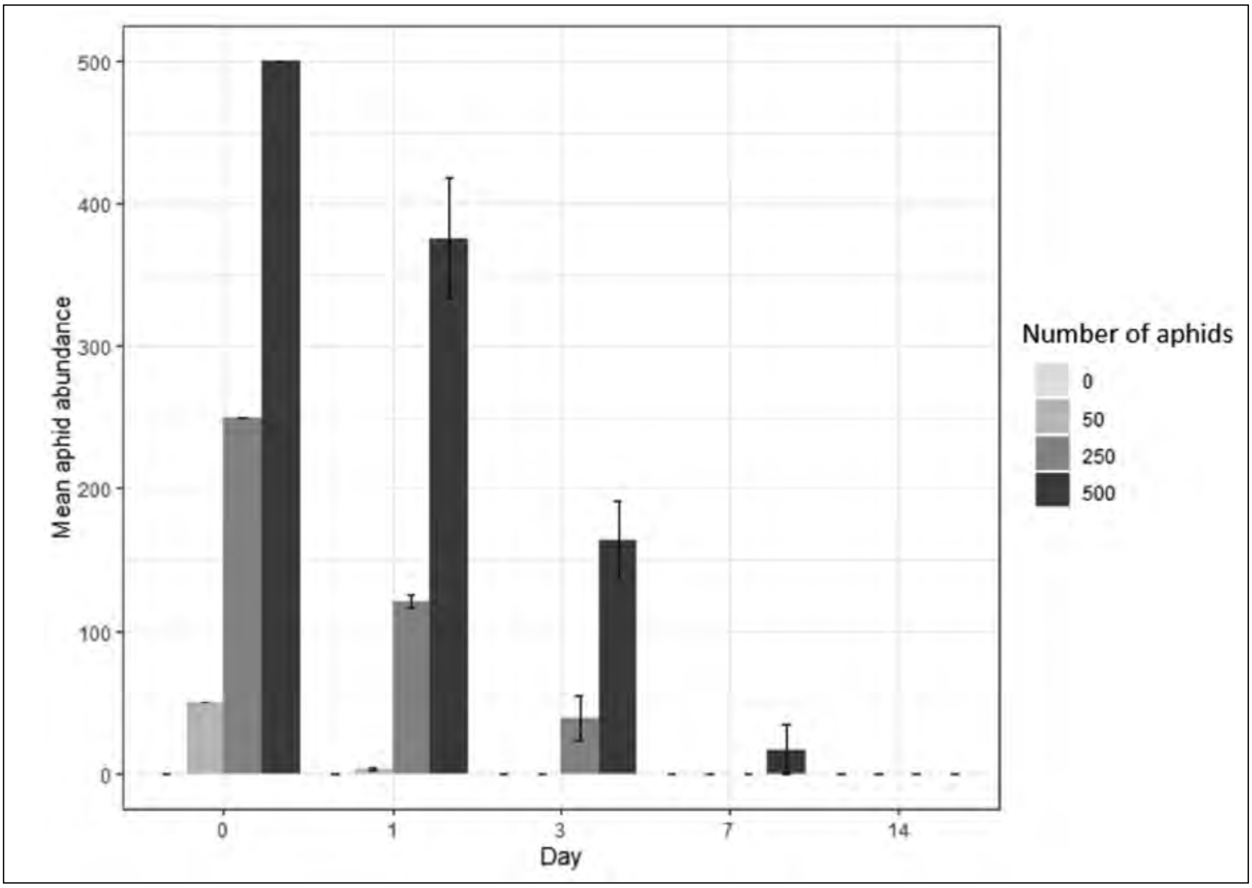

Figure 12. Aphid population over time when earwigs are present, day refers to the number of days after the earwigs were introduced to the microcosm.

European earwigs only have one generation per year (with potentially two broods per female), and they don't travel very far to feed as young juveniles. Once a nest is established, it is likely that the canola near the nest will be damaged, but the earwigs within that nest are likely to cause minimal damage to other parts of the crop. Extensive damage will be the result of many nests becoming established across large areas of the paddock. Monitoring for nests from April until June will allow for management before the earwigs reach the more destructive second instar stage from late June.

The role of European earwigs throughout the season is complex, and there are clear interactions with other invertebrates. We have demonstrated in laboratory tests that European earwigs will readily damage canola presented in isolation. However, when presented with canola that had been inoculated with aphids, the earwigs did not damage the canola at all until they had consumed the aphids. Aphid monitoring in the field suggests that earwigs may play a role in aphid suppression mid-late season. The importance of this role, and how earwig densities might interact with aphid densities and crop damage, are still unknown.

The accurate identification of species in the crop is the most important predictor of crop damage. Of the three dominant species found in canola, only European earwigs are confirmed as causing damage, while *N. lividipes* and *L. truncata* appear to have beneficial value. *Nala lividipes* is primarily reported as a pest of Queensland sorghum and maize during summer (Hargreaves 1970). However, we have confirmed that *N. lividipes* will not cause damage to canola or wheat; additional crops will be tested in 2020.

Our data so far suggests that the damage per earwig nest is spatially limited, but very high numbers distributed across a paddock will need to be controlled. So far, the data obtained around control methods is limited. The preliminary results of our trial suggest that fipronil might be useful as a seed treatment in areas with a history of earwig problems, although this pest is not listed on the current registered claims. There are reports suggesting cracked grain baits containing chlorpyrifos can be useful, these could be mixed with an attractant such as linseed oil. Due to the beneficial aspects of earwigs, reducing populations unnecessarily may have consequences for future crops. Therefore, before taking action, it is important to properly identify which species of earwig is in the field, how dense the population is, and how eliminating it may negatively impact the control of pests such as aphids.

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Useful resources

www.grdc.com.au/GRDC-FS-Earwigs

http://cesaraustralia.com/sustainable-agriculture/pestnotes/insect/European-earwig

https://grdc.com.au/resources-and-publications/all-publications/publications/2019/insect-pests-of-establishing-canola-in-nsw

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