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The "morning glory" psyllid? Potato psyllid development on morning glories and bindweed

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Encounters with two psyllid species. Potato psyllid (*Bactericera cockerelli*) is well-known for its ability to develop on plants other than cultivated potato and tomato, notably crop and non-crop relatives of potato such as matrimony vine, ground cherry, annual nightshades, and a number of other species in the Solanaceae. The ability of potato psyllid to feed, reproduce, and develop on non-crop species substantially complicates efforts to manage the psyllid and zebra chip disease in commercial potato fields, as we are finding that certain non-crop species in potato growing regions are important reservoirs of potato psyllids. These plants are basically acting as "green bridges" allowing the psyllid to survive and reproduce when potato is not available. Our research has helped show, for example, that shrubby perennials such as bittersweet nightshade and matrimony vine contribute to psyllid build-up and maintenance in potato growing regions of the Pacific Northwest.

What is less appreciated is that potato psyllid can be collected from – and will develop on – plants in the Convolvulaceae, the family that contains the bindweeds and morning glories. Field records include two genera, *Convolvulus* (the bindweeds) and *Ipomoea* (the morning glories). Currently, records

comprise only two species: *Convolvulus arvensis* (field bindweed), an invasive weedy introduction from the Mediterranean region; and sweet potato (*Ipomoea batatas*), including both crop and ornamental cultivars. Observations that potato psyllid develops on these two species of Convolvulaceae has prompted us to examine other species in this family. This report will summarize some of this work, and will show that potato psyllid readily develops on more species within the Convolvulaceae than previously known.

Our other objective is to present a brief overview of a second species of psyllid, which we are finding to be an important element of the Convolvulaceae – potato psyllid story. Sampling of field bindweed in potato growing regions for presence of potato psyllid has been complicated by the realization that a second psyllid, *Bactericera maculipennis*, is very common on field bindweed throughout the Pacific Northwest (and, southwards into other potato growing regions), to the extent that sampling of field bindweed is generally more likely to produce *B. maculipennis* than potato psyllid. Thus, monitoring of field bindweed for potato psyllid may regularly lead to encounters with *B. maculipennis*, and these encounters have led to instances of confusion in monitoring for potato psyllid. In this report we will summarize morphological traits that can be used to separate potato psyllid from its close relative *B. maculipennis*. The two species can readily be separated using a few easily viewed traits that should eliminate confusion in identifications that might arise during monitoring for potato psyllid.

Figure 1. Convolvulaceae. (A) *Ipomoea alba*; (B) *Ipomoea nil*, Scarlett O'Hara cultivar; (C) sweet potato, *Ipomoea batatas*; (D) *Ipomoea hederacea*; (E) *Ipomoea cordatotriloba*; (F) *Convolvulus tricolor*; (G) *Ipomoea ternifolia*; (H) field bindweed, *Convolvulus arvensis*; (I) *Ipomoea nil*; (J) *Ipomoea imperati*; (K) *Ipomoea tricolor*. Photo credits provided at end of article.

What is the Convolvulaceae? The Convolvulaceae constitutes approximately 1800 species worldwide, with more than one-third of species in two genera, *Ipomoea* (morning glories) and *Convolvulus* (bindweeds). The family is distributed worldwide but has highest diversity in the tropics and subtropics. Many plants in this family have a vining or twining habit, best illustrated by the bindweeds, but the family includes everything from shrubby perennials to herbaceous annuals (Fig. 1). The Convolvulaceae includes a number of commercially important taxa, including the ornamental morning glories, food crops such as sweet potato, and agricultural weeds known as bindweeds. Despite the large number of Convolvulaceae species worldwide, the family is very poorly represented as hosts for psyllids. Of the approximately 3800 species of psyllids worldwide, only five psyllids are known to use Convolvulaceae as hosts. These five species include two North American species: the potato psyllid and *B. maculipennis*.

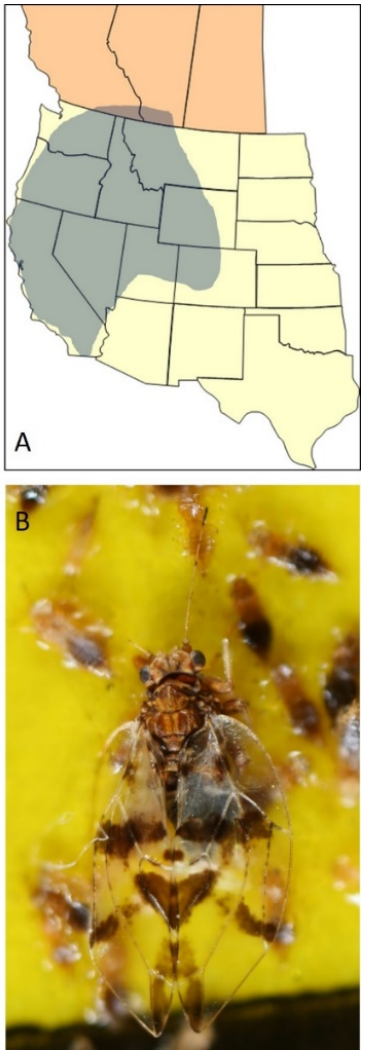

Figure 2. (A) Known distribution of *B. maculipennis* (shaded); (B) sticky card capture documenting presence of *B. maculipennis* in southern Alberta, Canada (D. Johnson and L. Kawchuk collectors).

Geography and traits of potato psyllid and *B. maculipennis*. The currently known distribution of *B. maculipennis* encompasses regions west of the Great Plains, with a latitudinal spread extending at least from southern California into southern Alberta, Canada (Fig. 2A). Thus, there is extensive geographic overlap between *B. maculipennis* and potato psyllid in important potato growing regions of North America. Virtually all recent plant records for *B. maculipennis* have been obtained from field bindweed, with a few additional observations in California and southern Oregon from close relatives of field bindweed known as false or hedge bindweeds (*Calystegia*). *Bactericera maculipennis* also shows up on yellow sticky cards used in region-wide monitoring programs for potato psyllid (Fig. 2B). In fact, the records from Canada for *B. maculipennis* were obtained on sticky cards that had been placed near potato fields east of Lethbridge, Alberta, Canada as part of a region-wide monitoring program for potato psyllid (Johnson et al. 2017; a web-link to the monitoring program provided at end of this report). It was not known that *B. maculipennis* reached as far north as southern Canada until it was detected on these cards while monitoring for potato psyllid.

Traits that separate the two species. The regular presence of *B. maculipennis* on field bindweed, where it may co-occur with potato psyllid, combined with the psyllid's presence on sticky cards in potato fields can complicate monitoring for potato psyllid in potato growing regions. The two psyllids are actually easily separated by a few fairly obvious morphological traits, which we summarize here. The primary diagnostic trait allowing separation of the adult psyllids is ***patterning of the wings.*** The forewing of *B. maculipennis* has a characteristic pattern of maculations (shadings and markings) that are absent from the forewing of the potato psyllid (Fig. 3: *B. maculipennis*: upper three photographs; potato psyllid: lower two photographs). These markings are visible even on psyllids captured by sticky cards (Fig. 2B). Another very useful diagnostic trait is the difference in egg morphology between the two species. This trait may be particularly useful when examining bindweed samples that fail to provide adult specimens of the psyllids. The ***stalk (pedicel) of the egg*** is noticeably longer for the *B. maculipennis* egg (Fig. 4AB) than the potato psyllid egg (Fig. 4CD). The eggs of *B. maculipennis* are often found extensively on the stems of the host plant where the long stalks may make the eggs visible even without magnification (Fig. 4EF). Finally, with practice, ***shape and color of the late-stage immature*** can be used to separate the two species (Fig. 5). As with the egg differences, these traits may be most useful for plant samples in which

the adult psyllids are not present. The late-stage nymph of *B. maculipennis* (Fig. 5AB) tends to be light brown or tan, in contrast to the often more greenish color of the potato psyllid nymph (Fig. 5C). The *B. maculipennis* immature also tends to be more oval than the late-stage immature of potato psyllid (Fig. 5DE). The oval shape of *B. maculipennis* is due to the evenly convex shape of the forewing pads of the insect, in contrast to the slightly concave shape of the forewing pad of the potato psyllid (Fig. 5DE: red arrows). These shape differences can be subtle and difficult to see except with practice. Traits of the late-stage immature generally require magnification to allow confidence in separating the two species.

Figure 3. *Bactericera maculipennis* (upper 3 photographs) showing highly visible wing-patterning not present on potato psyllid (*B. cockerelli*, lower 2 photographs). Photo credits provided at end of article.

Assaying morning glories and bindweeds for suitability to potato psyllid. Do Convolvulaceae other than field bindweed and sweet potato support development of potato psyllid? Our assays targeted 12 native species in four plant genera (*Convolvulus*, *Ipomoea*, *Calystegia*, and *Turbina*), and two introduced species of *Convolvulus*, including the invasive field bindweed. As with most Convolvulaceae, many of the species that we assayed are warm-climate plants and do not occur (other than as summer ornamentals) in the potato growing regions of the Pacific Northwest or southern Canada. However, they may often be abundantly present in the potato growing regions of the southwestern U.S., Mexico, and Central America. Plants to be assayed were grown either from seeds or from stem cuttings in four-inch pots. Potato (Ranger Russet) was used as a control treatment. Adult psyllids were allowed to lay eggs on test plants confined in ventilated plastic tubs until 20-40 eggs per plant had been deposited. Psyllids were then removed to allow hatching of eggs and development of immatures. For each plant we recorded whether the plant allowed successful development of psyllids to the adult stage. For plant species on which psyllids developed successfully, we also recorded number of days required to develop from egg deposition to production of the first adult. We had 10 replications per plant species.

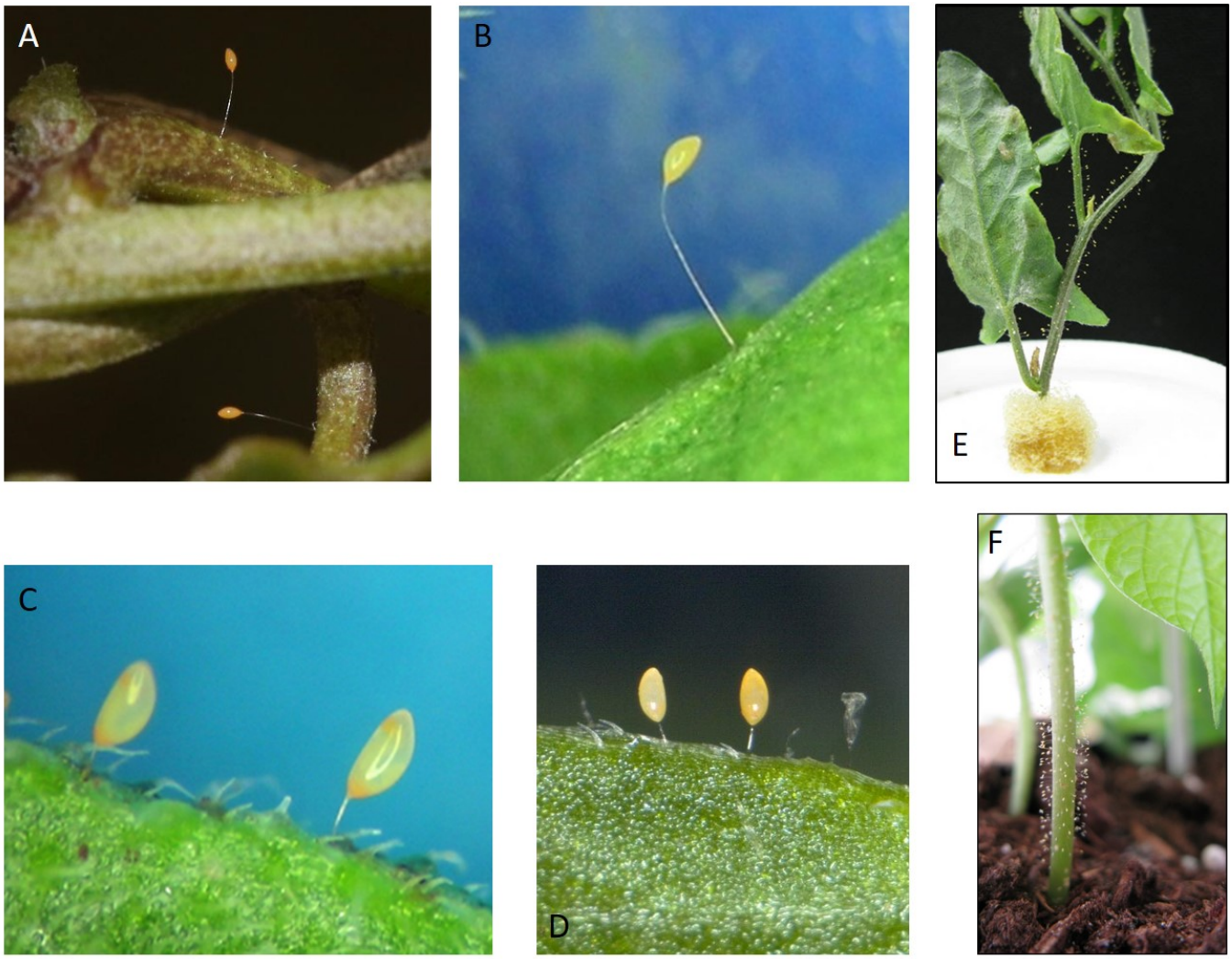

Figure 4. (A-B) Eggs of *B. maculipennis* showing long stalk; (C-D) eggs of potato psyllid showing much shorter stalk; (E-F) long-stalked eggs of *B. maculipennis* in often typical location on stems of host plant. Photo credits provided at end of article.

Results. Potato psyllid completed development on **potato**, **field bindweed** (*Convolvulus arvensis*), the popular ornamental **dwarf morning glory** (*Convolvulus tricolor*), ornamental **moonvine** (*Ipomoea alba*), **tievine morning glory** (*Ipomoea cordatotriloba*), **ivyleaf morning glory** (*Ipomoea hederacea*), **tripleleaf morning glory** (*Ipomoea ternifolia*), and the **Japanese** or **picotee ornamental morning glory** (*Ipomoea nil*). Photographs of several of these species are shown in Figure 1. We failed to obtain development on the other 7 species: **Texas morning glory** (*Convolvulus equitans*), **giant bindweed** (*Calystegia silvatica*), **beach morning glory** (*Ipomoea imperati*), **bush morning glory** (*Ipomoea leptophylla*), **man-of-the-earth morning glory** (*Ipomoea pandurata*), the popular ornamental **Heavenly blue morning glory** (*Ipomoea tricolor*), and **Christmas vine morning glory** (*Turbina corymbosa*). Immatures invariably died within a week of hatch on these species. For plants on which the potato psyllid successfully completed egg-to-adult development, time required to reach the adult stage varied between 27-30 days depending upon plant species (Fig. 6). Development was 5-8 days more rapid on potato than on Convolvulaceae hosts.

Figure 5. (A-B) Late-stage immature of *B. maculipennis* showing typical oval shape and tan coloration; (C) late-stage immature of potato psyllid showing more greenish appearance; (D-E) cleared specimens of immatures showing oval shape of forewing pads of *B. maculipennis* (E: red arrow) vs the slightly indented appearance of the forewing pad of the potato psyllid (D: red arrow); photograph taken from ventral side of specimens. Photo credits provided at end of article.

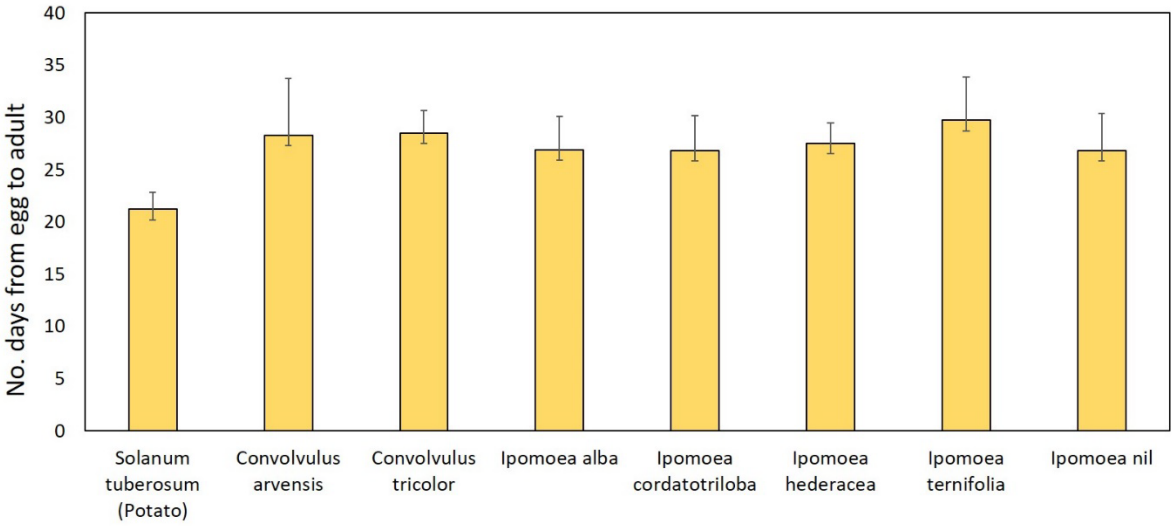

Figure 6. Mean (SE) egg-to-adult development times (days) for potato psyllid on Convolvulaceae that supported successful development in screening assays.

What might this mean for the potato industry? Our rearing assays substantially expand the list of Convolvulaceae known to support potato psyllid development beyond the two species (field bindweed and sweet potato) previously shown to support psyllid development. We identified species within both *Convolvulus* (bindweeds) and *Ipomoea* (morning glories) that support potato psyllid development. Given that these two genera together contain 600+ species, it is virtually a certainty that additional screening would identify many other hosts in these two genera. Is it possible that these species could act as "green bridges" in potato growing regions that would allow potato psyllid to reproduce and develop during seasonal intervals or in geographic regions in which solanaceous hosts are not available? There is evidence that field bindweed may provide this sort of bridging resource, particularly late in the season following potato harvest. Field surveys of weedy or ornamental Convolvulaceae would be necessary to determine whether potato psyllid makes extensive use of other species in this manner. One biogeographic factor that probably limits this concern for potato growers in the Pacific Northwest is the drastic drop in presence of Convolvulaceae in northern latitudes. While field bindweed is widespread in the Pacific Northwest, the morning glories (*Ipomoea*) with their preference for subtropical and tropical regions do not occur in the Pacific Northwest other than as summer ornamentals. Hedge bindweed species (*Calystegia*) occur in the Pacific Northwest, but our assays failed to show (for the single species assayed) that potato psyllid could complete development on plants in this genus. In more southern growing regions, the morning glories are much more abundant and are thus more available to potato psyllid than in the Pacific Northwest. Herbarium records and taxonomic syntheses indicate that at least 15 species of *Ipomoea* occur in Texas and northern Mexico, where they may overlap extensively with potato psyllid and important potato growing regions.

Successful development of potato psyllid on Convolvulaceae naturally prompts the question of whether the morning glories or bindweeds may also be reservoirs of the pathogen causing zebra chip disease in potatoes. Testing of Convolvulaceae for suitability to the zebra chip pathogen has been limited to field bindweed and sweet potato, and neither species appears to support survival and development of the pathogen. However, while there is yet no conclusive evidence that the pathogen survives in these plants, there is evidence from laboratory trials that some plants in the Convolvulaceae (including field bindweed) can act as avenues through which the pathogen is able to travel and move from infected to uninfected psyllids. Thus, simultaneous occurrence of infected psyllids and uninfected psyllids on field bindweed under field conditions could theoretically lead to spread of the pathogen between adult potato psyllids. The extent to which this type of psyllid-to-psyllid transmission occurs in the field – if at all – is not yet known.

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Figure 1. (A [*Ipomoea alba*], B [*Ipomoea nil*], C [*Ipomoea batatas*], H [*Convolvulus arvensis*) Photographs by D. Horton. (D) *Ipomoea hederacea*; photograph by IROZ (https://commons.wikimedia.org/w/index.php?title=File:Ipomoea_hederacea_003.jpg&oldid=148812494). (E) *Ipomoea cordatotriloba*; photograph by Kim (https://commons.wikimedia.org/w/index.php?title=File:Ipomoea.jpg&oldid=273016689). (F) *Convolvulus tricolor*; photograph by Magnus Manske (https://commons.wikimedia.org/w/index.php?title=File:Convolvulus_tricolor_(Convolvulaceae)_plant.JPG&oldid=130026877). (G) *Ipomoea ternifolia*; photograph by Anthony Mendoza (http://swbiodiversity.org/seinet/taxa/index.php?taxon=2241). (I) *Ipomoea nil*; photograph by Dinesh Valke (https://commons.wikimedia.org/w/index.php?title=File:Ipomoea_nil_(L.)_Roth_(6226167106).jpg&oldid=276749653). (J) *Ipomoea imperati*; photograph by Forest and Kim Starr (https://commons.wikimedia.org/w/index.php?title=File:Starr_010704-0024_Ipomoea_imperati.jpg&oldid=30843036). (K) *Ipomoea tricolor*; (https://commons.wikimedia.org/wiki/File:Ipomoea_violacea_flower_2.jpg; misnamed as *I. violacea* at link).

Figure 2. Photograph of *Bactericera maculipennis* on sticky card by Dan Johnson, University of Lethbridge.

Figure 3. Upper three panels, *Bactericera maculipennis*. From left to right: photograph by Chris Mallory, used with permission (https://bugguide.net/node/view/1423647); photograph by James Bailey, used with permission (https://bugguide.net/node/view/1402495); photograph by Andy Jensen, Northwest Potato Research Consortium. Lower two panels, *Bactericera cockerelli* (potato psyllid): photographs by Dan Johnson, University of Lethbridge.

Figure 4. (A) Eggs of *Bactericera maculipennis*; photograph by James Bailey, used with permission (https://bugguide.net/node/view/1391053). (B, C) Eggs of *Bactericera cockerelli* (potato psyllid); photographs by Andy Jensen, Northwest Potato Research Consortium. (D) Eggs of *Bactericera cockerelli* (potato psyllid); photograph by N A Martin, New Zealand Arthropod Factsheet Series Number 60 (https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Tomato-potato-psyllid---Bactericera-cockerelli.html). (E, F) Eggs of *Bactericera maculipennis* on field bindweed (E) and on *Ipomoea* sp. (F); photographs by David Horton, USDA-ARS.

Figure 5. Late-stage immatures of *Bactericera maculipennis* and *Bactericera cockerelli* (potato psyllid); photographs by David Horton, USDA-ARS.