Understanding Risks Posed by Cranberry Tipworms and Aphids in the Post-Diazinon Era

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Executive Summary

Integrated Pest Management (IPM) of cranberry pests entered a new era when the last broad-spectrum organophosphate insecticide – diazinon – was phased out in 2016. The first year of the post-diazinon era in Canadian cranberries was 2017. The research study reported here follows populations of cranberry tipworm (*Dasineura oxycoccana*), aphids (*Ericaphis fimbriata*), and beneficial predatory and parasitic insects that attack these pests, in the first year without diazinon. The cranberry farm chosen for the 2017 study was the one used for the 2016 study, and the study methods were similar.

In this first year of the post-diazinon era, populations of cranberry tipworm did not rebound in the absence of pre-bloom diazinon applications. The post-bloom application of Movento still killed tipworm larvae. In addition, some tipworm larvae apparently were eaten by ladybird beetle larvae that were searching cranberry shoots for aphids.

In the first year of the post-diazinon era, populations of aphids increased until late hook through early bloom stages of the crop (June 6 through 20, 2017). Ladybird beetle larvae and adults, and the parasitoids *Aphidius ericaphidus*, were plentiful. These beneficial insects apparently exerted a damping effect on aphid populations. No plant damage or crop damage was evident. Proposed research on aphid association with areas of plant virus has been postponed.

To further understand the contributions of natural enemies to pest control in cranberry, more quantitative, replicated field studies are recommended.

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Introduction

Integrated Pest Management (IPM) of cranberry pests entered a new era when the last broad-spectrum organophosphate insecticide – diazinon – was phased out in 2016 (Cranberry Institute 2016, 2017; Health Canada Pest Management Regulatory Agency 2013). IPM in the post-diazinon era is characterized by use of reduced-risk insecticides that have low mammalian toxicity and tend to act on groups of insects instead of all insects. The suite of reduced-risk insecticides is intended to manage populations of pest insects while sparing beneficial predatory, parasitic and pollinating insects. For example, the reduced-risk insecticide Altacor (chlorantraniliprole) kills caterpillars that chew on plant tissue by rapidly causing them to stop feeding (Hanning et al. 2009). The reduced-risk insecticide Movento (spirotetramat) penetrates through the leaf cuticle and moves inside the plant up to shoot tips where it kills sucking pests such as aphids (Brück et al. 2009) and cranberry tipworm larvae (Fitzpatrick 2013).

The first year of the post-diazinon era in Canadian cranberries was 2017. The research study reported here follows populations of cranberry tipworm (*Dasineura oxycoccana*), aphids (*Ericaphis fimbriata*), and beneficial predatory and parasitic insects that attack these pests, in the first year without diazinon. Research focused on two objectives, phrased as questions, and expanded on results of the previous four years of study (Fitzpatrick 2013, 2014; Fitzpatrick et al. 2015a; Fitzpatrick et al. 2016).

Objective 1:
Do populations of cranberry tipworm rebound in the absence of pre-bloom diazinon applications? Does post-bloom application of Movento still kill tipworm larvae?

Objective 2:
In the absence of pre-bloom diazinon applications, do populations of aphids increase and cause crop damage? Does the community of natural enemies (beneficial predatory and parasitic insects) exerting a damping effect on aphid populations? Aphids are often vectors of plant viruses; are aphid populations associated with areas where plant virus symptoms are evident?

Methods

The cranberry farm chosen for the 2017 study was the one used for the 2016 study (Fitzpatrick et al. 2016). This farm had the highest population of overwintered cranberry tipworms in 2015 (Fitzpatrick et al. 2015a) and has been a reliable site for cranberry tipworm research since 2009. Two fields ('First Field' and 'Second Field') were sampled in 2017. Sampling methods, illustrated in Figure 1, were the same as those in the 2016 study. Aphids and their predators and parasitoids were detected in sampled cranberry shoots and on stake traps.

IPM consultants monitored the study site and provided management recommendations to the grower. On May 25, Delegate (spinetoram) was applied to both fields. On June 22, Altacor (chlorantraniliprole) was applied to Second Field. On July 28, Movento (spirotetramat) was applied to First Field. Application rates and timing were consistent with instructions on the insecticide labels.

After discussions with members of the Cranberry Research Committee, the virus-sampling component of the project was modified. In 2017, only the Cranberry Research Farm was sampled for plant viruses. On July 11, Dr. Robert (Bob) Martin (USDA-ARS, Corvallis, Oregon) collected samples from all research plots in Beds 1 and 2. Bob was assisted by Dr. Renee Prasad (University of the Fraser Valley), Dr. Rod Serres and Miranda Elsby (Ocean Spray Cranberries), Dr. Rishi Burlakoti (AAFC- Agassiz), student Vlad Vasile (AAFC-Agassiz), and Dr. Sheila Fitzpatrick.

Results and Discussion

Objective 1: **Do populations of cranberry tipworm rebound in the absence of pre-bloom diazinon applications? Does post-bloom application of Movento still kill tipworm larvae?**

Very few overwintered cranberry tipworms were detected in the 10 emergence traps checked weekly from early May until late August 2017 (Figure 2). The earliest tipworm emerged in late May, and the latest emerged in mid-August. Emergence was also recorded during the first three weeks in June and the first three weeks in July. All but one tipworm (1 = 0.01 per trap on Figure 2) emerged in First Field. The population of overwintered tipworms was slightly greater than in 2016 (Fitzpatrick et al. 2016) but many times lower than in 2015 (Fitzpatrick et al. 2015a).

Overwintered parasitoids of cranberry tipworm were detected in emergence traps from late May until late August (Figure 3). As in 2015 and 2016, the majority of emergence took place in late July through late August, and *Ceraphron* sp. was the predominant species of overwintered parasitoid. One *Aprostocetus* sp. parasitoid (= 0.01 per trap on Figure 3) was detected on August 15. The number of overwintered parasitoids was greater than the number of overwintered tipworms (Figure 4).

Two other species of midges were detected in emergence traps. These are illustrated and discussed in Appendix A. These midges have been detected in previous years but have not emerged from field-collected cranberry shoots, so they are not cranberry pests. Mitochondrial DNA of the unidentified midges differs from that of cranberry tipworm (S. Mathur, unpublished data), so the unidentified midges are not cranberry tipworm adults. Voucher specimens were sent for identification by Dr. Bradley Sinclair at AAFC's National Identification Service in Ottawa. Dr. Sinclair noted that both species are in the family Cecidomyiidae, but are not cranberry tipworm. One of the species (Appendix A, image C) is in the subfamily Porricondylinae; these midges are generally mycetophagous (fungus-feeding) in decaying vegetation and wood. The second species (Appendix A, image B) could not be identified further. It is possible that *Ceraphron* sp. parasitoids attack larvae of these two unidentified midge species as well as larvae of cranberry tipworm.

Immature stages (eggs, larvae, pupae) of cranberry tipworm per cranberry shoot per week averaged 0.7 or less in First Field (Figure 5), and 0.5 or less in Second Field (Figure 6). First Field had more vegetative growth than Second Field, which was more fruitful. These numbers are considerably (three to four times) lower than in 2016 (Fitzpatrick et al. 2016, Figures 9 and 10). The reduced number of immature stages per shoot in 2017 indicates that the single application of Movento in 2016 killed larvae that would otherwise have overwintered. Action by beneficial parasitoids of cranberry tipworm, especially the numerous *Ceraphron* sp., may have killed tipworm larvae that Movento did not reach. Ladybird beetle larvae may also prey on, and kill, tipworm larvae (see p. 6).

Flying adult parasitoids of cranberry tipworm were detected on yellow sticky-card stake traps from May through late August (Figure 7). As in 2016, *Ceraphron* sp. was the most numerous parasitoid especially in late July through mid-August. Very few *Aprostocetus* sp. and *Platygaster* sp. were detected. In 2017, fewer flying adult parasitoids were detected than in 2016 (Fitzpatrick et al. 2016, Figure 13). The parasitoid *Inostemma* sp. was not detected in 2017; one individual was detected in 2016 (Fitzpatrick et al. 2016, Figure 13). Flying adult cranberry tipworms were detected on stake traps in both years; their numbers were slightly greater in 2017. It is probable that the single application of Movento in 2016 killed tipworm larvae that were already parasitized by *Ceraphron* sp., or *Aprostocetus* sp., or *Platygaster* sp., or *Inostemma* sp., thereby preventing some parasitoid larvae from surviving to 2017.

Objective 2: **In the absence of pre-bloom diazinon applications, do populations of aphids increase and cause crop damage? Does the community of natural enemies (beneficial predatory and parasitic insects) exerting a damping effect on aphid populations? Aphids are often vectors of plant viruses; are aphid populations associated with areas where plant virus symptoms are evident?**

The predominant species of aphid that feeds on cranberry in BC is *Ericaphis fimbriata* (Figure 8; Fitzpatrick et al. 2015b, p. 36). In spring, tiny wingless nymphs hatch from overwintered eggs. Nymphs and adult aphids feed by inserting their mouthparts into succulent leaf and bud tissue, and sucking up plant sap.

The community of natural enemies includes parasitoids, such as *Aphidius ericaphidus* (Figure 9; Fitzpatrick et al. 2015b, p. 37). The female parasitoid lays an egg inside an aphid body (Figure 10a). While the parasitoid larva develops inside the aphid, the outer skin of the dying aphid becomes brown and paperlike (Figure 10b). These mummified aphid bodies protect the immature parasitoid while it transforms from larva to pupa to adult parasitoid (Figure 10c). Fully formed adult parasitoids emerge from mummified aphids.

Predatory insects are also part of the community of natural enemies. The two most numerous and active predators observed at the study site in 2017 were syrphid flies (also known as hover flies) and ladybird beetles (also known as ladybugs) (Fitzpatrick et al. 2015b, p. 38, 39). Adult syrphid flies look like bees or wasps (Figure 11a) but do not sting. Female syrphids lay eggs (Figure 11b) on leaves near groups of aphids. Predatory larvae hatch from syrphid eggs. These larvae move about in search of aphid prey. When an aphid is detected, the syrphid larva inserts its mouthparts and digests the aphid's body contents (Figure 11c). Ladybird beetle larvae and adults are voracious predators of aphids (Figure 12). Larvae were often seen climbing up and down the cranberry uprights, searching shoot tips and upper leaves for aphid prey (Figure 13). Ladybird beetle larvae are known to prey on caterpillars such as blackheaded fireworm, and are suspected of preying on tipworm larvae that they encounter while searching for aphids.

In both fields at the study site, aphid populations increased steadily to a peak of about 1.1 to 1.3 aphids per cranberry shoot on June 6 (early hook through hook stage) (Figures 14, 15). Most aphids were nymphs; wingless reproducing adult females and occasional winged adults were also found. A small number of parasitized aphids was detected in shoots throughout the season in both fields, but many more were detected on yellow sticky-card stake traps in July through early August (Figure 16). In Second Field, syrphid eggs or larvae were occasionally found in shoots in late May (Figure 15). The most remarkable observation was that ladybird beetle larvae were seen at most sampling points on June 6 and 13, coincident with the peak and decline in aphids in First Field, and the peak of aphids in Second Field (Figure 14, 15). From June 20 through early August, ladybird beetle pupae were seen and most ladybird beetles in the fields were at the adult stage (Figure 14, 15). By late June, aphid populations in both fields had declined to about 0.5 aphids per cranberry shoot, or less.

Parasitoids that developed within aphid nymphs in June became flying adult parasitoids that were detected by sticky yellow-card stake traps in June, July and August. Winged adult aphids that developed from unparasitized aphid nymphs were also detected by these traps in June, July and August. The number of flying parasitoids peaked at about 40 per trap on July 11. The number of winged adult aphids peaked at about 15 per trap on July 25. These data suggest that survival of aphid parasitoids was much greater than survival of aphids.

Data and observations support the hypothesis that aphid populations increase in the absence of diazinon but are damped by populations of natural enemies, particularly ladybird beetles, which would have perished if diazinon had been applied. There was no plant damage or crop damage due to aphid feeding.

Virus-testing of research plots in Beds 1 and 2 at the Cranberry Research Farm showed that all plots were free of *Blueberry Scorch Virus* and *Blueberry Shock Virus*. All but one plot was free of *Tobacco Streak Virus*. Further information can be obtained from Dr. Renee Prasad.

Conclusions and Next Steps

In the first year of the post-diazinon era, populations of cranberry tipworm did not rebound in the absence of pre-bloom diazinon applications. The post-bloom application of Movento still killed tipworm larvae. In addition, some tipworm larvae apparently were eaten by ladybird beetle larvae that were searching cranberry shoots for aphids.

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To further understand the contributions of natural enemies to pest control in cranberry, more quantitative, replicated field studies are recommended.

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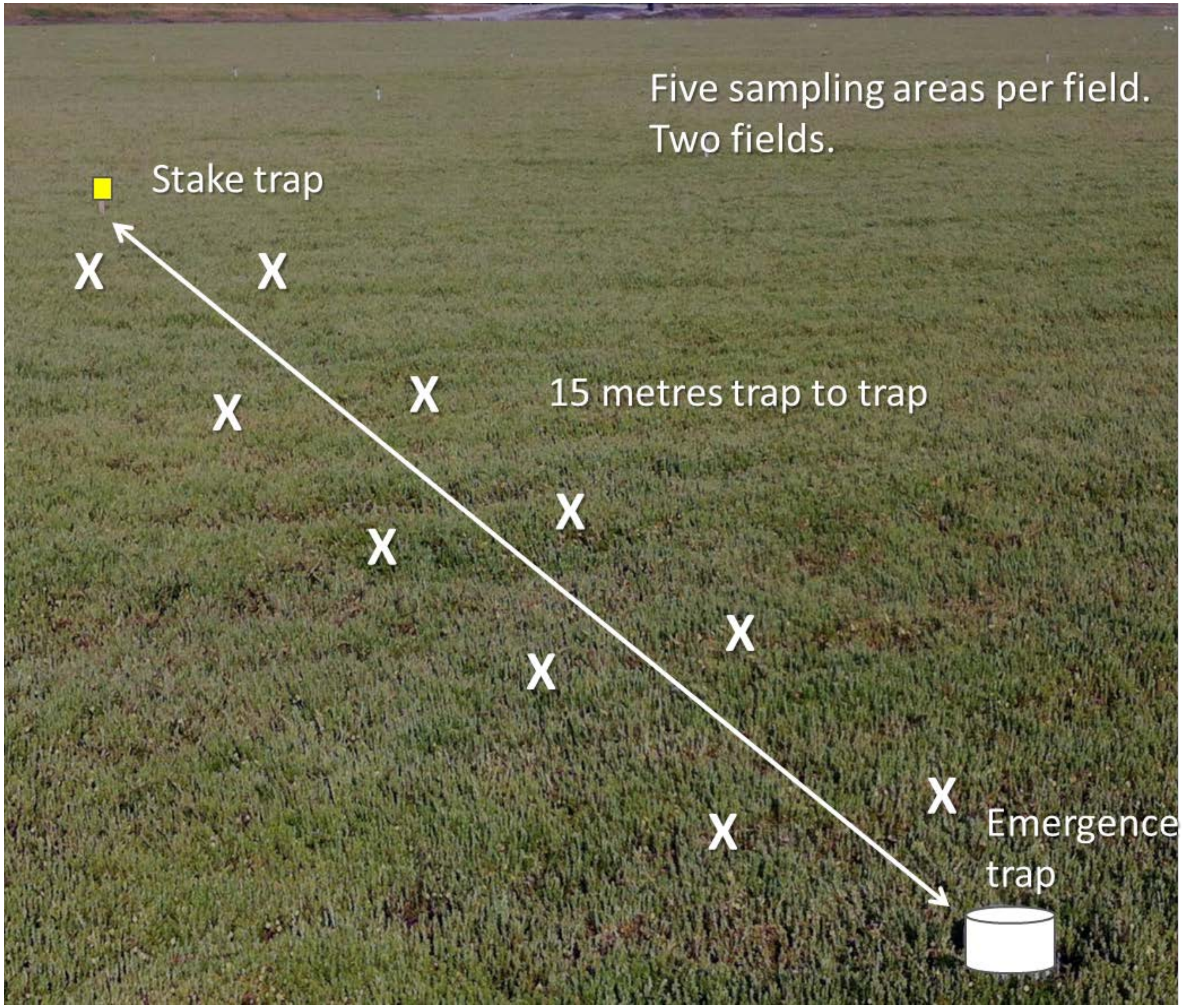

Figure 1. Illustration of trap positions and cranberry shoot sampling pattern. One shoot was clipped at each **X**.

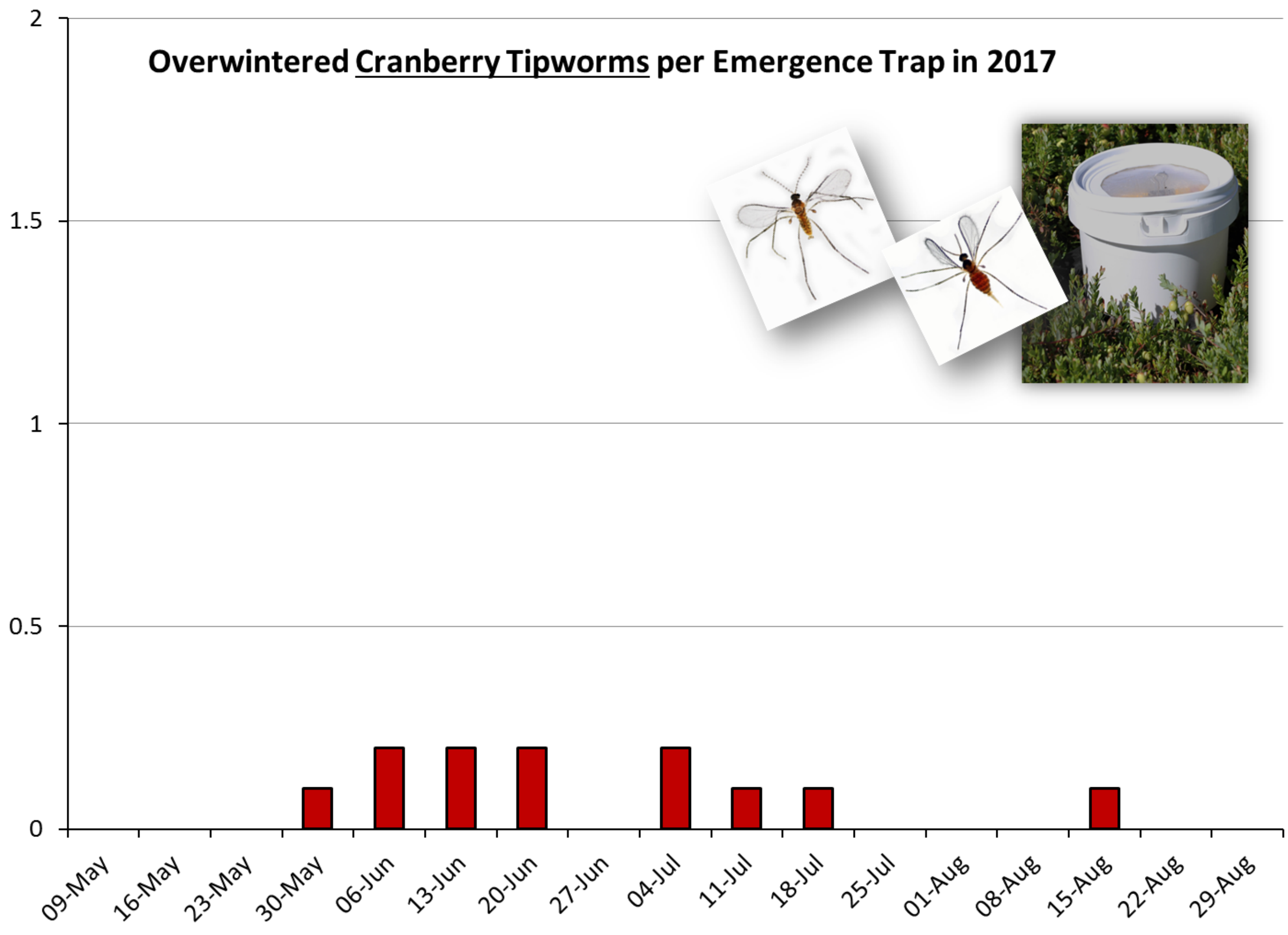

Figure 2. Average number of overwintered cranberry tipworms per emergence trap (10 traps) in both fields.

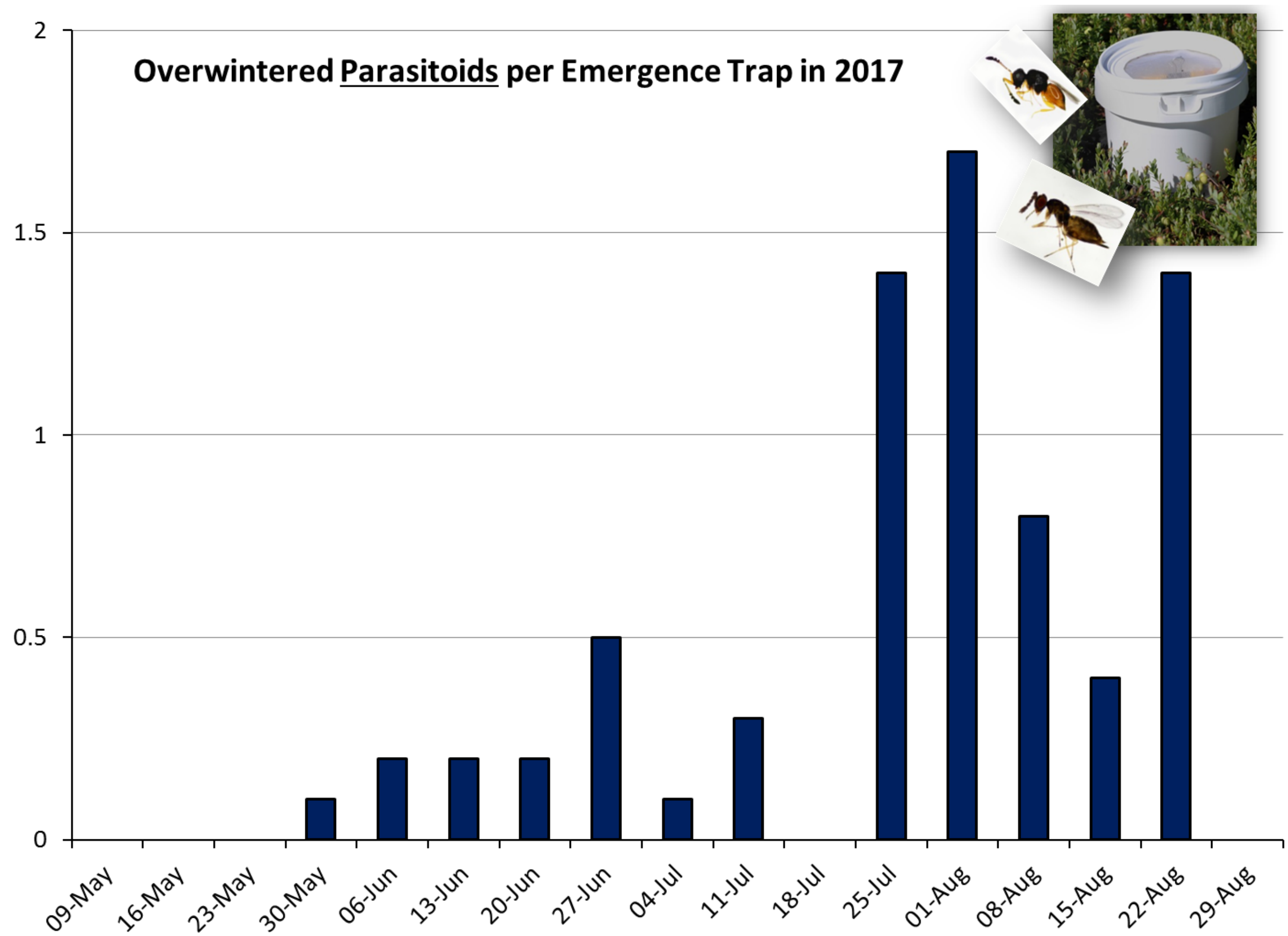

Figure 3. Average number of overwintered parasitoids of cranberry tipworm per emergence trap (10 traps) in both fields.

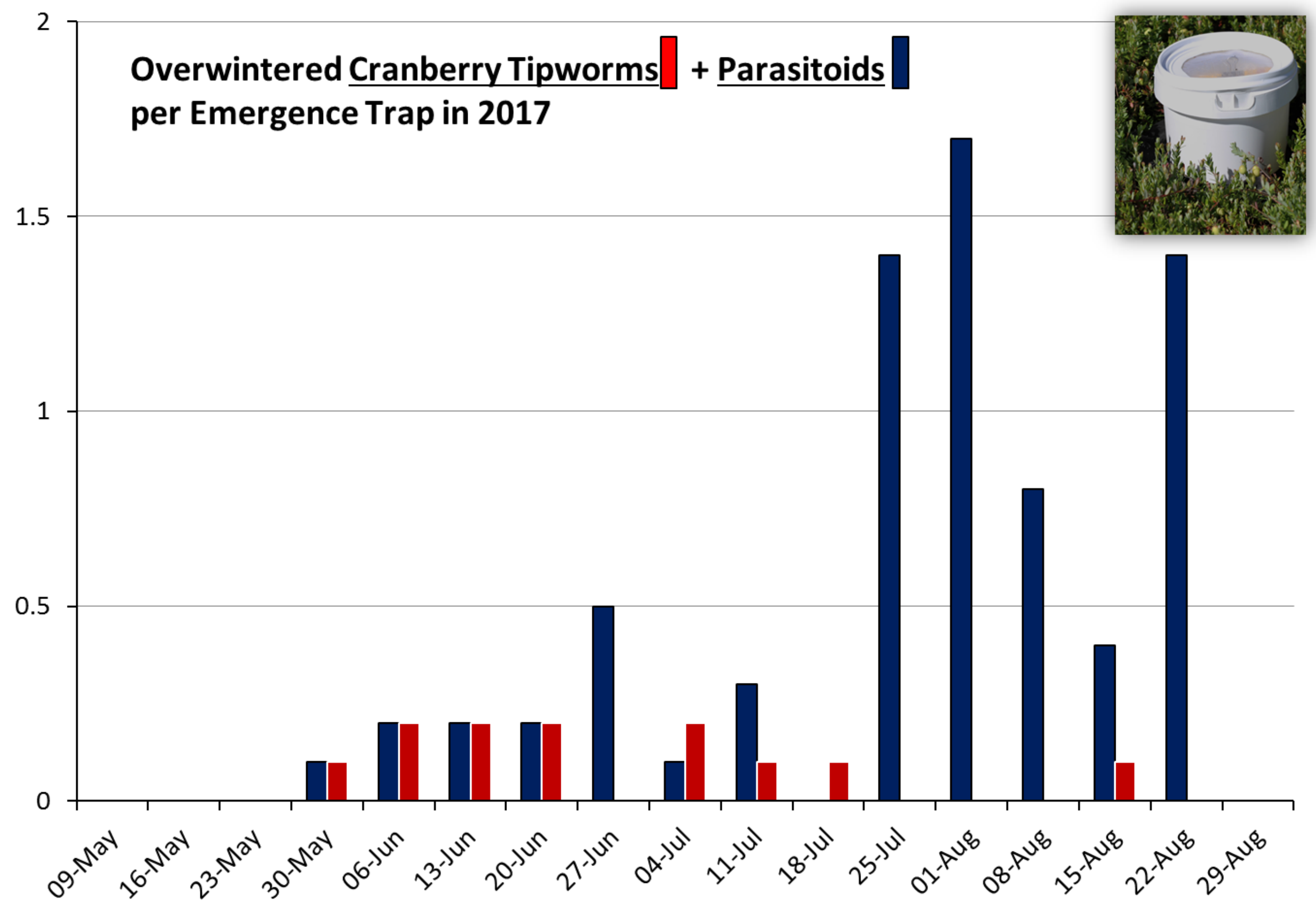

Figure 4. (= Fig. 2 + Fig. 3) Average number of overwintered cranberry tipworms and their parasitoids per emergence trap.

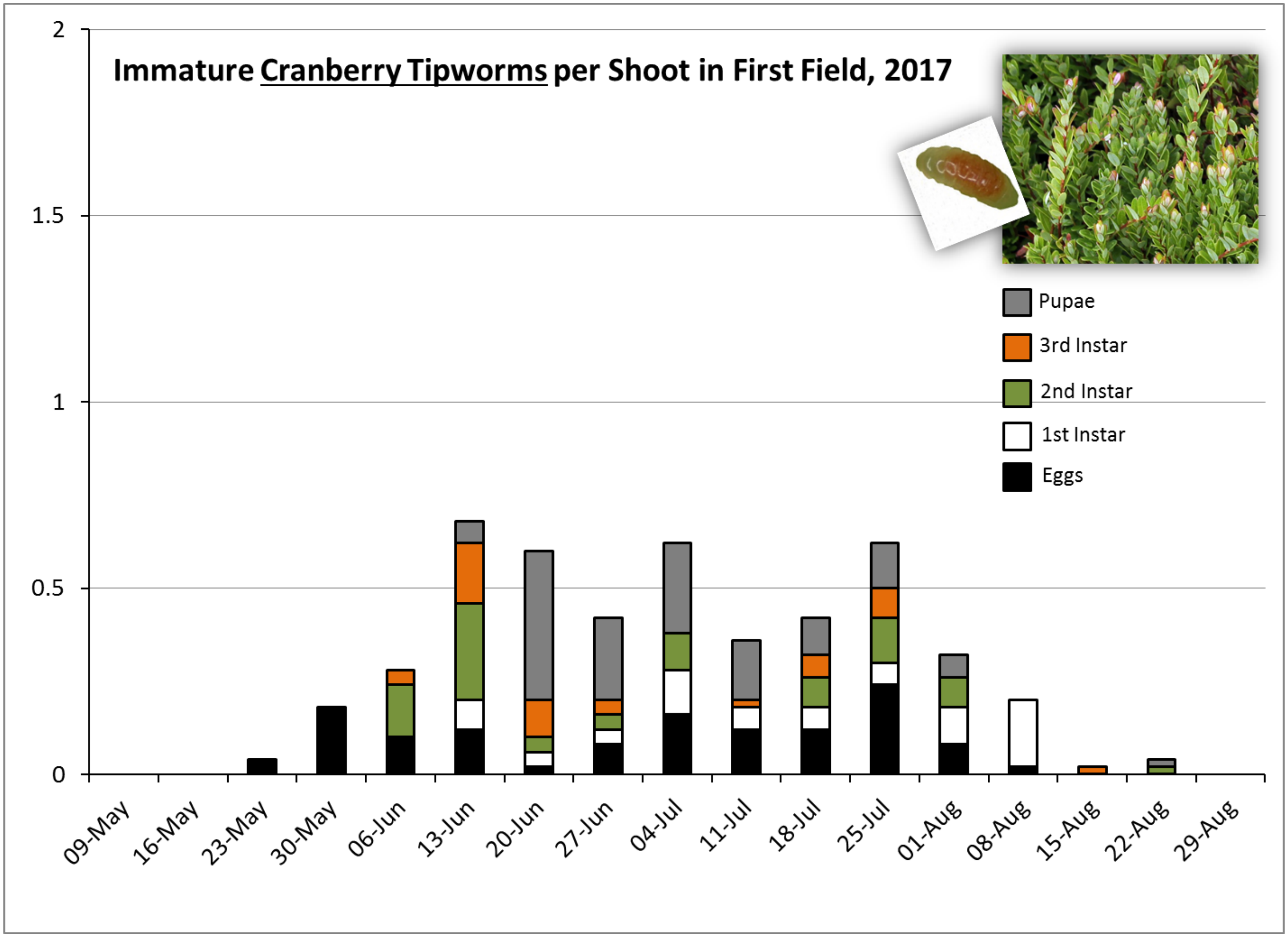

Figure 5. Average number of immature cranberry tipworms per cranberry shoot (50 shoots) in First Field.

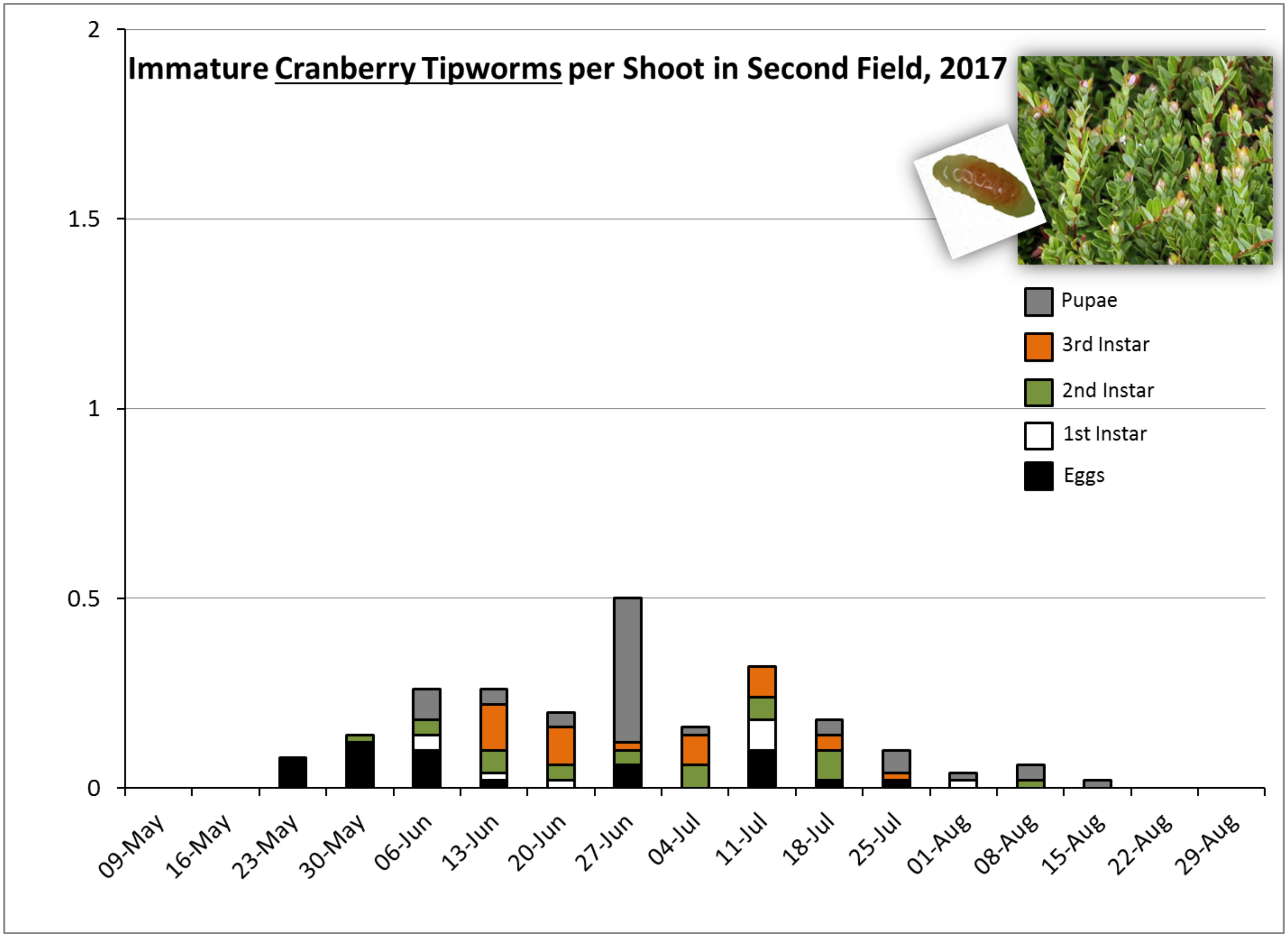

Figure 6. Average number of immature cranberry tipworms per cranberry shoot (50 shoots) in Second Field.

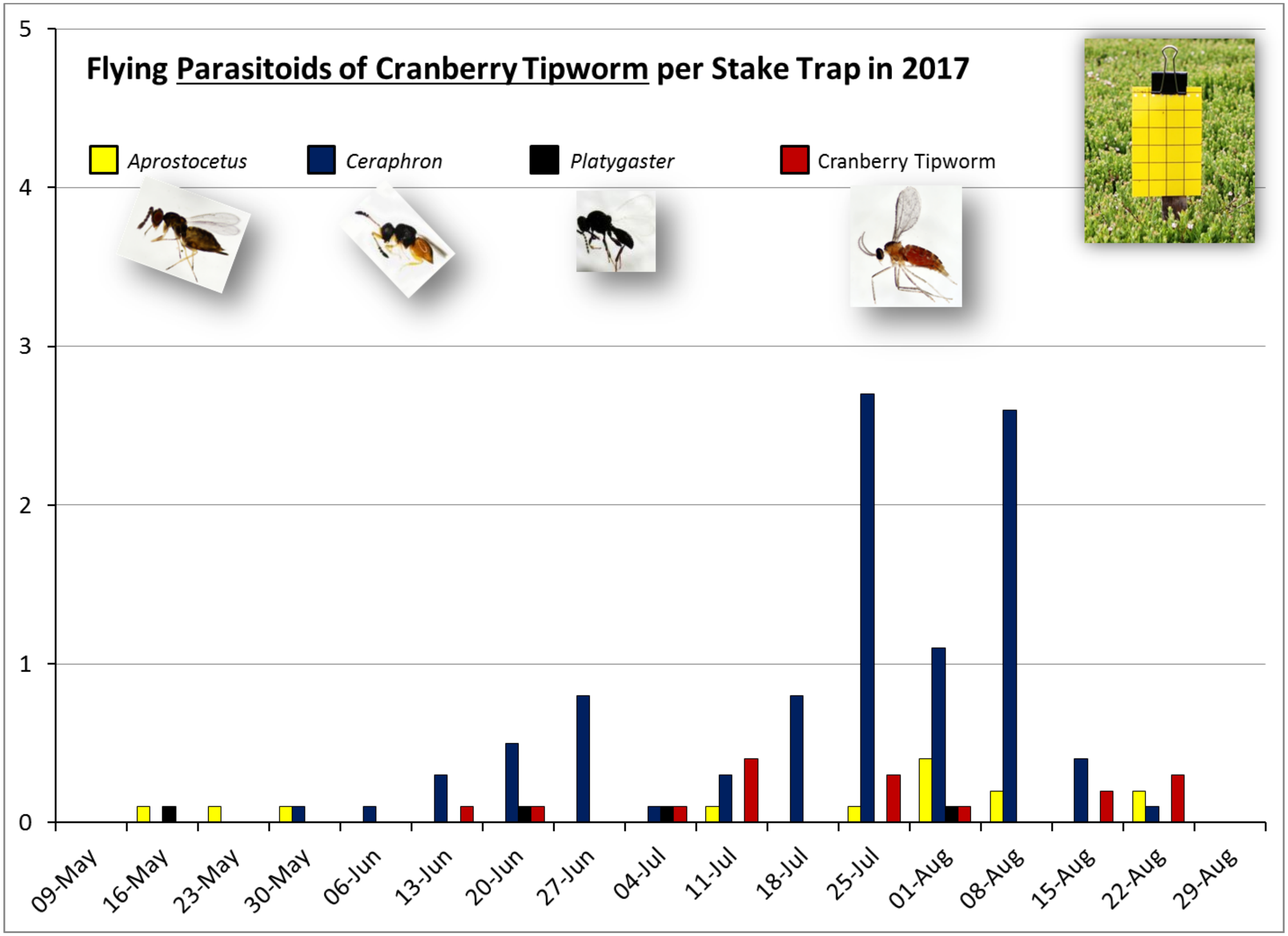

Figure 7. Average number of flying parasitoids of cranberry tipworm per stake trap (10 traps) in both fields.

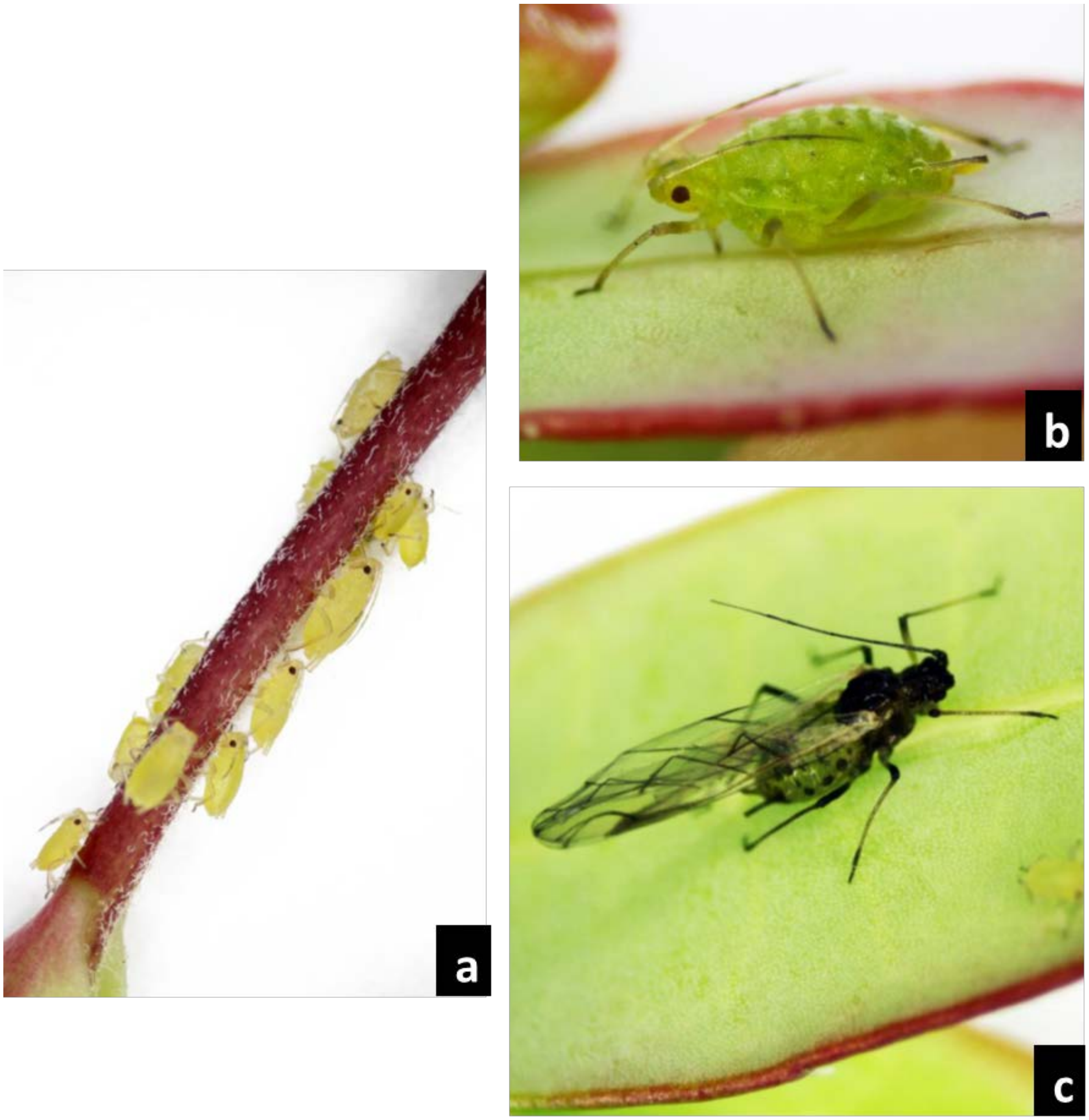

Figure 8. *Ericaphis fimbriata*, the predominant species of aphid that feeds on cranberry in British Columbia. The stages most commonly seen are: (a) nymphs (immatures); (b) wingless adult females; (c) winged adult females. The overwintering stage is the egg, which is shiny and black (not shown here).

All photos taken by Miranda Elsby.

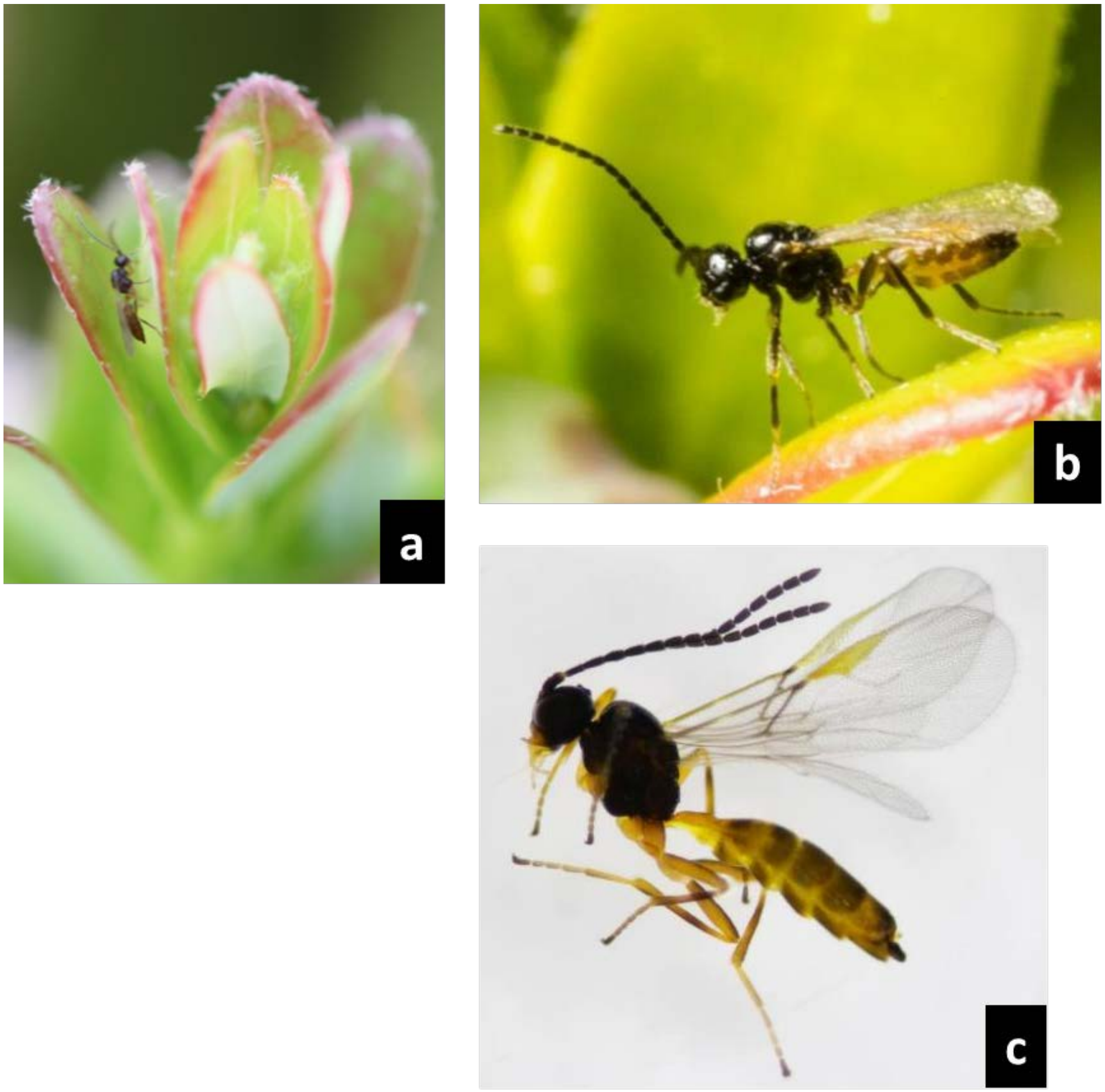

Figure 9. *Aphidius ericaphidus*, the predominant species of parasitoid that attacks aphids on cranberry in British Columbia. The adult female parasitoid is shown in all 3 photos. Photograph (a) taken by Miranda Elsby; (b) by Warren Wong; (c) by Snehlata Mathur.

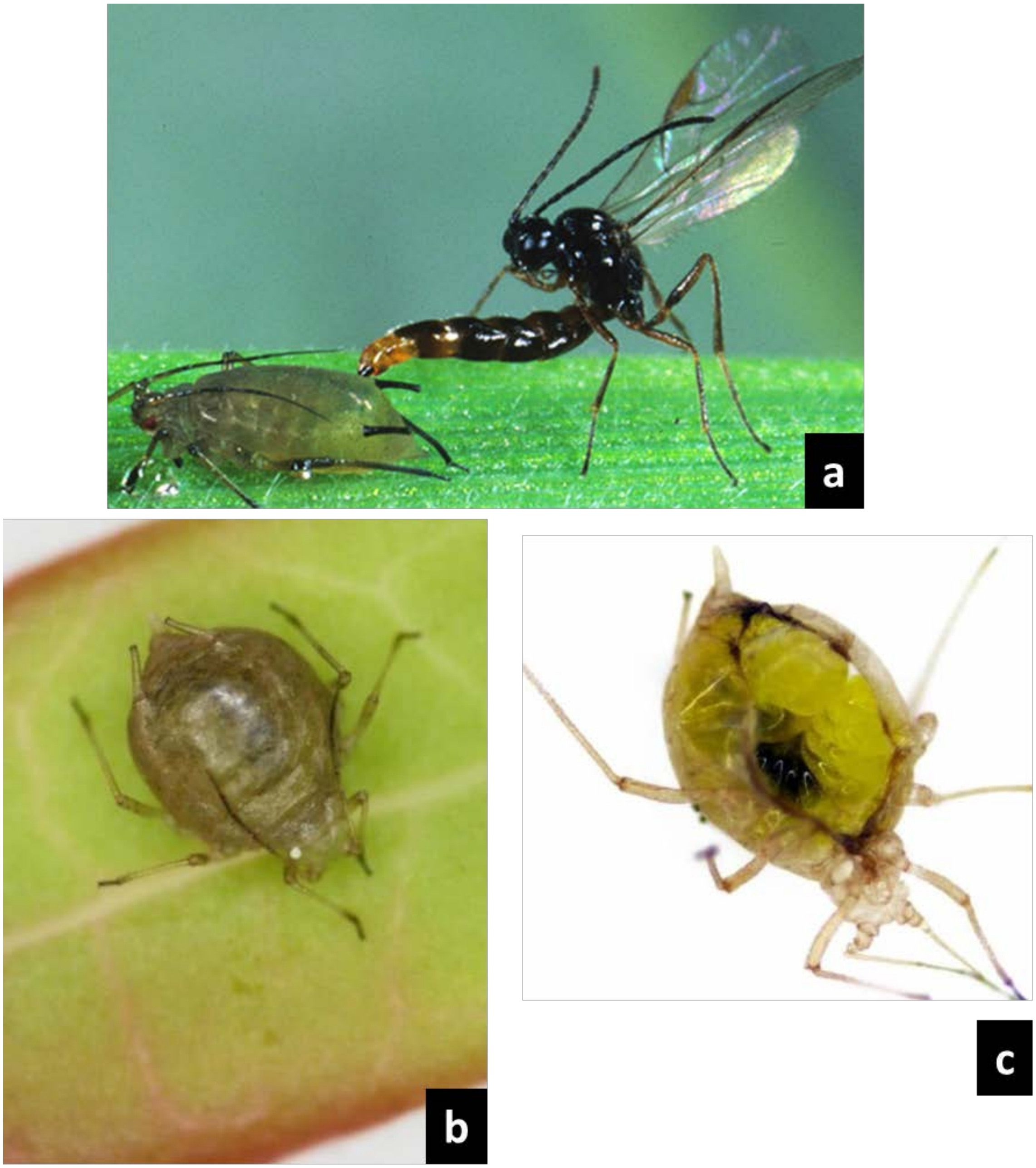

Figure 10. (a) An *Aphidius* female attacks an aphid by bending her abdomen forward to insert an egg into the aphid body; photo downloaded from Universidad de Talca, Chile. The parasitoid egg hatches and the parasitoid larva feeds on the aphid body from within. (b) The mummified body of a parasitized aphid; photo by Snehlata Mathur. (c) Inside the mummified aphid, the parasitoid larva fills the aphid's body cavity; photo by Miranda Elsby.

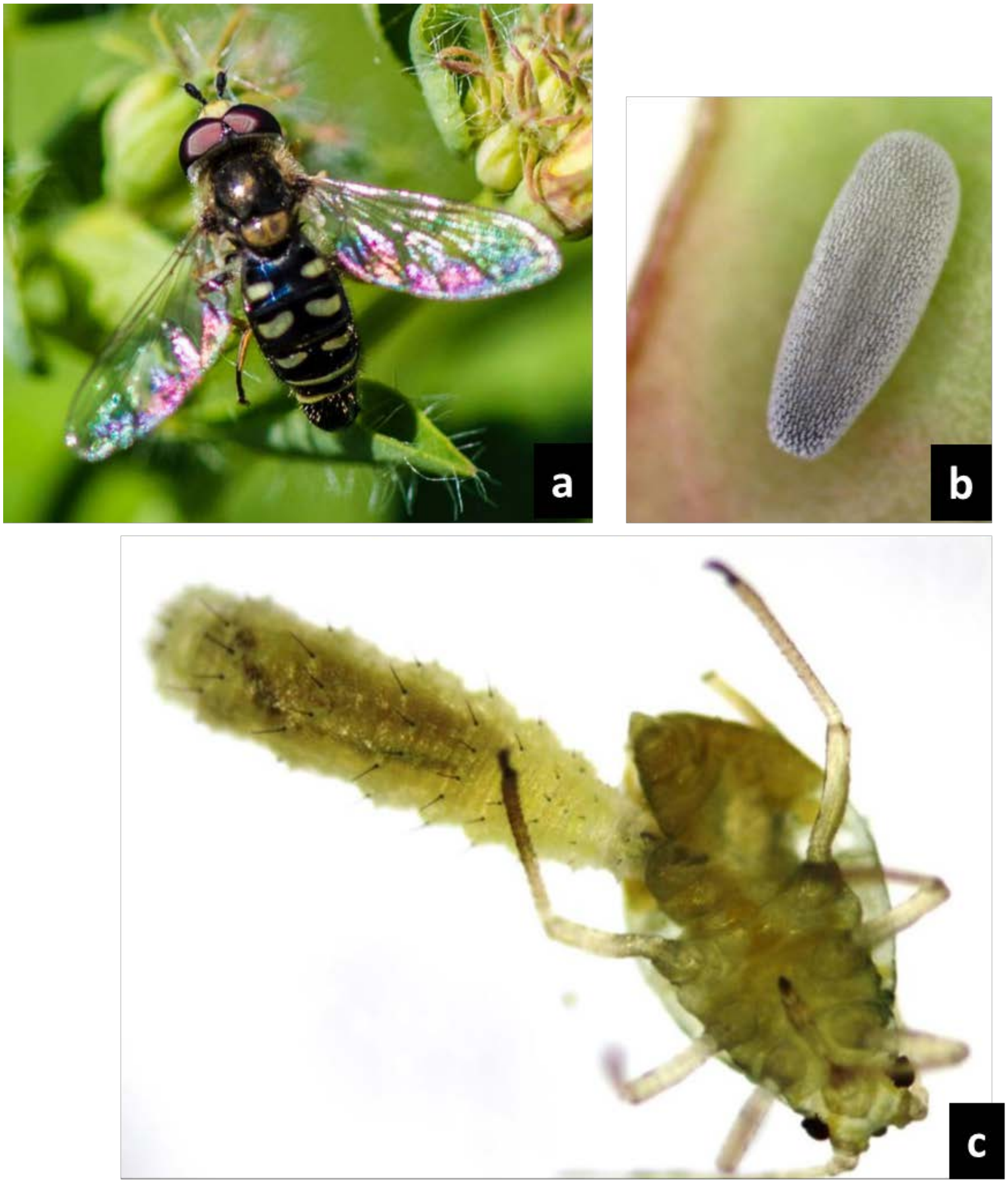

Figure 11. (a) An adult syrphid fly (a.k.a. hover fly) resembles a bee. Adults feed on pollen, nectar and sugary secretions of aphids. Photo by Warren Wong. (b) A syrphid egg (actual size 1 mm) laid near aphids by adult female syrphid. Photo by Snehlata Mathur. (c) A syrphid larva, recently hatched, inserts mouthparts into an aphid and digests the aphid's body contents. Photo by Snehlata Mathur.

Figure 12. An immature ladybird beetle (a) undergoes metamorphosis during the pupal stage (b) to become an adult ladybird beetle, a.k.a ladybug (c). Larvae and adults are voracious predators of aphids. Photos (a), (b) by Warren Wong; (c) by Sheila Fitzpatrick.

Figure 13. (a)-(e) An immature ladybird beetle searches cranberry uprights for aphids and other prey. Photos by Sheila Fitzpatrick.

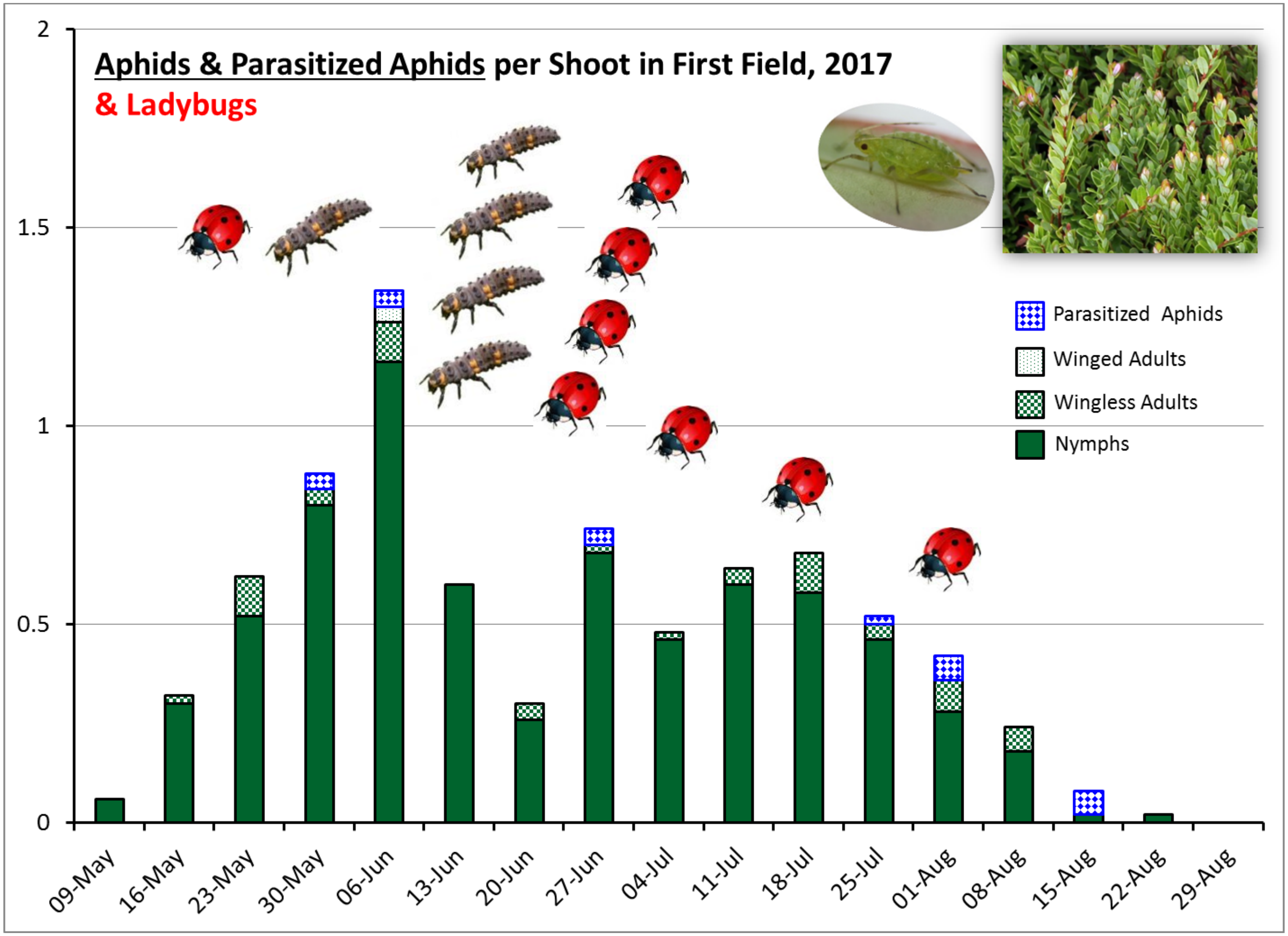

Figure 14. Average number of aphids and parasitized aphids per cranberry shoot (50 shoots) in First Field. Estimated relative abundance of ladybird beetles observed in trapping and sampling area.

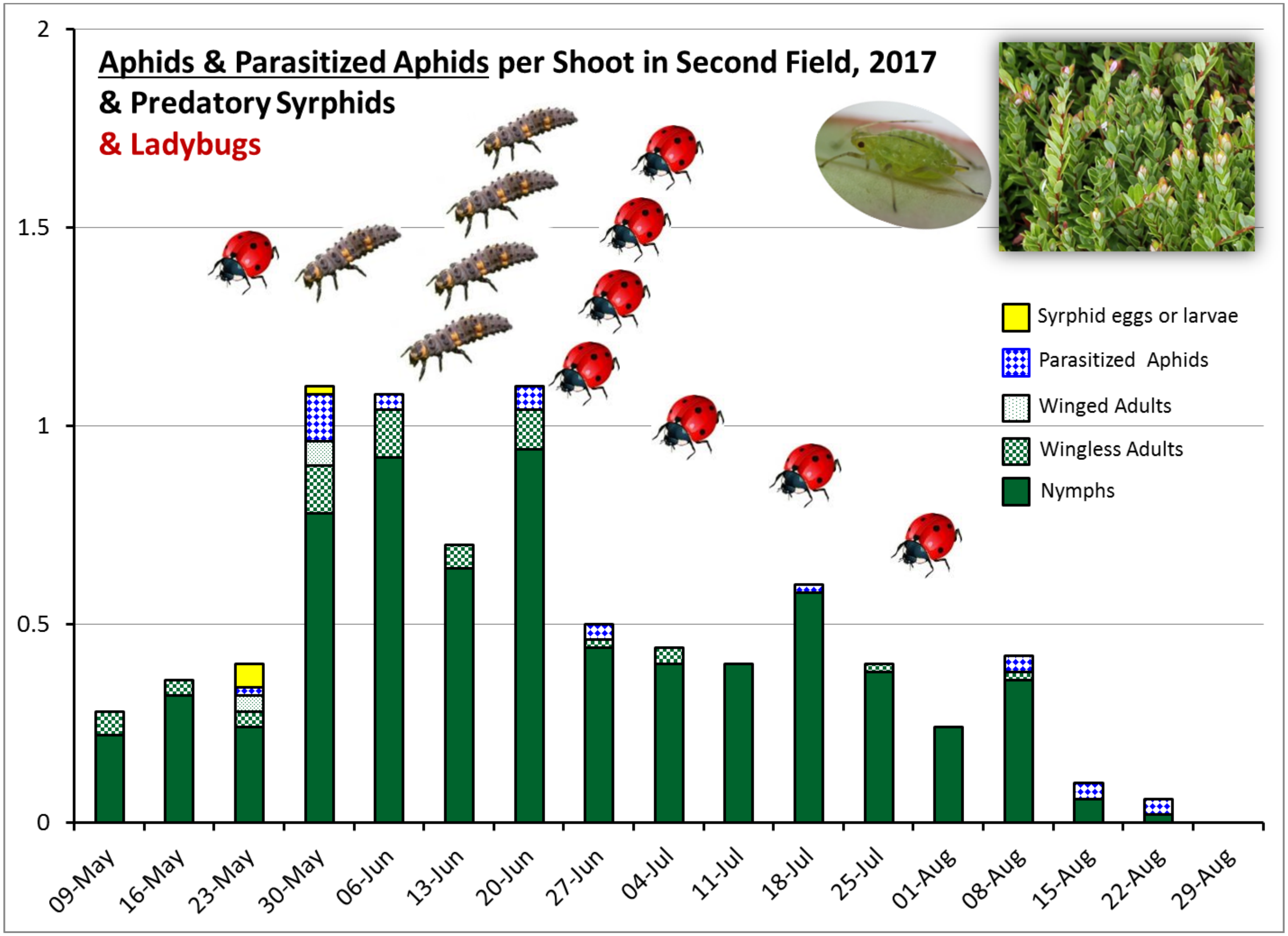

Figure 15. Average number of aphids and parasitized aphids per cranberry shoot (50 shoots) in Second Field. Estimated relative abundance of ladybird beetles observed in trapping and sampling area.

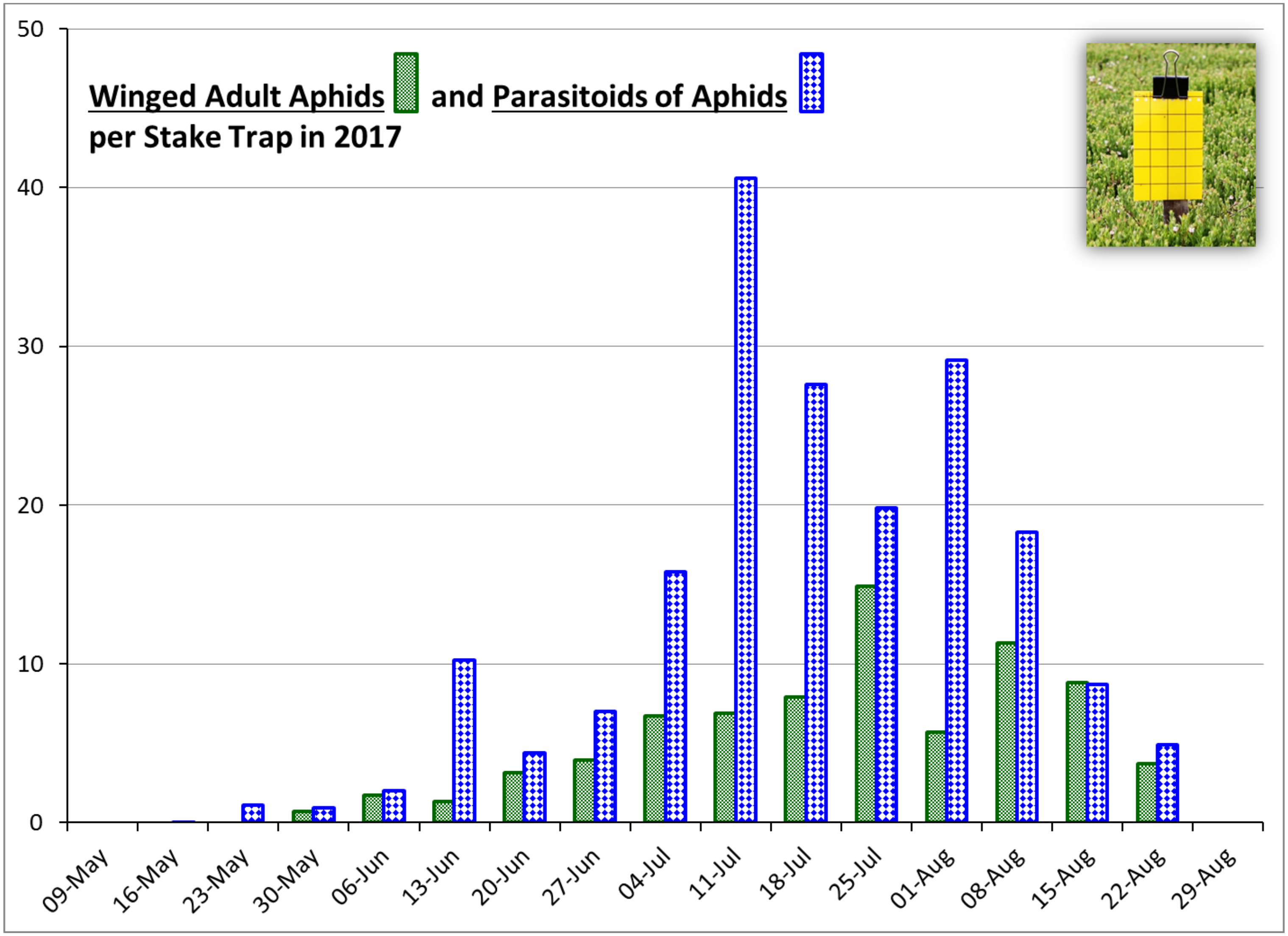

Figure 16. Average number of flying winged adult aphids and parasitoids of aphids per stake trap (10 traps) both fields.

APPENDIX A: Wing venation of midges caught in emergence traps in 2017

Three kinds of midges were detected in emergence traps. Analysis of mitochondrial DNA shows that the first kind, *Dasineura oxycoccana* (cranberry tipworm), differs from the second (darker) and third (lighter) type.

Dasineura oxycoccana: *R5 wing vein joins vein C before the wing apex (A).*

Darker midge*: R5 wing vein joins vein C close to the wing apex and is kind of straight (B)*

Lighter midge*: R5 wing vein joins vein C after the wing apex and is slightly curved down (C)*