SCIENTIFIC NOTE

The invasive strawberry blossom weevil, *Anthonomus rubi* Herbst (Coleoptera: Curculionidae), uses *Dasiphora fruticosa* for reproduction in British Columbia

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ABSTRACT

The first North American report of the Eurasian strawberry blossom weevil, *Anthonomus rubi* Herbst, was in the Fraser Valley of British Columbia (BC), Canada in 2019. This weevil feeds on and reproduces in closed developing flower buds of plants in the family Rosaceae, including commercial crops such as small fruit and ornamental plants grown for their flowers, and wild fruit or non-commercial flowering plants (non-crop plants) outside of crop fields. In its native range, *A. rubi* has been observed feeding and ovipositing on shrubby cinquefoil, *Dasiphora fruticosa.* In the Fraser Valley, *D. fruticosa* is a commonly grown landscaping shrub and therefore could serve as an important flowering ornamental host for *A. rubi.* To investigate the potential of *D. fruticosa* as a host for *A. rubi*, we monitored four landscaping beds in Abbotsford and Chilliwack, BC, containing *D. fruticosa* during the 2022 growing season for *A. rubi* adults, immature stages, and parasitoids that target immature stages of *A. rubi*. We collected damaged flower buds weekly and monitored for weevil and parasitoid emergence. We observed *A. rubi* adults feeding on flowers and ovipositing in *D. fruticosa* buds at all field sites. The emergence rate of *A. rubi* from damaged buds was 45%. In addition, two species of parasitoid wasps associated with *A. rubi* in the genus *Pteromalus* Swederus (Hymenoptera: Pteromalidae) emerged from damaged buds. Parasitism levels were low at all surveyed sites, with a mean parasitism rate of 1.4%. This is the first report of *A. rubi* using *D. fruticosa* as a host plant in North America and suggests that this plant could be an important flowering ornamental non-crop host for *A. rubi* in the newly invaded range, where attack by natural enemies is low.

Keywords: strawberry blossom weevil, host plants, shrubby cinquefoil, invasive insect, parasitoid, non-crop habitats

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Non-crop host plants can facilitate the growth of insect crop pest populations by offering resources such as food, overwintering habitat, and breeding sites outside of managed crops (Leach *et al*. 2018; Urbaneja-Bernat *et al*. 2020). These non-crop habitats are often viewed as beneficial for pest control because they serve as refuges for predators and parasitoids that can aid in the suppression of insect pests (Karp *et al*. 2018). However, invasive insects in newly invaded ranges often lack top–down controls from natural enemies, and non-crop habitats may favour pests by providing additional resources to promote population growth and further dispersal (Urbaneja-Bernat *et al*. 2020; Buck *et al*. 2023). Non-crop host plants are known to facilitate the growth of invasive insect pest populations in invaded ranges. For example, the spotted lanternfly, *Lycorma delicatula* (Hemiptera: Fulgoridae), is known to feed on more than 100 plant taxa, with preferences for the non-crop host tree of heaven, *Ailanthus altissima* (Miller) Swingle (Sapindales: Simaroubaceae) (Barringer and Ciafré 2020). Similarly, the invasive vinegar fly, spotted-wing drosophila, *Drosophila suzukii* Matsumura (Diptera: Drosophilidae), uses a wide variety of wild fruit species in crop field margins (Leach *et al*. 2018; Urbaneja-Bernat *et al*. 2020; Buck *et al*. 2023). These non-crop host plants may act as substantial reservoirs for these pest populations, which then disperse and cause damage to adjacent crops. Thus, a clear understanding of the effect of non-crop host plants on population dynamics of invasive insects is important in the development of integrated pest management practices.

The strawberry blossom weevil, *Anthonomus rubi* Herbst (Coleoptera: Curculionidae), was first reported in British Columbia (BC), Canada, in 2019, and subsequently in Washington State, United States of America, in 2020 (Franklin *et al*. 2021; Roueché *et al*. 2022). Native to Europe, Asia, and parts of North Africa (Alonso-Zarazaga *et al.* 2017), this weevil poses a threat to both wild and cultivated crops in the family Rosaceae, including strawberries, caneberries, and roses (Kovanci *et al*. 2005; Aasen and Trandem 2006; Linder *et al*. 2011; Tonina *et al.* 2021). Adult female weevils damage plants by laying eggs inside developing flower buds and then severing the peduncle below, causing the bud to wilt and die and allowing the larvae to mature within it. In its native range, *A. rubi* can cause 5–90% bud clipping in strawberries and 68% in roses (Kovanci et al. 2005; Tonina et al. 2021). Yield losses of up to 60% have been reported in strawberries, and complete yield loss has been observed in some early-season strawberry varieties when the *A. rubi* population reached high numbers (Kovanci *et al*. 2005; Cross 2008; Tonina *et al*. 2021). In Switzerland, *A. rubi* was observed to clip buds and reproduce in the ornamental plant, shrubby cinquefoil, *Dasiphora fruticosa* (Rosaceae) (J. Sherwood, unpublished data). As a hardy deciduous perennial flowering shrub, *D. fruticosa* is commonly used in landscaping. It is often planted along roadways and in public garden spaces in the Fraser Valley, BC, because of its long bloom period (April–June) and its resilience against summer droughts and cold winters (Stubbendieck *et al*. 2017). Determining whether *A. rubi* is using *D. fruticosa* as a host plant in the Fraser Valley is important because *D. fruticosa* could contribute to the weevil's population growth and expansion in the region. At least one parasitoid wasp in the genus *Pteromalus* Swederus (Hymenoptera: Pteromalidae) has been found to parasitise *A. rubi* in the Fraser Valley of BC (Franklin *et al*. 2021). To date, no reports of parasitism of *A. rubi* in *D. fruticosa* have been published, but given that non-crop habitats can be important refugia for natural enemies (Karp *et al.* 2018), evaluating the impact of parasitism on *A. rubi* in *D. fruticosa* is important.

With the present study, we aimed to determine if: (1) adult *A. rubi* feed and oviposit on *D. fruticosa*, and (2) *A. rubi* can develop from egg to adult inside of *D. fruticosa*. In addition, we estimated the rate of parasitism of *A. rubi* larvae in *D. fruticosa* buds in the Fraser Valley of BC. *Dasiphora fruticosa* was sampled at four locations from 2 June to 18 August 2022 in the Fraser Valley of BC (Table 1; Fig. 1). The Abbotsford sites (sites 1 and 2) were 4.3 km apart, whereas the Chilliwack sites (sites 3 and 4) were 1.5 km apart. The distance from the Chilliwack sites to the Abbotsford sites was approximately 35 km. The total number of shrubs varied at each location (from 4 to 25), and clipped buds were randomly selected from four *D. fruticosa* shrubs. We collected and pressed flowers and stems of *D. fruticosa* from each site, and A. Reid (University of the Fraser Valley, Abbotsford, BC) confirmed identification. Thirty-five severed buds were collected from each site each week. Thirty buds were monitored for emergence, and five were dissected to determine if weevil eggs or larvae were present. During site visits, we found adult weevils on *D. fruticosa* at all field sites (Fig. 2). Visual inspections also revealed clipped buds and feeding damage on flowers from *A. rubi* at all four sites.

Table 1. A summary of the collection locations, collection dates during 2022, number of collected clipped *Dasiphora fruticosa* buds, number of *Anthonomus rubi* weevils that emerged, and percentage of parasitised weevils at each of the four collection sites in Abbotsford and Chilliwack, British Columbia.

Site	Latitude	Longitude	Collection start date	Collection end date	No. of buds collected	No. of *A. rubi* emerged	Percentage parasitism *
1	49.047636	–122.261520	14 June	16 August	439	112	1.75%
2	49.053189	–122.225611	14 June	16 August	330	131	1.50%
3	49.146470	–121.977410	7 June	18 August	362	168	1.75%
4	49.146000	–121.962440	7 June	18 August	382	167	0.60%

$$\text{* \% Parasitism} = \frac{\textit{No. of parasitoids emerged from buds}}{\textit{(No. of parasitoids + No. of A. rubi emerged from buds)}} \times 100$$

Clipped buds were collected from each site and placed on paper towels in a pint-sized (480-mL) insect pot with a mesh screen snap-on lid (Bugdorm, MegaView Science Co., Ltd., Taichung, Taiwan). Buds were misted with water three times each week to keep buds moist and humidity high in the containers. Clipped buds were kept in the greenhouse at the Agassiz Research and Development Centre, Agriculture and Agri-Food Canada, Agassiz, BC from 2 June to 30 October, 2022. The temperature in the greenhouse during this period ranged from a minimum of 17 °C to a maximum of 33 °C, and the humidity ranged from a minimum of 51.3% to a maximum of 83.9%. We found it necessary to maintain high humidity to ensure weevil emergence.

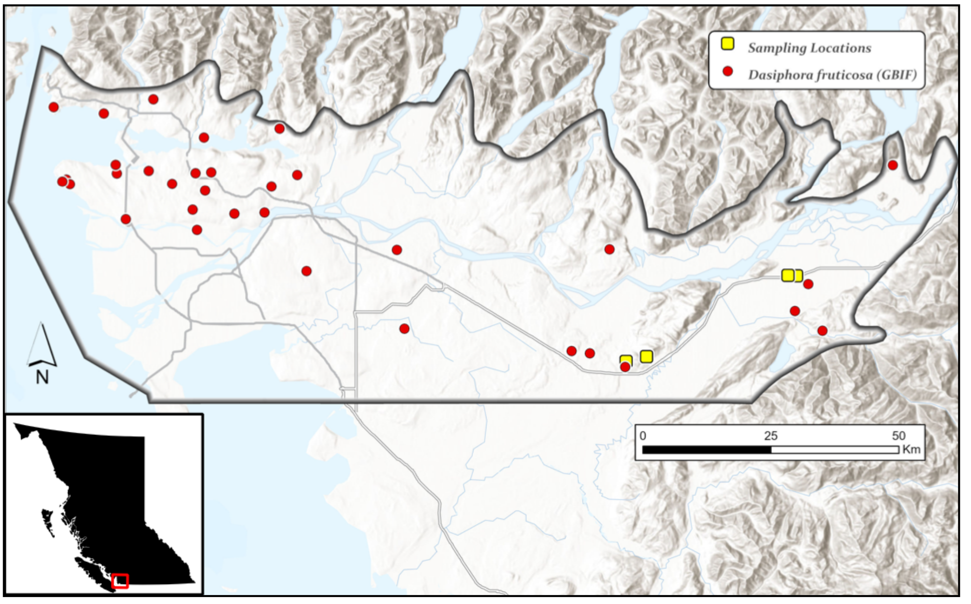

Figure 1. A map of observations (red dots) of *Dasiphora fruticosa* from Vancouver to Agassiz, British Columbia, Canada, based on records from the Global Biodiversity Information Facility (GBIF) database. Field sites (yellow squares) include: (1) Abbotsford Recreation Centre, Abbotsford; (2) Sandringham Drive, Abbotsford; (3) Evans Road, Chilliwack; and (4) Vedder Road, Highway 1 exit, Chilliwack.

Figure 2. An adult *Anthonomus rubi* on an ornamental *Dasiphora fruticosa* bud. Photo credit: A.B. McConkey

Weevils were counted and placed in 95% ethanol upon emergence. From the four sites, we collected a total of 1,513 clipped buds, from which 578 adult weevils emerged (Table 1). The proportion of weevil emergence from collected buds ranged from 25 to 46% at the four sites (Table 1; Fig. 3). Species identifications were confirmed by P. Bouchard, and voucher specimens of *A. rubi* from each of the four sites were deposited at the Canadian National Collection of Insects, Arachnids and Nematodes (CNC; Agriculture and Agri-Food Canada, Ottawa, Ontario, Canada). In addition, *CO*1 sequences were generated to confirm species identification. We isolated DNA from the head and thorax of 12 adult weevils using a DNAeasy Blood and Tissue Kit (Qiagen, Hilden, Germany) automated on a QIAcube Connect (Qiagen). We used polymerase chain reaction to amplify the 658-base-pair region of the mitochondrial *CO*1 gene using universal primers LCO 1490 and HCO 2198 (Folmer *et al.* 1994). A 20-μL reaction was prepared containing 20–30 ng of total genomic DNA, 0.2 mM dNTP, (1×) HF buffer (Thermo Fisher Scientific, Waltham, Massachusetts, United States of America), 10 pmol of each primer (Integrated DNA Technologies, Coralville, Iowa, United States of America), 0.4 units of Phusion High-fidelity DNA polymerase (Thermo Fisher Scientific), 20 μmol betaine. Polymerase chain reaction amplification conditions were as follows: 98 °C for 30 seconds, cycled 35 times at 98 °C for 10 seconds, 55 °C for 30 seconds, 72 °C for 30 seconds, followed by 72 °C for 5 minutes. Polymerase chain reaction products were purified using ExoSAP-IT Express (Thermo Fisher Scientific) and sequenced on the SeqStudio at the Applied Genomics Centre (Kwantlen Polytechnic University, Surrey, BC, Canada). We trimmed and aligned all sequences in Sequencer 5.4.6, used a BLAST search (Genbank, National Institutes of Health, Bethesda, Maryland, United States of America) to confirm the species identification, and deposited all sequences in the Barcode of Life Database systems (Reference No. AGAAR001-23 to AGAAR009-23). We found our sequences to be 100% identical to an *Anthonomus rubi* voucher (van de Vossenberg *et al.* 2019; accession number NC_0044714.1).

Weevils emerged from 8 July to 3 October, with emergence peaking from 16 to 24 August. Weevils were sexed based on the presence of thorns on the intermediate coxae of male weevils (Innocenzi *et al*. 2002). Of the emerged weevils from collected *D. fruticosa* buds, 47.2% were females and 52.7% were males. Parasitoid wasps emerged from damaged buds collected at each site; however, parasitism was extremely low, with only six parasitoids emerging from all collected buds. The average percent parasitism from all four sites was 1.4% (Table 1). Two species of parasitoids were identified by G. Gibson to the genus *Pteromalus* and deposited as voucher specimens at the CNC. Based on morphological comparisons and review of available keys, four of the individuals were consistent with the *Pteromalus* sp. reported by Franklin *et al.* (2021) to attack *A. rubi*, whereas the other two individuals were identified as a different species from the genus *Pteromalus*, but species level identification will require further research. These parasitoids are not associated with *A. rubi* in its native range in Europe.

Based on our results, we conclude that *A. rubi* is able to feed and reproduce on *D. fruticosa* in its invaded range. Adult weevils emerged from clipped buds collected at each of the four sites. This is the first record of *A. rubi* using *D. fruticosa* in North America. Understanding the host range of *A. rubi* will inform management of this new invasive pest at the landscape level. Non-crop hosts could provide *A. rubi* with additional food sources, reproductive resources, overwintering sites, and refugia. As a result, non-crop habitats could enhance population growth and spread of *A. rubi* to neighbouring berry crop fields or flowering ornamentals grown as landscape plants. *Dasiphora fruticosa* is widely distributed throughout the Northern Hemisphere and could be an important host plant for this weevil if it expands its range (Fig. 2). Other non-crop hosts could also contribute to the population growth of *A. rubi.* For example, Franklin *et al.* (2021) found *A. rubi* can use wild hosts such as salmonberry (*Rubus spectabilis* Pursh), thimbleberry (*Rubus parviflorus* Nuttall), wild rose (*Rosa* spp.), and the invasive Himalayan blackberry, *Rubus armeniacus* Focke (Rosaceae) throughout BC's Fraser Valley.

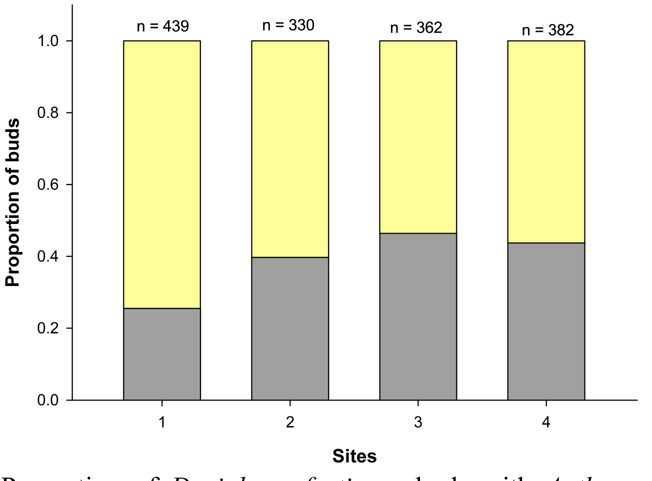

Figure 3. Proportion of *Dasiphora fruticosa* buds with *Anthonomus rubi* weevil emergence (grey) and with no weevil emergence (yellow), calculated from total number of buds collected at each site (n).

British Columbia is the largest raspberry-producing province in Canada, representing 76% of national production (Statistics Canada 2019; Pest Management Program 2021). In addition, the province produces 5% of all Canada's strawberries (Statistics Canada 2019). Caneberry crops in BC are mostly grown in perennial cropping systems. Dispersal of *A. rubi* from non-crop hosts could increase pest pressure in nearby crop fields. Adults of the closely related *Anthonomus grandis* (Boheman), the cotton boll weevil, a major pest of cotton in the southern United States of America, are capable of flights lasting 2–3 hours or even longer when ovaries are underdeveloped, suggesting the genus can disperse over long distances (Rankin *et al.* 1994). *Anthonomus rubi* is known to overwinter in the leaf litter underneath host plants (Jary and Dip 1931). Dispersal of *A. rubi* from unmanaged or undisturbed leaf litter underneath non-crop hosts to berry fields could be expected and would help to sustain populations in or near berry fields in BC. Additionally, this would enable recolonisation of strawberry and caneberry fields each season or after new plantings.

We found two parasitoid species in association with *A. rubi* in *D. fruticosa*; however, estimated rates of parasitism are very low (~1%). This result is expected, as these parasitoids are not associated with *A. rubi* in its native range. Further investigation of parasitism of *A. rubi* on other host plants is required to establish a baseline level for parasitism of *A. rubi* in the newly invaded range before considering introducing exotic parasitoids for control of *A. rubi*. In summary, identifying non-crop hosts that are used by *A. rubi* could provide a better understanding of this pest's behaviour and biology. Consideration of the proximity of berry crops to suitable non-crop hosts that can serve as refugia for *A. rubi* could be important to the future management of this pest in crop fields.

ACKNOWLEDGEMENTS

We would like to thank Agriculture and Agri-Food Canada greenhouse staff Ricardo Sarte and Paige Bogaerts for maintaining the greenhouse compartment where *D. fruticosa* buds were stored. We also want to thank the City of Abbotsford and the City of Chilliwack, BC, for allowing us to collect *D. fruticosa* buds in their landscaping plots. We would like to thank Alan Reid, associate professor, Biology Department, University of the Fraser Valley, for confirming the species identification of *Dasiphora fruticose* at our field sites. We also thank Gary Gibson and Pat Bouchard, CNC, Ottawa Research and Development Centre, for species identification of *Anthonomus rubi* and parasitoids, and Taylor Chin, Lyndsey Baillie, and Paul Adams, Applied Genomics Centre, Kwantlen Polytechnic University, Surrey, BC, for barcoding specimens for species identification. Lastly, we thank and acknowledge the Sto:lo people and the Coast Salish First Nations on whose unceded land the research centre operates and where our field sites were located.

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