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Non-potato host plants of potato psyllid in the Pacific Northwest: a year-round complication?

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The 2011 outbreak of potato psyllid and zebra chip disease in the Pacific Northwest led to disruption of established IPM programs, including often a shift by growers to calendar-based sprays of insecticides for controlling the psyllid. This shift has had several undesirable effects, including jumps in IPM costs, increases in quantities of insecticides applied annually, weakening of biological control, and potential for insecticide resistance. The shift away from previously established IPM practices is due to one primary factor: We cannot predict when and in what fields potato psyllid is likely to first arrive. A monitoring program initiated by WSU personnel in response to the 2011 outbreak shows this dilemma. Potato psyllid begins to slowly appear in potato fields of Washington State in late May and early June **(Figure 1)**. The initial arrival appears to be highly patchy, with psyllids first showing up in often widely

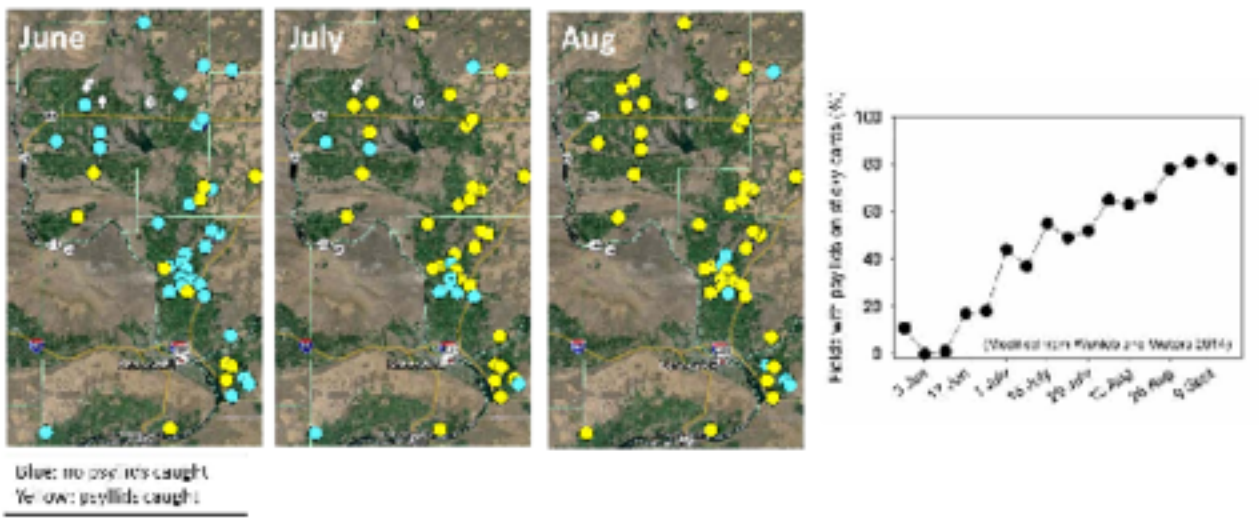

Figure 1. Results of trapping in central Washington potato fields. Each yellow or blue circle depicts a single field: blue – no psyllids captured on sticky cards; yellow – at least one psyllid captured at that location. Panel at right shows percentage of fields at which sticky cards captured at least one potato psyllid. Figures modified from Wohleb and Waters (2014).

separated fields. The patchy nature of these initial arrivals is poorly understood. Timing of arrival is extensively drawn out, in that psyllids are captured in but a small percentage of fields early, with that percentage climbing steadily between late June and August **(Figure 1)**.

Predicting psyllid arrival in potato fields of the Pacific Northwest will require a much better understanding of the roles that host plants other than potato have as reservoirs of potato psyllid. We use the term "host plant" to indicate plant species (like potato) that support egg laying, development, and production of new adults. Potato psyllid survives and develops on a number of plant species, primarily (but not exclusively) members of the Solanaceae, the family which includes potatoes, tomatoes, and their relatives. The concern for potato growers is that these non-potato hosts may be reservoirs of potato psyllid and thus sources of psyllids colonizing potato fields. Complicating efforts to define the roles of these plants in the life history of potato psyllid in the Pacific Northwest is the realization that these plants potentially contribute to psyllid development and survival throughout the year. This realization has led us to develop a simple model which we believe describes most of the potentially important psyllid – host plant associations in the Pacific Northwest **(Figure 2)**. We are currently using this model to help guide host-related research priorities. Here, we examine some of these seasonal associations.

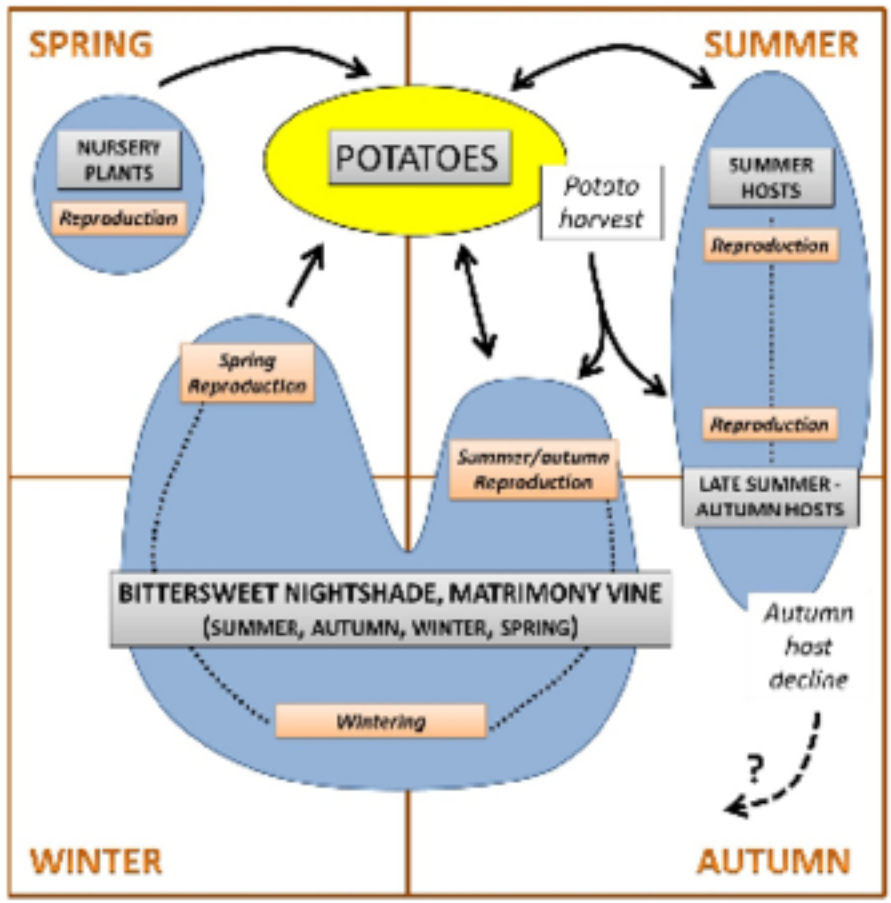

Figure 2. Hypothetical associations between non-potato host plants and potatoes. Arrows depict potential directions of psyllid movement at different times of the season (entirely hypothetical at this time). See **Table 1** for list of plant species potentially available for each seasonal interaction.

Non-potato host plants of potato psyllid

While we are not anywhere near full understanding of the interactions shown in **Figure 2**, observations in the literature and from our own research have allowed us to make some educated guesses of what plant taxa might be of interest at specific critical times of the year. **Table 1** lists plant taxa found in the Pacific Northwest that have been shown to support potato psyllid development under

field conditions, as indicated by the presence of eggs or nymphs in field samples. These observations are culled from the literature (especially from Pletsch 1947 and Wallis 1955) and from our own studies. The list includes species that are quite common in the Pacific Northwest (e.g., several of the weedy nightshades) as well as species that are present but not widespread in the Pacific Northwest (e.g., buffalo bur; *Solanum rostratum*).

Table 1. Potential reservoirs of potato psyllid categorized by season (following model categories in **Figure 2**). Only plant taxa known to occur in the Pacific Northwest shown here. An "X" indicates demonstrated presence of adult and immature psyllids (from literature observations or personal observations); a question mark indicates that the presence of psyllid eggs or nymphs has been inferred from text provided in literature sources.

	Nursery plants	Summer hosts	Autumn hosts	Winter hosts	Spring post-winter hosts
Weedy nightshades (*Solanum* species)					
Cutleaf nightshade (*S. triflorum*)		X			
Hairy nightshade (*S. physalifolium*)		X			
Black nightshade (*S. nigrum*)		X	X		
Bittersweet nightshade (*S. dulcamara*)		X	X	X	X
Horsenettle (*S. carolinense*)		X			
Silverleaf nightshade (*S. elaeagnifolium*)		X			
Buffalo bur (*S. rostratum*)		X			
Other Solanum species					
Eggplant (*S. melongena*)		X	X		
Tomato (*S. lycopersicum*)	X	X	X		
Other genera					
Peppers (*Capsicum* spp.)	X	X	X		
Jimsonweed (*Datura* spp.)		X			
Matrimony vine (*Lycium* spp.)		X	X	X	X
Wild/cultivated tobacco (*Nicotiana* spp.)		X			
Ground cherry/tomatillo (*Physalis* spp.)		X	X		X?
Black henbane (*Hyoscyamus niger*)		X			
Petunia (*Petunia* spp.)	X				
Convolvulaceae					
Field bindweed (*Convolvulus arvensis*)		X	X	X?	
Morning glory (*Ipomoea* spp.)		X			
Sweet potato (*Ipomoea batatas*)		X			
Ornamental sweet potato (*Ipomoea batatas*)	X?				

Some of the plant taxa listed in **Table 1** are distributed in spring as seedlings through nursery outlets **(Figure 2: Spring)**. Taxa include ornamentals (e.g., *Petunia*), as well as plants destined for backyard vegetable gardens (tomatoes, peppers). While the extent to which nursery-produced plants are actual sources of psyllids in potato fields remains to be determined, it is not apparent that we can afford to ignore them as sources of psyllids. For example, we have found psyllid-infested seedlings of peppers (*Capsicum*) at multiple nursery outlets in southern Idaho and eastern Oregon. We have also seen psyllid infestation of ornamental sweet potato (*Ipomoea batatas*) in planter boxes in downtown Walla Walla, presumably transplanted as seedlings into those planters. Reproduction of potato psyllid on these

nursery-sources – once the seedlings have been transplanted into gardens or ornamental pots – could theoretically lead to production of psyllids over a long period of time in spring and summer.

Potato psyllids in all life history stages have been found on a large number of weedy and cultivated host plants during the summer months **(Table 1)**. Some of these species are known to be excellent reproductive hosts for potato psyllid. It is possible that psyllids move in both directions between potato fields and these non-potato summer hosts throughout the growing season, as illustrated by presence of bidirectional arrows in **Figure 2 (Summer)**, although we stress that there is as yet no research demonstrating this two-way movement. Summer host plants include those having an annual life cycle, such as certain vegetable species and weedy nightshades, and plants having a perennial life history such as silverleaf nightshade (*Solanum elaeagnifolium*) and ground cherry (*Physalis* spp.). (Bittersweet nightshade and matrimony vine, also perennials, will be discussed in detail below). Some summer hosts are important weeds in agriculture, such as hairy nightshade (*Solanum physalifolium*) and cutleaf nightshade (*Solanum triflorum*). Field bindweed (*Convolvulus arvensis*), a member of Convolvulaceae, is a common and extremely widespread weed, and is known to support development and survival of potato psyllid in the laboratory and in the field.

Late-summer or autumn occurrence of psyllids on hosts could be due to season-long presence and reproduction on summer-colonized hosts, or because psyllids have been forced to move from potato onto other host species because of harvest **(Figure 2: Late summer/autumn)**. No data are available examining either hypothesis. Indeed, there is very little information in the literature about use of autumn hosts by potato psyllid at Washington State latitudes. Pletsch (1947) identified a few Solanaceae and Convolvulaceae in Montana that supported late-summer and autumn infestations of psyllids, including vegetables (tomatoes, peppers), ground cherry (*Physalis*; also known as tomatillo), black nightshade (*Solanum nigrum*), and field bindweed. Pletsch found both adult and immature psyllids on these plants, indicating that psyllids were reproducing well into autumn on the plants. It is unclear what happens to psyllids on annual autumn hosts once those plants go down in late autumn **(Figure 2: Autumn)**. It is possible that death of hosts in late autumn might prompt psyllids to move onto perennial species, although this remains to be determined.

Bittersweet nightshade and matrimony vine: season-long hosts of potato psyllids

Two perennial species of Solanaceae, matrimony vine (*Lycium* sp.) and bittersweet nightshade (*Solanum dulcamara*), appear to be part of the psyllid's life history in the Pacific Northwest at multiple time points during the season **(Figure 2)**. Both species grow in large mats, often near fence lines or waterways **(Figures 3 and 4)**. We collect potato psyllid from both species throughout summer and into autumn, thus both hosts are potential sources of psyllids moving into potato during the summer growing season. Potato psyllid overwinters on dormant woody stems of the two hosts, often near the soil surface below dead plant litter. Wintering populations on either host species could hypothetically include a

Figure 3. Fence row stand of matrimony vine growing near Selah WA.

mixture of psyllids which had used these plants as summer and autumn reproductive hosts, or which had colonized the plants in late summer following harvest of potato. Colonists presumably would continue with reproductive activities that had been initiated on potato. Additionally, it is at least possible that these perennial species are colonized in late autumn by psyllids that must find a new host plant as annual weedy or vegetable hosts begin to disappear with the onset of cold temperatures. We have yet to determine the relative importance of these various host-use decisions in producing winter populations of psyllids on bittersweet nightshade and matrimony vine.

Following overwintering, psyllids begin egglaying on bittersweet nightshade in late March as newly flushed tissues first appear **(Figure 4)**. We have no data yet for onset of egglaying on matrimony vine. Egglaying on bittersweet nightshade begins substantially earlier than appearance of the potato crop, and we believe the psyllid is able to produce at least a partial generation on bittersweet nightshade preceding emergence of potato. Thus, bittersweet nightshade is potentially an important late-spring source of psyllids colonizing potatoes in the Pacific Northwest. We are in the process of examining life history of the psyllid on matrimony vine at multiple sites in Washington State, and we anticipate learning that this plant species – like bittersweet nightshade – is a reservoir of psyllids in early spring.

Figure 4. Large stand of bittersweet nightshade (Eagle ID) in late spring and in late winter. Top right panel shows psyllid eggs deposited on newly flushed foliage (late March; Wapato WA).

Discussion

It needs to be emphasized that the routes to infestation of potato by potato psyllid that are shown in **Figure 2** are entirely hypothetical at this time. For example, we may find that some hosts listed in **Table 1** are sufficiently attractive to potato psyllid that the insect is actually quite content to remain on those hosts rather than dispersing into potato fields. Until host-to-host movements of the psyllid have actually been studied under field conditions, we cannot predict which of the interactions shown in **Figure 2**, and which of the host records in **Table 1**, deserve the most attention from growers. At the ARS laboratory in Wapato, we are combining field observations and monitoring with molecular work to begin exploring movement by psyllids among host plants, with ultimate aims to clarify the relative importance of the different interactions hypothesized in **Figure 2**. Second, the model in **Figure 2**

ignores the idea that colonization of potatoes in the Pacific Northwest might include migrants from southern growing regions. Those colonists, if this indeed is a route of infestation, could hypothetically include psyllids that arrive directly in potato fields from southern regions, or migrants that first colonize host plants listed in **Table 1** before moving into fields. Finally, we have almost no information about the role of these non-potato hosts as sources of the zebra chip pathogen. There is some suggestion in the literature that weedy hosts of the psyllid may support the pathogen (Murphy et al. 2014, Thinakaran et al. 2015), but considerably more research is needed to determine whether these plant taxa are actual sources of infective psyllids moving into potatoes.

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