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**Integrated Pest Management Guidelines for
Insects and Mites in
Idaho, Oregon and Washington Potatoes**

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PURPOSE

Potato growers in Idaho, Oregon and Washington are facing new insect pests that pose significant management challenges. These pests, combined with historical potato insect pests, leave pest management decision makers with a complicated set of choices. The following document is our best set of guidelines as to how potato insect pests in Idaho, Oregon and Washington can be cost effectively managed.

The practices outlined in this report may not be appropriate for all locations. We advise that you modify this program according to the specific needs of your location. Consult with your local extension or pest management specialist for more information.

A Generic Statement on Generic Insecticides

A number of insecticide groups, such as pyrethroids and neonicotinoids, are increasingly available as generic equivalents. A generic insecticide is usually functionally identical to its brand name equivalent, but not always. The proliferation of generic products available for use on potatoes has made it difficult to keep track of all product names for each active ingredient. For example, there are currently 48 products containing imidacloprid registered on potatoes by 18 different companies in the Pacific Northwest (PNW). Forty of these products are generic products. Sometimes generic products are registered in our area but are not available. We are unable to include the names for all generic products for the active ingredients that are included here. We use the brand name or best known name for a product in our industry. It is up to growers, crop protection advisors and extension specialists to identify the product that best meets identified needs.

Plant Back Restrictions

Most pesticides contain label language discussing restrictions on what crops can be planted following their application. It can be easy to overlook these restrictions particularly when this language is situated far away on the label from the potato section. Potato growers have been placed in difficult situations by applying an insecticide or miticide and then realizing that they cannot plant alfalfa the same year or sweet corn the following year. The statement “read and follow the label” is probably said too many times, but there is no substitute for reading and following the label. Most labels change from year to year so reading the label last year may not suffice for this year. Crop advisors, manufacturer representatives, and extension specialists can be valuable sources of information for label changes.

Pesticide Disclaimer

Some of the pesticides discussed in this publication were tested under an experimental use permit granted by WSDA, ODA and ISDA. Application of a pesticide to a crop or site that is not on the label is a violation of pesticide law and may subject the applicator to civil penalties up to \$7,500. In addition, such an application may also result in illegal residues that could subject the crop to seizure or embargo action by WSDA, ODA, ISDA and/or the U.S. Food and Drug Administration. It is your responsibility to check the label before using the product to ensure lawful use and obtain all necessary permits in advance.

Resistance to Insecticides

Resistance arises through the over-use or misuse of an insecticide or miticide against a pest species and results in the selection of resistant forms and their progeny that are also resistant to that insecticide or miticide. The Insecticide Resistance Action Committee (IRAC) defines resistance to insecticides as “a heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label for that pest species.” For more information about IRAC visit <http://www.irc-online.org/>.

Insect pests of potatoes have a long history of developing resistance to insecticides. Colorado potato beetle (CPB), green peach aphid (GPA), potato tuberworm (PTW), potato psyllid and two spotted spider mite (TSSM) are notorious for development of resistance to products used for their control. The two most significant insect pests of potatoes in the world, CPB and GPA, have developed resistance to many insecticides used for their control. Potato psyllid has developed resistance to neonicotinoid, pyrethroid, organophosphate and carbamate insecticides in Texas and California. While the PNW (along with Colorado) has escaped this problem thus far,

the development of insecticide resistance in these pests is still an issue for which the potato industry needs to be prepared. One exception is CPB which has developed resistance to pyrethroid insecticides in certain regions of Idaho.

Reasons that the PNW potato industry has avoided much of the resistance problems other regions have experienced include: 1) PNW growers rotate potato fields, 2) PNW growers practice resistance management tactics, 3) there are a number of alternative hosts that serve as refuges for susceptible populations, and 4) the PNW is geographically isolated from resistant insect strains.

Once an insect or mite develops resistance to an insecticide, it is possible for the resistant species to develop cross-resistance to all insecticides that share the same mode of action. Consequently, the entire class to which the product belongs is largely lost. Therefore, one of the most important things that potato growers can do to avoid resistance is to **rotate modes of action of insecticides**. Each class of insecticides has its unique mode of action. By alternating sequences or rotations of products from different modes of action, pest populations are exposed to differing causes of mortality, which decreases the likelihood that a population will develop resistance to any of those products. When rotating products with different modes of action, it is preferable to apply products with the same mode of action back to back rather than rotating to a different mode of action after every application. For example, apply a 1b followed by a 1b followed by a 4c followed by a 4c product as opposed to apply 1b, then 4c, then 1b and then 4c.

In order to aid growers in figuring out how to help avoid resistance, all insecticides and miticides have been classified into groups (from 1 to 28) according to their mode of action (MoA) and subgroups according to their unique active ingredients. We have included the group number and subgroup number for each insecticide. For example, neonicotinoid insecticides are in subgroup 4A; pyrethroid insecticides belong to group 3.

Potatoes have registered alternatives that are in the same group but in different subgroups. In the absence of other alternatives, it may be possible to rotate compounds between sub-groups if it is clear that cross resistance mechanisms do not exist in the target populations. By definition, subgroups are established to represent distinct chemical classes with a common MoA. Since the only resistance that is known to occur in PNW insects is Colorado potato beetle to pyrethroid insecticides in limited areas of Idaho, products from different subgroups from the same group may be rotated. For example, neonicotinoid insecticides belong to Group 4a and may only be rotated with the newly registered Group 4c product, Transform (sulfoxaflor) only if a product from a different Group was applied between the Group 4 products. Fulfill (pymetrozine) is a 9b product and can be rotated with Beleaf which is a 9c product. If cross resistance mechanisms develop in potato pests targeted by Group 4 or Group 9 products, then these products could no longer be used in rotation.

Neonicotinoid Resistance Management. Resistance management is the best means to preserve the effectiveness of potato insecticides. PNW potato growers have access to a variety of planting time neonicotinoid products, including Admire Pro, Platinum, CruiserMaxx, Venom and Belay and a wide array of foliar products, including Assail, Admire Pro, Leverage, Actara, Venom and Belay, that belong to the same class of chemistry, neonicotinoids. Due to certain characteristics of this pesticide class and the propensity of CPB and GPA to develop resistance, there exists the potential for development of resistance to the entire class if the products are not used carefully. CPB populations in locations in the Midwest and East Coast have already developed resistance to neonicotinoid insecticides in potatoes, potentially jeopardizing the use of this class of insecticides. It is critical that this situation be avoided in the PNW.

A simple method exists that can help avoid the development of resistance to these valuable products. If Group 4 insecticides such as Admire Pro, Belay, Venom or Platinum are applied in-furrow or as a side dress or if Admire Pro, Belay and CruiserMaxx are applied as a seed treatment, do not use any foliar insecticide containing an active ingredient in the same Group 4 such as Assail, Admire Pro, Brigadier, Endigo or Actara in the same

field in the same season. This restriction includes Leverage and other products included in the package mix paragraph below. This will help prevent subsequent generations of the pests from being exposed to this chemistry.

A number of products are registered that contain two active ingredients. Five products, Leverage, Endigo, Voliam Flexi, Brigadier and Athena, are package mixes which contain a Group 4 insecticide. Other package mixes exist that do not contain Group 4 insecticides, such as Hero. If a Group 4 insecticide has been used at planting, do not apply a product containing two active ingredients if one contains a Group 4 insecticide.

A second resistance management tactic that can be used is to avoid treating all potato fields on one farm or in one localized area with products containing a Group 4 insecticide. For example, a grower could forgo treatment on one circle out of five, or if a field of early potatoes was not treated with a product from the class, then other fields could all be treated with products of the same class at planting. A grower should not plant more than 80% of his potato acres with a neonicotinoid at planting/cracking. This tactic should only be used in conjunction with the former tactic and never as a substitute.

Management of Wireworm

Wireworms (Figure 1) are the larval stage of click beetles. They tend to be most damaging in potatoes that follow corn or small grains and on ground just entering cultivation. Those causing the most damage in irrigated lands are the Pacific coast wireworm and the sugar beet wireworm, although less important species such as the Columbia Basin wireworm and the western field wireworm may also be present. An invasive European wireworm has been detected in northwestern Washington, and could become a problem. Wireworms can cause damage to potatoes in two ways: 1) feeding upon potato seed pieces and their emerging sprouts in spring, thus allowing infection by pathogens or 2) damaging developing tubers by directly feeding on them during the growing season (Figure 2). The latter damage can result in downgrading or rejection of the crop.



Figure 1. Wireworms from tuber infested at harvest.

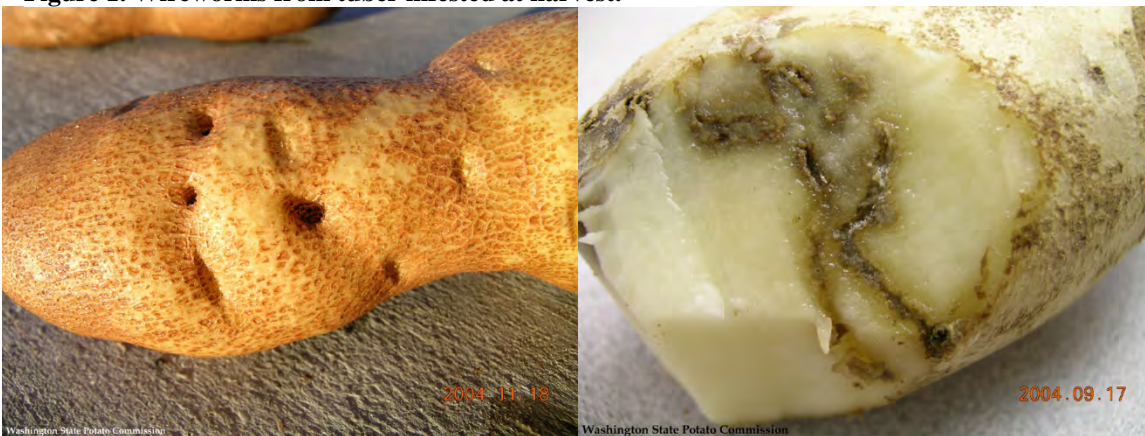


Figure 2. . Two types of damage caused by wireworms.

In Figure 2, the type on the left is more common. It occurs relatively early in the growing season, and the wounds are healed at harvest. The type on the right is less common, but more serious because wireworms are present in the tubers at harvest. In Idaho, most wireworm damage occurs late in the season. In Oregon, damage occurs early in the season. In Washington damage occurs earlier and later in the season.

Wireworm larvae require 2 to 6 years to mature, overwintering at a depth of 12 to 24 or more inches in the soil, returning near the surface in spring to resume feeding. Soil temperatures are important in wireworm development and control. Larvae start to move upward in the spring when soil temperatures at the 12-inch depth exceed 50°F. Later in the season when temperatures reach 80°F and above, the larvae tend to move

deeper than 6 inches. Movement downward in preparation for overwintering begins in early autumn or as soil temperatures at 1 foot drop below 60°F.

Wireworm presence or absence in a field should be determined before using control measures. The sequence of crops should be considered. For example, planting a susceptible crop such as potatoes immediately after red clover, pasture grasses or a grain crop is risky. Other than crop rotation with non-host crops, there are no cultural and no biological control methods available for wireworm.

One recommendation to determine if a field has a wireworm infestation is to use bait stations:

1. Dig a hole about 3-4 inches deep and 9-10 inches wide at the soil surface.
2. Bury 1/2 cup of a mixture of equal parts untreated corn and wheat at the bottom of the hole. The germinating seeds attract wireworms. Soaking the seeds in water overnight the day before will speed up germination and should attract more wireworms.
3. Fill the hole and mound a "soil dome" over the covered bait.
4. Cover each mound with a black plastic, topped with a 1-yard-square sheet of clear plastic, and cover the edges with soil to hold the plastic sheets down. The black plastic will speed germination and wireworm movement toward the bait.
5. A few days before planting, remove the plastic and soil covering the bait and count the number of wireworm larvae found at each station.
6. Place about a dozen bait stations per 40 acres. Your placement of the bait stations should represent different areas of a field.

If you find an average of one or more wireworms per bait station, consider the use of a registered insecticide or fumigation.

If wireworms are present in a field, chemical control is the only management option.

Telone II (dichloropropene), Group 11 is effective on wireworms that are present at the time of fumigation and within the zone of fumigation. Therefore, as a guideline, it is important that Telone is applied when soil temperature is 50 degrees or higher or if baiting/sampling indicates the presence of wireworms. For best results, fall applications should be made prior to the movement of wireworms down the soil profile and out of the fumigation zone.

Mocap (ethoprop, Group 1B) may be applied as a broadcast incorporation or over the row at planting. If the product is broadcast, it is critical that it is incorporated to a depth of at least 6 inches. Applications of 1 gallon of the 6 EC liquid formulation or 40 pounds of the 15% granular formulation are recommended. Ideally the incorporation should be in the 6 to 12 inch depth. An in-furrow application should be made as a band that is as wide as possible, ideally 12 inches. Applications of 2 quarts of the 6EC liquid formulation or 20 pounds of the 15% granular formulation are recommended for the band treatment. Narrow, in furrow bands are not recommended.

Regent 4 SC (fipronil, Group 2B) is applied in-furrow at 3.2 ounces per acre. The rate changes for row spacing over 36 inches. The product should be applied one time, in furrow in a 5 to 7 inch band. No T-banding over the top of a closed furrow is permitted.

For some excellent information regarding wireworm biology and control refer to:

<http://ir.library.oregonstate.edu/xmlui/handle/1957/20798>

<http://cdn.intechopen.com/pdfs-wm/28267.pdf>

Planting Time Insecticide Treatments

Based on trials conducted in Idaho, Oregon and Washington, imidacloprid-based products (Admire Pro), thiamethoxam-based products (Platinum and Cruiser) and clothianidin-based products (Belay) provide significantly better CPB and aphid control than alternatives. Imidacloprid, thiamethoxam and clothianidin (all neonicotinoid insecticides) applied at planting will provide 80 to 100 days of residual control. Other soil applied systemic insecticides such as phorate (Thimet, Phorate) do not provide reliable Colorado potato beetle and GPA control beyond 50 days. Use of Thimet increases the likelihood that foliar application of insecticides will be necessary. Venom is another neonicotinoid insecticide labeled for use at planting time on potatoes. However, it is not recommended for use at planting time potatoes in the PNW due to its short period of residual activity.

Insecticide Seed Treatments

Admire Pro (imidacloprid, Group 4A). Admire Pro is a liquid seed piece treatment offering control of all aphid species, Colorado potato beetle, flea beetle, potato leafhopper, and psyllids with the flexibility of ultra-low volume liquid seed-piece application. Admire Pro may reduce wireworm damage in seed-pieces. The application rate is 0.17 – 0.35 fl. oz./cwt. of seed-pieces (**Note:** Based on a 2000 lb/acre seeding rate, this rate range is equivalent to 3.5 -7.0 fl. oz./acre). Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Brigadier, Venom, Endigo, Brigadier, Actara, Assail) following this application.

CruiserMaxx Potato (thiamethoxam, Group 4A). Cruiser is a seed-applied neonicotinoid product recently registered for use on potatoes. Use CruiserMaxx Potato seed treatment to provide protection against injury from aphids, Colorado potato beetles, flea beetles, and psyllids. Cruiser 5FS will also control wireworms that feed on the seed piece. The rate range is 0.19 to 0.27 oz per 100 lbs of seed pieces, depending on the seeding rate (consult label). Length of control will vary depending on the rate used, soil and environmental conditions, and insect pressure. Use approved application equipment (Spudgun or Milestone barrel treater). It is important to note that the application rate will vary by the number of sacks planted per acre with a maximum use rate of 0.125 lb ai/A. This Cruiser Maxx Potato formulation is a combination of Cruiser 5FS and Maxim 4FS fungicide. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Endigo, Brigadier, Actara, Assail) following this application.

Cruiser Maxx Potato Extreme (thiamethoxam, Group 4A) is the same product as CruiserMaxx but includes difenconazole for increased control of Fusarium. It is used identically to CruiserMaxx except it is applied at a higher rate of 0.31 oz/100 pounds of seed. This product was developed for the Northeastern potato market where Fusarium has developed resistance to existing fungicides. It will be commercially available in the Pacific Northwest but offers identical insect control as to CruiserMaxx. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Endigo, Brigadier, Actara, Assail) following this application.

Insecticide In-Furrow Treatments

Platinum 75SG (thiamethoxam, Group 4A). Platinum is a soil-applied insecticide providing long residual control in potatoes. Apply Platinum at 1.66 to 2.67 oz/A in-furrow at planting in a 6-8 inch band with sufficient water for good coverage for the control of aphids, Colorado potato beetle, potato leafhoppers, flea beetles, and potato psyllid. Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Do not apply foliar neonicotinoids (Admire Pro, Leverage, Endigo, Brigadier or Actara) following this application. Alternatively, Platinum may be applied POST plant, pre-emergence as a broadcast application at 1.66 to 2.67 oz/A and watered in with 0.10 -0.25 inches of water. All precautions listed above must be followed.

Admire Pro (imidacloprid, Group 4A). Admire Pro is a soil-applied insecticide providing long residual control of insect pests of potatoes. Admire Pro will control Colorado potato beetles, aphids, wireworms (seed piece only), and psyllids. Dosage rates are 5.7 to 8.7 fl oz/A applied as an in-furrow spray at seeding or as a side dress to both sides of the hill after planting (treated areas of both hillsides should be covered with approximately 3 inches of soil). Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Do not apply foliar neonicotinoids (Admire Pro, Leverage, Brigadier, Endigo or Actara) following this application.

Belay 16 WSG (clothianidin, Group 4A). Apply Belay at 12 to 18 ounces in-furrow or at soil cracking. Use 10 gallon of water per acre. Belay has an REI of 12 hours. Water immediately after application when applied at soil cracking. Belay has no crop rotation restrictions. Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Do not apply foliar neonicotinoids (Admire Pro, Leverage, Brigadier, Endigo or Actara) following this application.

Colorado Potato Beetle

Colorado potato beetle (CPB) feeds exclusively on solanaceous crops and weeds, and can be a significant pest of potatoes. Adult beetles have characteristic yellow and black stripes across the back; females deposit eggs in clusters on the leaves. The eggs are orange and each mass will contain between 20-45 eggs. CPB larvae early instars have black legs and two rows of black spots on the sides of their body. Pupae are located in the soil. Larvae and adults are ferocious feeders. The behavior of adults varies greatly based on photoperiod (day length), crop fed upon, and temperature.

Cultural Control

Crop rotations: Crop rotations help in delaying or reducing CPB pressure. Adult beetles spend the winter buried 4 to 10 inches in the soil and emerge in the spring just as the first volunteer potatoes appear. Recently emerged beetles either mate close to the overwintering sites or fly to new potato fields to find a mate. Colonizing females need to feed before starting to lay eggs. Therefore, rotating crops and planting the new potato fields as far as possible from fields that were planted to potato the previous year will reduce the number of immigrant beetles moving into the new field. Although cereal crops favor wireworm populations as mentioned before, planting cereal grains after potatoes aids in reducing CPB migrations from overwintering sites to new fields.

Control of volunteers and weeds: Because overwintering adults need to feed before walking or flying into new fields, controlling volunteer potatoes and weeds such as nightshades is important, as they are an early food source for these emerging adults. This tactic does not provide complete control, but may reduce or delay population growth.



Figure 3. Colorado potato beetle adults.

Chemical Control

The use of systemic insecticides in early potatoes, presented in the previous section for aphid control, will also contribute to the control of early-season CPB populations. Do not use disruptive foliar products, such as pyrethroid insecticides, for control of CPB after June 15. Pyrethroid insecticides (Group 3 products) kill beneficial organisms and may flare aphids and mites. Foliar applied products available for CPB control include Assail, Success, Blackhawk Radiant, abamectin, Imidan, Admire Pro, Leverage, Endigo, Rimon, Coragen and Actara.



Figure 4. CPB small larvae. boron should be avoided. In addition, prior to adding Success to a tank it is recommended to conduct a compatibility test.

Success SC (spinosad, Group 5). For light larval populations, apply 3 to 4 fluid oz/acre of Success per acre by air, ground or chemigation. Time applications to target egg hatch or young larvae. For heavy larval populations, apply 5 to 6 fluid oz/acre. Applications by chemigation at either rate should be made with 0.25 acre inches of water or less. If the plant is actively growing, applying 3 or 4 fluid oz/acre in sequence may be more effective than applying 6 fluid oz singularly. Acidic (< 6 pH) spray solutions may shorten the residual activity of Success and should be avoided. The pH of spray solution should be checked prior to adding Success into the tank and adjusted, if necessary. Acidifying products such as

The Success label states that this product should not be applied against two successive generations of Colorado potato beetle. Two applications against the same generation is considered acceptable.

Blackhawk (spinosad, Group 5). Apply 1.7 to 3.3 oz of Blackhawk per acre to potatoes for control of Colorado potato beetle. Begin at first signs of infestations. Follow resistance management recommendations on the product label.



Figure 5. CPB larvae and foliar damage.

Radiant SC (spinetoram, Group 5). Apply 6 to 8 fluid oz of Radiant per acre by air, ground or chemigation. Time applications to target egg hatch or young larvae. For heavy larval populations, repeat applications may be necessary but follow resistance management guidelines. Applications by chemigation at either rate should be made with 0.25 acre inches of water or less. Acidic (< 6 pH) spray solutions should be avoided. The pH of spray solution should be checked prior to adding Radiant into the tank and adjusted, if necessary. Acidifying products such as boron should be avoided. In addition, prior to adding Radiant to a tank it is recommended to conduct a compatibility test.

Abamectin 0.15EC (abamectin Group 6). Apply 1.75 to 3.5 fl oz with 5 gallons of water per acre by air or 20 gallons by ground. Avoid the use of abamectin with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield). The addition of a nonionic surfactant or organosilicone-based surfactant, at the manufacturer's recommended rate is suggested for optimum control.

Imidan 70W (phosmet, Group 1B). Apply 1.33 pounds of product per acre by air or ground. Imidan is very sensitive to chemical hydrolysis in the presence of alkaline or neutral pH. Half-life for technical phosmet is only 33 minutes at pH 8.3, and 10 hours at pH 7, but increases steeply to approximately 4 to 13 days, respectively, between pH of 5.5 to 4.5. For optimum stability and residual, adjust tank mixture pH to between 3.5 and 5.0 using a suitable buffer that will maintain proper pH entirely through the course of application. Test kits for checking water pH are available from Gowan Company. For optimum control, apply early when CPB population is primarily in larval stage. If a second application is needed, apply no sooner than a 10-day schedule. Use adequate volume for good coverage; 5 gallons per acre by air; 20-40 gallons per acre by ground.

Actara (thiamethoxam, Group 4A). Apply 1.5 oz/acre by either ground or by air. A total of 6.0 oz may be applied per season. Apply Actara in a minimum of 10 gallons of water when application by ground and a minimum of 5 gallons when applying by air. When applying Actara by ground or air use an oil blend adjuvant. For chemigation, use from 0.10-0.25 inches of water. Avoid the use of Actara with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield. Examples of appropriate adjuvants include crop oil concentrates (COC) (e.g. Herbimax), methylated seed oils (MSO) (e.g. Dynamic), ethylated seed oils (ESO) (e.g. Hasten) and organosilicone (OS) blends (e.g. Aerodynamic). Do not apply this product if the field has been treated this year with Admire Pro, Belay, Cruiser or Platinum.

Pyrethroid Warning. Do not use disruptive foliar products, such as pyrethroid insecticides, for insect control between June 15 and two weeks before harvest. Pyrethroid insecticides (Group 3 products) kill beneficial organisms and may flare aphids and mites.

Leverage 360 (imidacloprid and cyfluthrin, Group 4A and 3). Leverage may be applied by aerial, ground or chemigation equipment at 3.0-3.75 fl oz/A. Use the 3.0 fl oz rate for ground applications only. Aerial applications should be made in a minimum of 5 gallons per acre with 10 gallons per acre recommended. The addition of a silicone or MSO type surfactant may aid in control. Do not apply Leverage if the field has been treated this year with Admire Pro, Belay, Cruiser or Platinum.

Brigadier (imidacloprid and bifenthrin, Group 4A and 3). Brigadier may be applied by ground, air or chemigation at 3.9 to 6.14 fl oz/A. There is a 21-day PHI, applications should not be made closer than 7 days apart and there is a season maximum limit of 25.6 fl oz/A. Do not apply Brigadier if the field has been treated this year with Admire Pro, Belay, Cruiser or Platinum.

Hero (zeta-cypermethrin, bifenthrin, Group 3). Apply at 4 to 10.3 oz per acre. Applications must be at least 21 days apart, do not apply more than 46.35 ounces of product per acre per season. There is a seasonal limit of two foliar applications per year. Apply by ground or air only, no chemigation application.

Voliam Xpress (lambda-cyhalothrin, chlorantraniliprole, Group 3, Group 28). Apply at 6.0 to 9.0 fluid oz per acre for control of CPB by ground air or chemigation. When applying by chemigation, apply in 0.1 to 0.2 acre inches of water per acre. Do not exceed a total of 27 ounces of product per season per acre. Minimum time between application intervals is 7 days. There is a preharvest interval of 14 days. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum.)

Endigo (thiamethoxam, lambda-cyhalothrin, Group 4a, Group 3). Apply at 3.5 to 4.5 fluid oz per acre by ground, air or by chemigation. Do not apply more than 10 ounces per season per acre. There is a minimum

interval between applications of 7 days. Do not harvest the field for 14 days after application. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum).

Rimon 0.83 EC (novaluron, Group 15). Rimon may be applied by air, chemigation or ground equipment at 9 to 12 fl oz/A. Applications should be made when the majority of CPB larvae are between egg hatch and second instar. Rimon is an insect growth regulator type insecticide which must be ingested by larvae or applied either over or under eggs to act as an ovicide, therefore, reapplication at 7 to 14 days is needed to protect new plant tissue during periods of active foliar growth. The product must be ingested to affect larval CPB. It will not control adult beetles. Do not make more than two applications per season. Do not apply to two successive generations in the same growing season. Use a minimum of 5 gallons per acre when applying by air; apply a minimum of 10 gallons per acre when applying by ground. Rimon has a 12 hour restricted entry interval and a 14 day pre harvest interval. Do not apply more than 24 oz per acre per season.

Assail 70WP (acetamidiprid, Group 4A). Apply 0.6 to 1.7 oz/acre by ground, air or chemigation for Colorado potato beetle control. Use the higher rate under conditions of heavy pest pressure, dense foliage and/or application by chemigation. Apply before larvae cause defoliation damage that would result in economic loss. A total of 6.8 oz may be applied per season. Do not make more than 4 applications per season and do not apply more than once every 7 days. Do not apply less than 7 days prior to harvest (7 day PHI). Complete plant coverage, including the lower portion of the plant if pests are present in that area, is necessary for best results. Apply Assail in a minimum of 20 gallons of water by ground, 5 gallons by air and a maximum of 0.2 inch/acre by chemigation. When applying Assail by ground or air, use a crop oil adjuvant such as crop oil concentrates (COC), methylated seed oils (MSO), ethylated seed oil (ESO), or use an organo-silicone crop oil blend adjuvant. Do not irrigate within 12 hours of an Assail application. There are no rotational crop plant back restrictions for Assail. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum).

Coragen (rynaxypyr, Group 28). Apply 3.5 to 5.0 oz of product per acre. Do not apply more than four applications and 15.4 fluid oz per season. Do not apply more than twice to a generation of Colorado potato beetle or within a 30 day period. If applied to one generation of beetle, do not apply Coragen to the subsequent generations. Coragen may be applied by air, ground or chemigation. If applying by chemigation, refer to specific instructions on the label in a section outside of the potato section. The preharvest interval is 14 days. The restricted entry interval is 4 hours.

Voliam Flexi (thiamethoxam, chlorantraniliprole, Group 4a, Group 28). Apply at 4 fluid oz per acre by ground, air or chemigation. Do not apply more than 8 ounces total per season per acre. There is a minimum interval between applications of 7 days. Do not harvest the field for 14 days after application. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum.)

Torac (tolfenpyrad, Group 21a). Apply at 14 to 21 fluid oz per acre by ground, air or chemigation. When applying by ground use at least 20 gallons of water per acre, when applying by air use at least 5 gallons of water and when applying by chemigation refer to the specific label language. Do not apply more than 2 applications per cropping season. Torac has a 14 day pre harvest interval and a 14 day retreatment interval. A total of 42 fluid oz can be applied during a single cropping season.

Aphids

Aphids may transmit virus disease and, when abundant, reduce yield. If wingless aphids are found on potato, they almost certainly will be either green peach aphid or potato aphid, both of which can transmit potato leaf roll virus (PLRV). Potato aphid is generally more common in the spring and fall, while green peach aphid peaks during July and early August.

Aphids on potato are a serious pest mainly because of their ability to transmit several plant viruses. The most important virus disease during the twentieth century, PLRV, causes a tuber symptom in some varieties called net necrosis. This internal discoloration is not acceptable in the marketplace, and its prevention accounts for most aphid control efforts. PLRV is transmitted in a persistent manner, which means that once an aphid is infected by the virus, it can transmit to uninfected plants for the rest of its life. Relatively few aphid species can transmit this virus to potatoes, and green peach aphid is by far the most important vector. The low tolerance in the marketplace for net necrosis, and the high vectoring capacity of green peach aphid, means there is a very low treatment threshold for this pest in most potato fields destined for storage and processing. PLRV has become very uncommon in the 21st century, probably due to effective prevention in the seed potato industry.

Potato virus Y (PVY) is increasingly serious in potato production in the PNW, surpassing PLRV in importance. New strains of PVY that can cause internal brown lesions in tubers of some cultivars are becoming common. This sort of damage is unacceptable in the marketplace. PVY is transmitted by many different aphid species in a non-persistent manner. This means that almost any aphid that happens to alight, even for a moment, on a potato plant could be transmitting the virus. PVY is transmitted very quickly – in a far shorter time than most insecticides can act to prevent aphid feeding. This, and the fact that most PVY transmission is by aphids that are not living in the potato field, means that PVY control with insecticides is poor at best.

Desiccation of Early Season Potatoes for Control of Aphids

Desiccation of early season potatoes can influence the formation and emigration of winged aphids. Use of acid desiccation is the recommended practice to reduce the likelihood of infesting other potato fields with aphid survivors from early season potatoes. Chemical desiccants, such as Reglone or Rely, can also be used to decrease the likelihood of aphids moving to other fields. Desiccation by removal of irrigation results in slow

dehydration of potatoes, which triggers wing formation in aphids and stimulus for flights. Desiccation of potatoes by ending irrigation should only be used as a last resort. If water management is used to desiccate the crop, it is critical that an effective aphicide such as Fulfill or Beleaf be used.



Figure 6. Green peach aphids on potato leaf.



Figure 7. Potato aphid on potato stem. This aphid can be red or green.

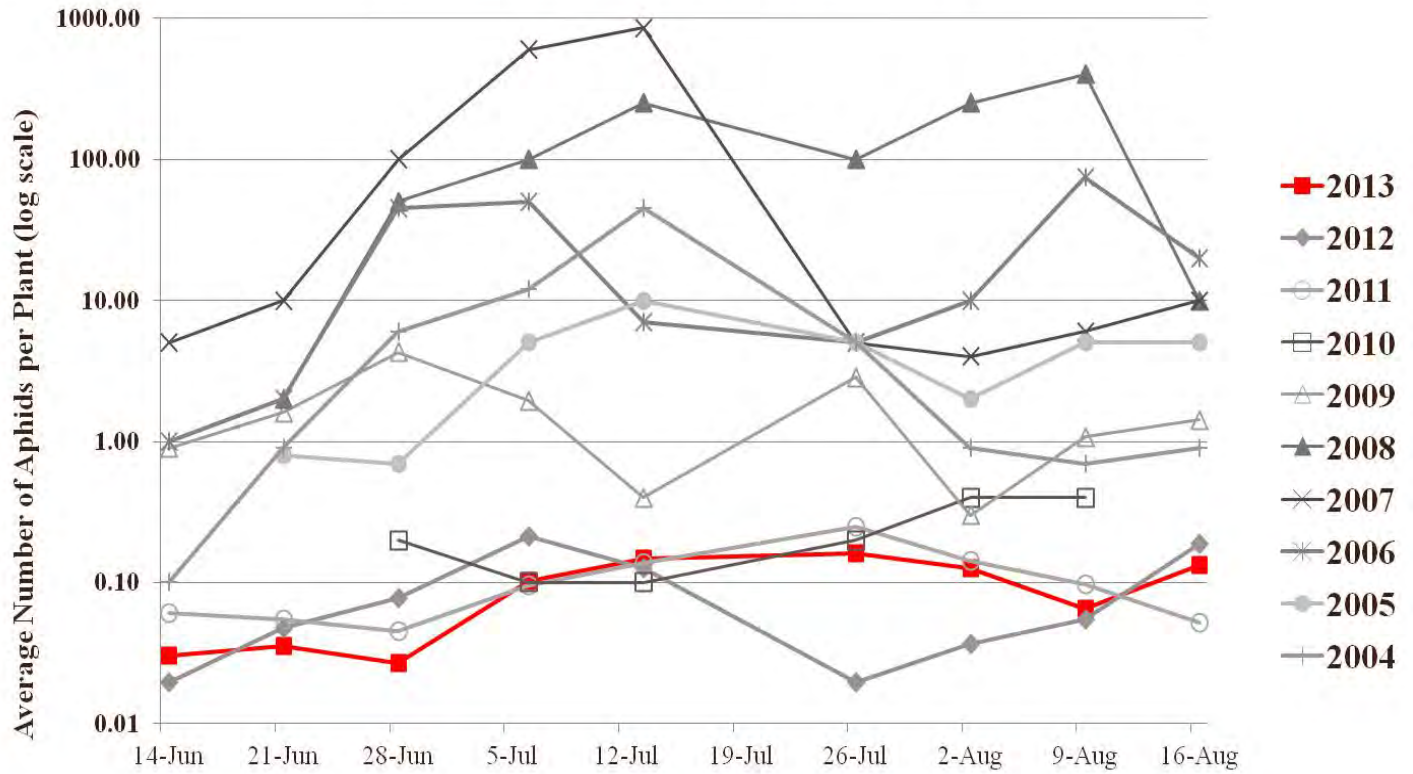
- Use only clean seed tubers with low or no virus content based on winter tests.
- If potato growers do not use a systemic insecticide at planting, it is even more important that foliar aphid insecticides be used later in the season if PLRV prevention is the goal.
- Fields should be scouted at 3 to 4 day intervals before aphid flights begin (early May); a minimum of ten locations per 100 acre field should be checked. For potatoes that are not to be stored application of foliar aphid insecticides should begin when 5 aphids per 100 leaves or 5 aphids/plant are detected. Use a beat sheet or a bucket to count aphids. Place either device underneath plants and shake plants vigorously. Aphids will fall.

- Control volunteer potatoes and potatoes growing in cull piles.
- Based on trials conducted in Idaho, Oregon and Washington, imidacloprid-based products (Admire Pro), thiamethoxam-based products (Platinum and Cruiser) and clothainidin-based product (Belay) provide significantly better aphid control than alternatives. Imidacloprid, thiamethoxam and chlothianidin applied at planting will provide 80 to 100 days of residual control. Phorate (Thimet, Phorate) do not provide reliable green peach aphid (GPA) control beyond 50 days. Use of Thimet will increase the likelihood that foliar application of insecticides mid to late season will be necessary. Use of phorate in a full season potato production system is of minimal value for pest management.
- In years with high numbers of winged GPA, a management program that uses only foliar insecticides applied in response to scouting is insufficient to prevent potato leaf roll virus (PLRV) transmission in late season Russet Burbank potatoes. This is because the high number of aphids can transmit PLRV before 100% of aphids are killed.
- Following a soil or seed treatment applied insecticide a “no gap” program is required to reduce the extent of transmission of PLRV from infected plants to non-infected plants within a field. It is possible that even with a “no gap” intensive GPA control program some level of transmission from virus bearing aphids migrating into a field from early season potatoes or weedy hosts may occur. A no gap program includes use of a long-term residual insecticide applied at time of planting, application of an effective foliar aphid insecticide prior to the “break” and then sequential applications of foliar aphid insecticides at intervals no longer than their period of residual control.
- Research in Idaho indicates that hairy nightshade is an excellent aphid and virus host. The mere presence of this weed increases the amount of PLRV and PVY in the crop. Therefore, control of this weed is highly recommended. Other solanaceous weeds should also be controlled.

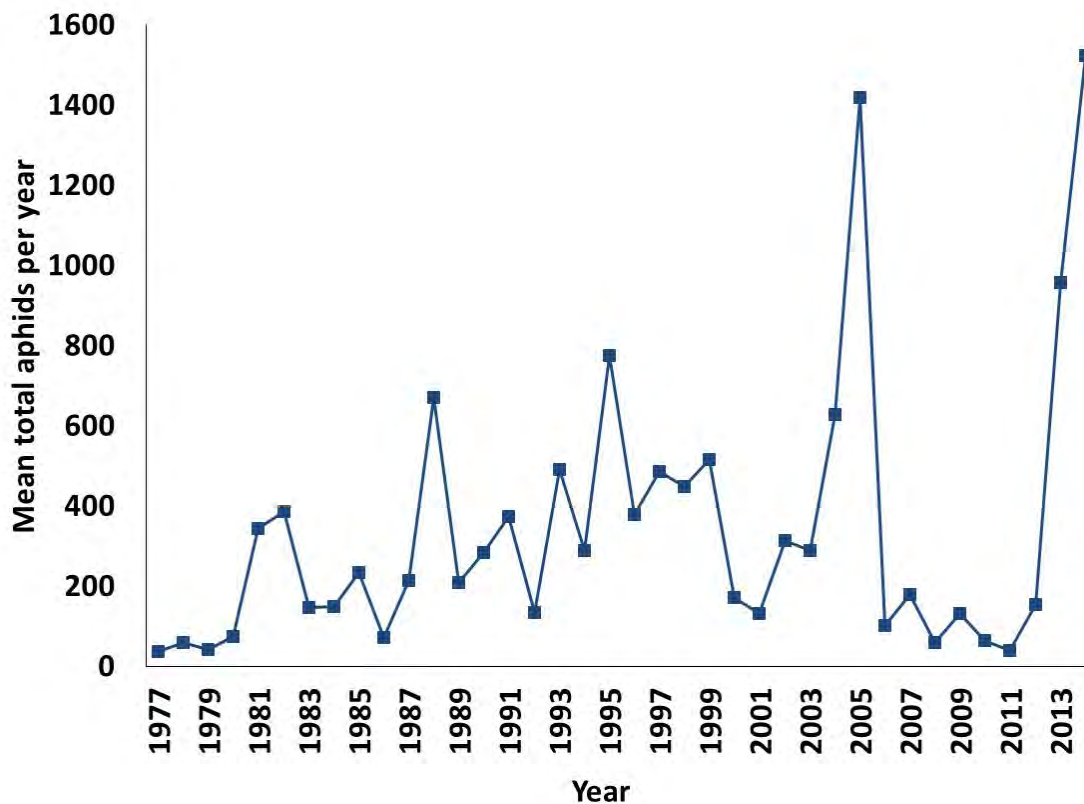
It was previously thought that the primary means by which GPA survives the winter is in the egg stage on peach trees. We now know that if they are not subjected to temperatures cold enough to kill them, they can also overwinter on various perennial, biennial, and winter annual weeds, such as tumble mustard, flixweed, shepherd’s-purse, chickweed, mallow, horseweed, pennycress and redstem filaree. While it is not entirely possible or practical to control aphids originating from these weeds, it is important to understand that early

sources of aphid outbreaks can occur throughout most, if not all of the PNW potato growing regions as these weeds dry out.

Green Peach Aphid Populations in the Columbia Basin 2004-2013 Weekly Potato Field Sampling Data



C.H. Wohleb and T.D. Waters, 2013. Sampling Network for Insect Pests of Potato in the Columbia Basin of Washington.



S.I. Rondon Historical population dynamic of aphids in the lower Columbia Basin, 1977-2014

Cultural Control

Reducing overwintering GPA populations on the primary host. In some Idaho areas, the number of GPA present in the spring to infest crops depends upon winter survival. The common means of overwintering in most parts of Idaho is on the winter host in the egg stage. Peach trees are the most common winter hosts, although apricots and other species of *Prunus* are sometimes infested. Fields near commercial peach orchards or urban areas with backyard and abandoned peach trees, usually have higher populations than those in isolated areas. Therefore, removing and replacing peach and apricot trees and spraying insecticides on commercial peach orchards are effective ways to prevent aphid buildup in Idaho.

Eliminating GPA populations on bedding plants. Bedding plants in home gardens are a good source of aphids -- fields close to towns are often the ones with the most GPA problems. Significant numbers of winged aphids can be produced in home gardens. Aphids moving directly from home gardens to potato plantings often transport viruses since home garden potato plants can have a high rate of disease infection. Effective programs to control GPA on the winter host and on bedding plants will greatly reduce the need for applications of insecticides to potato crops.

Eliminating secondary hosts. Early aphid infestations commonly occur on a number of weeds including species of mustards, nightshade and ground cherries. Winged forms produced on these weeds later infest crop plants, including potatoes, and high numbers may appear during a short period when one or more species of weeds dry up or mature. Research from Idaho has shown that hairy nightshade is an excellent aphid host and also harbors potato viruses; GPA reproduce up to 50% better on the weed than on potatoes. Green peach aphids and other species of colonizing and non-colonizing aphids can transmit potato viruses (PLRV and PVY) from hairy nightshade to potatoes at higher rates than from potatoes to potatoes. Therefore, nightshades should be kept well in check, especially in seed-growing areas where disease prevention is essential.

Chemical Control

Application of aphid insecticides should begin just prior to the time or expected time in decline in performance (“break”) of the soil or seed treatment insecticides applied at planting or layby, OR as soon as non-winged aphids are detected, OR if significant aphid flights have been forecast for your area. To ensure prevention of PLRV transmission there should be no gaps in aphid protection of potatoes, regardless of the insecticide used, or whether applied in furrow, to the seed piece or to the foliage. Complete insect control from planting until aphid flights have ceased is the only means to manage PLRV in full season potatoes. Any gap in coverage may result in substantial virus transmission. It is important to remember that even with complete insecticidal coverage of a potato field some transmission of PLRV from winged aphids landing on potatoes is possible. In most years for most fields, applications of aphid insecticides should be completed by Labor Day. However, treatment may be warranted beyond Labor Day if there is significant late season rise in aphid numbers in areas where potatoes are still green, still actively growing and bulking. Though yields are not likely to be impacted, late season virus transmission by aphids can increase the risk of PLRV net necrosis in stored tubers.

Foliar insecticides suggested for use in suppressing aphids in late-season potatoes include the following:

Dimethoate (Group 1B). The 4E formulation may be used at 0.5 to 1.0 pints per acre. It may be applied by ground, air or chemigation. (There are no data showing efficacy by chemigation.) Dimethoate has a short period of residual activity. Use of the higher rate is recommended. Efficacy may be marginal against higher populations of aphids. It has a 2 day post-harvest interval, a 48 hour reentry interval and a 7 day retreatment interval. A total of 2 pints may be applied per season.

Belay 50 WDG (clothianidin Group 4A). Apply Belay at the full label rate of 1 to 1.5 oz. Belay can be applied by ground only in 10 to 20 gallons per acre. The product has a 14 day PHI, a 12 REI and a 14 day application interval. There is a season limitation of 3 applications. Belay has no crop rotation restrictions. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum.)

Assail 70WP (acetamidiprid, Group 4A). Apply 1.0 to 1.7 oz/acre by ground, air or chemigation for aphid control in full season potatoes. Use the higher rate under conditions of heavy pest pressure, dense foliage and/or application by air or chemigation. Apply Assail when aphids are first detected. Repeat applications at 7-10 day intervals may be required if aphid pressure continues. A total of 6.8 oz may be applied per season. Do not make more than 4 applications per season and do not apply more than once every 7 days. Do not apply less than 7 days prior to harvest (7 day PHI). Complete plant coverage, including the lower portion of the plant if pests are present in that area, is necessary for best results. Chemigation may provide the best coverage when the canopy is dense and closed. Apply Assail in a minimum of 20 gallons of water by ground, 5 gallons by air and a maximum of 0.2 inch/acre by chemigation. When applying Assail by ground or air use a crop oil adjuvant such as crop oil concentrates (COC), methylated seed oils (MSO) or ethylated seed oil (ESO), or use an organosilicone crop oil blend adjuvant. Avoid the use of Assail with any product containing sticker/binder-type adjuvants when aphid and leafhopper are the target pests. Do not irrigate within 12 hours of an Assail application. There are no rotational crop plant back restrictions for Assail. Do not apply this product if the field has been treated this year with Admire Pro, Belay, Cruiser or Platinum.

Actara (thiamethoxam Group 4A). Apply 3.0 oz/acre by either ground or by air (24C registration). This product should be applied just prior to the “break” in control of the soil applied insecticide or at the very first detection of wingless aphids in the field (see GPA action threshold at the end of this section). A total of 6.0 ounces may be applied per season. Apply Actara in a minimum of 10 gallons of water when application by ground and a minimum of 5 gallon when applying by air. When applying Actara by ground or air use an oil blend adjuvant. For chemigation, use 0.10-0.25 inches of water. Avoid the use of Actara with any product

containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield). Examples of appropriate adjuvants include crop oil concentrates (COC) (e.g. Herbimax), methylated seed oils (MSO) (e.g. Dynamic), ethylated seed oils (ESO) (e.g. Hasten) and organosilicone (OS) blends (e.g. Aerodynamic). Do not apply this product if the field has been treated this year with Admire Pro, Belay, Cruiser, CruiserMaxx or Platinum.

Transform WG (sulfoxaflor, Group 4C). Apply at 0.75 to 1.5 fluid oz per acre by ground, air or chemigation for aphid control.. Use the higher rate under conditions of heavy pest pressure, dense foliage and or application by air or chemigation. Transform has a preharvest interval of 7 days and a 14 day interval between applications and a seasonal crop limit of four applications per season. Do not make more than two consecutive applications and do not apply more than 8.5 fluid oz total per cropping season. If a 4A (neonicotinoid) or 4D insecticide (Sivanto) has been previously applied apply an insecticide with a different mode of action (different group number) prior to use of Transform. This product does not have a full set of Maximum Residue Limits (MRLs). Use this product with caution if your potatoes have the potential for export. See the section on MRLs at the end of this report for specific MRLs for this product by country.

Sivanto 200SL (flupyradifurone, Group 4D). Apply at 7.0 to 10.5 fluid oz per acre by ground or by air for aphid control. Use the higher rate under conditions of heavy pest pressure, dense foliage and or by air. Transform has a preharvest interval of 7 days and a 7 day interval between applications and a seasonal crop limit of 28 fluid oz per acre. Do not make more than two consecutive applications. If a 4A (neonicotinoid) or a 4C (Transform) insecticide has been previously applied, apply an insecticide with a different mode of action (different group number) prior to the use of Sivanto. This product does not have a full set of Maximum Residue Limits (MRLs). Use this product with caution if your potatoes have the potential for export. See the section on MRLs at the end of this report for specific MRLs for this product by country.

Fulfill (pymetrozine Group 9B). Apply Fulfill at the label rates of 2.75 to 5.5 oz./A oz per acre using a penetrating surfactant. Use the higher rate with heavier aphid populations. This product should be applied just prior to the “break” in control of soil applied insecticide or at the very first detection of wingless aphids in the field (see GPA action threshold at the end of this section.) A minimum of five gallons of water should be used when applying Fulfill by air. Fulfill can be applied via irrigation systems. The Fulfill label permits a maximum of only two applications. When applying Fulfill by ground or air use an oil blend adjuvant. Always use a penetrating adjuvant when used with other products that contain sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield). Examples of appropriate adjuvants include crop oil concentrates (COC) (e.g. Herbimax), methylated seed oils (MSO) (e.g. Dynamic), ethylated seed oils (ESO) (e.g. Hasten) and organosilicone (OS) blends (e.g. Aerodynamic). Note, there is no quick knock down of aphid populations with Fulfill; the product causes aphids to cease feeding, with actual death occurring in 3-5 days.

Beleaf (flonicamid, Group 9C). Apply Beleaf at 2.0 to 2.8 oz/acre. The product may be applied by ground, air or chemigation for aphid control. This product will only control aphids. Apply no more than 3 applications per season. Beleaf has a 7 day pre harvest interval. Always use a high quality organosilicone blend surfactant with Beleaf

Voliam Xpress (lambda-cyhalothrin, chlorantraniliprole, Group 3, Group 28). Apply at 6.0 to 9.0 fluid oz per acre for control of CPB by ground air or chemigation. When applying by chemigation, apply in 0.1 to 0.2 acre inches of water per acre. Do not exceed a total of 27 oz of product per season per acre. Minimum time between application intervals is 7 days. There is a preharvest interval of 14 days.

Voliam Flexi (thiamethoxam, chlorantraniliprole, Group 4a, Group 28). Apply at 4 fluid oz per acre by ground, air and chemigation. Do not apply more than 8 ounces total per season per acre. There is a minimum interval between applications of 7 days. Do not harvest the field for 14 days after application. Do not apply

this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum.)

Endigo (thiamethoxam, lambda_cyhalothrin, Group 4a, Group 3). Apply at 4.5 fluid oz per acre by ground, air or by chemigation. Do not apply more than 10 ounces per season per acre. There is a minimum interval between applications of 7 days. Do not harvest the field for 14 days after application. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum).

Torac (tolfenpyrad, Group 21a). Apply at 17 to 21 fluid ounces per acre by ground, air and chemigation for control of aphids. Use the higher rate or heavier pest infestations or applying by chemigation. When applying by ground use at least 20 gallons of water per acre, when applying by air use at least 5 gallons of water and when applying by chemigation refer to the specific label language. Do not apply more than 2 applications per cropping season. Torac has a 14 day pre harvest interval and a 14 day retreatment interval. A total of 42 fluid ounces can be applied during a single cropping season.

Movento (spirotetramat, Group 23). Movento may be applied by air, ground or chemigation for control of aphids. We do not recommend this product be applied to potatoes by chemigation. Apply Movento at 5.0 oz of product per acre; there is a seasonal limit of 10 oz per acre. Movento requires up to 14 days to become fully effective in the plant. If following an application of a neonicotinoid at planting/cracking, apply Movento at 14 days prior to expected “break” of the planting time insecticide. Research has shown that the most effective means of controlling psyllids, aphids and other pests is to apply Movento consecutively twice with a 10 to 14 day treatment interval. For resistance management purposes, do not allow more than 21 days between applications of Movento unless an insecticide with a different mode of action is applied between the two applications. If a planting time insecticide has not been made, apply Movento 14 days prior to the appearance of aphid. The product is more effective when applied earlier in the outbreak cycle due to its systemic properties and efficacy against eggs and nymphs. Use of Movento requires inclusion of a penetrating surfactant, such as a MSO. One feature of consequence for Movento is that there is a 30 day plant back restriction after the the last application for all crops. Since this product would almost always be applied more than 30 days before harvest, there are functionally no plant back restrictions for Movento.

Aphid Management Guidelines for Seed Potatoes

Alan Schreiber, Agriculture Development Group, Inc., and Andrew Jensen, Idaho, Oregon and Washington State Potato Commissions

PVY Control Considerations.

- Use only clean seed tubers with low or no virus content based on winter tests.
- It is recommended that growers do use a systemic insecticide at planting however, if potato growers do not use a systemic insecticide at planting, it is even more important that foliar aphid insecticides be used later in the season if PLRV prevention is the goal.
- Fields should be scouted at 3 to 4 day intervals before aphid flights begin (early May); a minimum of ten locations per 100 acre field should be checked. For potatoes that are not to be stored application of foliar aphid insecticides should begin when 5 aphids per 100 leaves or 5 aphids/plant are detected. Use a beat sheet or a bucket to count aphids. Place either device underneath plants and shake plants vigorously. Aphids will fall.
- Control volunteer potatoes and potatoes growing in cull piles.
- Based on trials conducted in Idaho, Oregon and Washington, imidacloprid-based products (Admire Pro and Gaucho), thiamethoxam-based products (Platinum and Cruiser) and clothainidin-based product (Belay) provide significantly better aphid control than alternatives. Imidacloprid, thiamethoxam and chlothianidin applied at planting will provide 80 to 100 days of residual control. Phorate (Thimet, Phorate) does not provide reliable green peach aphid (GPA) control beyond 50 days. Use of Thimet will increase the likelihood that foliar application of insecticides mid to late season will be necessary. Use of phorate in a full season potato production system is of minimal value for pest management.
- In years with high numbers of winged GPA, a management program that uses only foliar insecticides applied in response to scouting is insufficient to prevent potato leaf roll virus (PLRV) transmission in late season Russet Burbank potatoes. This is because the high number of aphids can transmit PLRV before 100% of aphids are killed.
- Following a soil or seed treatment applied insecticide a “no gap” program is required to reduce the extent of transmission of PLRV from infected plants to non-infected plants within a field. It is possible that even with a “no gap” intensive GPA control program some level of transmission from virus bearing aphids migrating into a field from early season potatoes or weedy hosts may occur. A no gap program includes use of a long-term residual insecticide applied at time of planting, application of an effective foliar aphid insecticide prior to the “break” and then sequential applications of foliar aphid insecticides at intervals no longer than their period of residual control.
- Research in Idaho indicates that hairy nightshade is an excellent aphid and virus host. The mere presence of this weed increases the amount of PLRV and PVY in the crop. Therefore, control of this weed is highly recommended. Other solanaceous weeds should also be controlled.

It was previously thought that the primary means by which GPA survives the winter is in the egg stage on peach trees. We now know that if they are not subjected to temperatures cold enough to kill them, they can also overwinter on various perennial, biennial, and winter annual weeds, such as tumble mustard, flixweed, shepherd's-purse, chickweed, mallow, horseweed, pennycress and redstem filaree. While it is not entirely possible or practical to control aphids originating from these weeds, it is important to understand that early

sources of aphid outbreaks can occur throughout most, if not all of the PNW potato growing regions as these weeds dry out.

Cultural Control

Planting disease free seed. Planting PVY free seed is the most effective way to reducing PVY infection in subsequent generations of seed.

Eliminating aphid populations on bedding plants. Bedding plants in home gardens are a good source of aphids -- fields close to towns are often the ones with the most aphid problems. Significant numbers of winged aphids can be produced in home gardens. Aphids moving directly from home gardens to potato plantings often transport viruses since home garden potato plants can have a high rate of disease infection. Effective programs to control aphids on the winter host and on bedding plants will greatly reduce the need for applications of insecticides to potato crops.

Eliminating secondary hosts. Early aphid infestations commonly occur on a number of weeds including species of mustards, nightshade and ground cherries. Winged forms produced on these weeds later infest crop plants, including potatoes, and high numbers may appear during a short period when one or more species of weeds dry up or mature. Research from Idaho has shown that hairy nightshade is an excellent aphid host and also harbors potato viruses; some aphids reproduce up to 50% better on the weed than on potatoes. Green peach aphids and other species of colonizing and non-colonizing aphids can transmit potato viruses (PLRV and PVY) from hairy nightshade to potatoes at higher rates than from potatoes to potatoes. Therefore, nightshades should be kept well in check, especially in seed-growing areas where disease prevention is essential.

Aphid Planting Time Options

Based on trials conducted in Idaho, Oregon and Washington, imidacloprid-based products (Admire Pro and Gaucho), thiamethoxam-based products (Platinum and Cruiser) and clothianidin-based products (Belay) provide significantly better CPB and aphid control than alternatives. Imidacloprid, thiamethoxam and clothianidin (all neonicotinoid insecticides) applied at planting will provide 80 to 100 days of residual control. Other soil applied systemic insecticides such as phorate (Thimet, Phorate) do not provide reliable Colorado potato beetle and GPA control beyond 50 days. Use of Thimet increases the likelihood that foliar application of insecticides will be necessary. Venom is another neonicotinoid insecticide used at planting time on potatoes. At this time, it is not recommended for use at planting in potatoes in the PNW due to its short period of residual activity.

Insecticide Seed Treatments

Admire Pro (imidacloprid, Group 4A). Admire Pro is a liquid seed piece treatment offering control of all aphid species, Colorado potato beetle, flea beetle, potato leafhopper, and psyllids with the flexibility of ultra-low volume liquid seed-piece application. Admire Pro may reduce wireworm damage in seed-pieces. The application rate is 0.17 – 0.35 fl. oz./cwt. of seed-pieces (Note: Based on a 2000 lb/acre seeding rate, this rate range is equivalent to 3.5 -7.0 fl. oz./acre). Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Endigo Actara, Assail) following this application.

CruiserMaxx Potato (thiamethoxam, Group 4A). Cruiser is a seed-applied neonicotinoid product recently registered for use on potatoes. Use CruiserMaxx Potato seed treatment to provide protection against injury from aphids, Colorado potato beetles, flea beetles, and psyllids. Cruiser 5FS will also control wireworms that feed on the seed piece. The rate range is 0.19 to 0.27 oz per 100 lbs of tubers, depending on the seeding rate (consult label). Length of control will vary depending on the rate used, soil and environmental conditions, and insect pressure. Use approved application equipment (Spudgun or Milestone barrel treater). It is important to note that the application rate will vary by the number of sacks planted per acre with a maximum use rate of 0.125 lbai/A. This Cruiser Maxx Potato formulation is a combination of Cruiser 5FS and Maxim 4FS. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Endigo Actara, Assail) following this application.

Cruiser Maxx Potato Extreme (thiamethoxam, Group 4A) is the same product as CruiserMaxx but includes difenconazole for increased control of Fusarium. It is used identically to CruiserMaxx except it is applied at a higher rate of 0.31 oz/100 pounds of seed. This product was developed for the Northeastern potato market where Fusarium has developed resistance to existing fungicides. It will be commercially available in the Pacific Northwest but offers identical insect control as to CruiserMaxx. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Endigo Actara, Assail) following this application.

Insecticide In-Furrow Treatments

Platinum 75SG (thiamethoxam, Group 4A). Platinum is a soil-applied insecticide providing long residual control in potatoes. Apply Platinum at 1.66 to 2.67 oz/A in-furrow at planting in a 6-8 inch band with sufficient water for good coverage for the control of aphids, Colorado potato beetle, potato leafhoppers, flea beetles, and potato psyllid. Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Do not apply foliar neonicotinoids (Admire Pro, Leverage or Actara) following this application. Alternatively, Platinum may be applied POST plant, pre-emergence as a broadcast application at 1.66 to 2.67 oz/A and watered in with 0.10 -0.25 inches of water. All precautions listed above must be followed.

Admire Pro (imidacloprid, Group 4A). Admire Pro is a soil-applied insecticide providing long residual control of insect pests of potatoes. Admire Pro will control Colorado potato beetles, aphids, wireworms (seed piece only), and psyllids. Dosage rates are 5.7 to 8.7 fl oz/A applied as an in-furrow spray at seeding or as a side dress to both sides of the hill after planting (treated areas of both hillsides should be covered with approximately 3 inches of soil). Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Do not apply foliar neonicotinoids (Admire Pro, Leverage or Actara) following this application.

Belay 16 WSG (clothiniadin, Group 4A). Apply Belay at 12 to 18 ounces/A in-furrow or at soil cracking. Use 10 gallon of water per acre. Belay has an REI of 12 hours. Water immediately after application when applied at soil cracking. Belay has no crop rotation restrictions. Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Do not apply foliar neonicotinoids (Admire Pro, Leverage or Actara) following this application.

Foliar Aphid Management Options

Aphids may transmit virus disease and, when abundant, reduce yield. If wingless aphids are found on potato, they almost certainly will be either green peach aphid or potato aphid, both of which can transmit potato leaf roll virus (PLRV). Potato aphid is generally more common in the spring and fall, while green peach aphid peaks during July and early August.

Aphids on potato are a serious pest mainly because of their ability to transmit several plant viruses. The most important virus disease during the twentieth century, PLRV, causes a tuber symptom in some varieties called net necrosis. This internal discoloration is not acceptable in the marketplace, and its prevention accounts for most aphid control efforts. PLRV is transmitted in a persistent manner, which means that once an aphid is infected by the virus, it can transmit to uninfected plants for the rest of its life. Relatively few aphid species can transmit this virus to potatoes, and green peach aphid is by far the most important vector. The low tolerance in the marketplace for net necrosis, and the high vectoring capacity of green peach aphid, means there is a very low treatment threshold for this pest in most potato fields destined for storage and processing. PLRV has become very uncommon in the 21st century, probably due to effective prevention in the seed potato industry.

Potato virus Y (PVY) is increasingly serious in potato production in the PNW, surpassing PLRV in importance. New strains of PVY that can cause internal brown lesions in tubers of some cultivars are becoming common. This sort of damage is unacceptable in the marketplace. PVY is transmitted by many different aphid species in a non-persistent manner. This means that almost any aphid that happens to alight, even for a moment, on a potato plant could be transmitting the virus. PVY is transmitted very quickly – in a far shorter time than most insecticides can act to prevent aphid feeding. Most PVY transmission is by aphids that are not living in the potato field. More than 50 aphid species are known to vector PVY and the list is growing longer.

Crop Oils. Limited research has shown that certain kinds of oils such as crop oils/stylet oils have been found effective in reducing transmission of PVY, although the mechanism of this action is unknown. Insufficient information is available to advise growers on how best to use these products.

Chemical Control

Application of aphid insecticides should begin just prior to the time or expected time in decline in performance (“break”) of the soil or seed treatment insecticides applied at planting or layby, OR as soon as non-winged aphids are detected, OR if significant aphid flights have been forecast for your area. To ensure prevention of PVY transmission there should be no gaps in aphid protection of potatoes, regardless of the insecticide used, or whether applied in furrow, to the seed piece or to the foliage. Complete insect control from planting until aphid flights have ceased is the only means to manage PVY in full season potatoes. Any gap in coverage may result in substantial virus transmission. It is important to remember that even with complete insecticidal coverage of a potato field some transmission of PVY from winged aphids landing on potatoes is possible.

Foliar insecticides suggested for use in suppressing aphids in late-season potatoes include the following:

Belay 50 WDG (clothianidin Group 4A). Apply Belay at the full label rate of 1 to 1.5 oz. Belay can be applied by ground only in 10 to 20 gallons per acre. The product has a 14 day PHI, a 12 REI and a 14 day application interval. There is a season limitation of 3 applications. Belay has no crop rotation restrictions. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Gaucho, Belay, Cruiser or Platinum.)

Actara (thiamethoxam Group 4A). Apply 3.0 oz/acre by either ground or by air (24C registration). This product should be applied just prior to the “break” in control of the soil applied insecticide or at the very first

detection of wingless aphids in the field (see GPA action threshold at the end of this section). A total of 6.0 ounces may be applied per season. Apply Actara in a minimum of 10 gallons of water when application by ground and a minimum of 5 gallon when applying by air. When applying Actara by ground or air use an oil blend adjuvant. For chemigation, use 0.10-0.25 inches of water. Avoid the use of Actara with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield. Examples of appropriate adjuvants include crop oil concentrates (COC) (e.g. Herbimax), methylated seed oils (MSO) (e.g. Dynamic), ethylated seed oils (ESO) (e.g. Hasten) and organosilicone (OS) blends (e.g. Aerodynamic). Do not apply this product if the field has been treated this year with Admire Pro, Gaucho, Belay, Cruiser, CruiserMaxx or Platinum.

Voliam Flexi (thiamethoxam, chlorantraniliprole, Group 4a, Group 28). Apply at 4 fluid oz per acre by ground, air and chemigation. Do not apply more than 8 ounces total per season per acre. There is a minimum interval between applications of 7 days. Do not harvest the field for 14 days after application. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Gaucho, Belay, Cruiser or Platinum.)

Assail 70WP (acetamidiprid, Group 4A). Apply 1.0 to 1.7 oz/acre by ground, air or chemigation for aphid control in full season potatoes. Use the higher rate under conditions of heavy pest pressure, dense foliage and/or application by air or chemigation. Apply Assail when aphids are first detected. Repeat applications at 7-10 day intervals may be required if aphid pressure continues. A total of 6.8 oz may be applied per season. Do not make more than 4 applications per season and do not apply more than once every 7 days. Do not apply less than 7 days prior to harvest (7 day PHI). Complete plant coverage, including the lower portion of the plant if pests are present in that area, is necessary for best results. Chemigation may provide the best coverage when the canopy is dense and closed. Apply Assail in a minimum of 20 gallons of water by ground, 5 gallons by air and a maximum of 0.2 inch/acre by chemigation. When applying Assail by ground or air use a crop oil adjuvant such as crop oil concentrates (COC), methylated seed oils (MSO) or ethylated seed oil (ESO), or use an organosilicone crop oil blend adjuvant. Avoid the use of Assail with any product containing sticker/binder-type adjuvants when aphid and leafhopper are the target pests. Do not irrigate within 12 hours of an Assail application. There are no rotational crop plant back restrictions for Assail. Do not apply this product if the field has been treated this year with Admire Pro, Gaucho, Belay, Cruiser or Platinum.

Transform WG (sulfoxaflor, Group 4C). Apply at 0.75 to 1.5 fluid oz per acre by ground, air or chemigation for aphid control. Use the higher rate under conditions of heavy pest pressure, dense foliage and or application by air or chemigation. Transform has a preharvest interval of 7 days and a 14 day interval between applications and a seasonal crop limit of four applications per season. Do not make more than two consecutive applications and do not apply more than 8.5 fluid oz total per cropping season. If a Group 4 insecticide has been previously applied, apply an insecticide with a different mode of action (non Group 4) prior to use of Transform.

Sivanto 200 SL (flypyradifurone, 4D). Apply at 7.0 to 10.5 fluid oz per acre by ground, air or chemigation for aphid control. Use the higher rate under conditions of heavier pest pressure, dense foliage and or application by air or chemigation. Sivanto has a preharvest interval of 7 days and a 7 day interval between applications and a seasonal crop limit of 28 fluid ounces per cropping season. If a Group 4 insecticide has been previously applied, apply an insecticide with a different mode of action (non Group 4) prior to use of Sivanto.

Fulfill (pymetrozine Group 9B). Apply Fulfill at the label rates of 2.75 to 5.5 oz./A oz per acre using a penetrating surfactant. Use the higher rate with heavier aphid populations. This product should be applied just prior to the “break” in control of soil applied insecticide or at the very first detection of wingless aphids in the field (see GPA action threshold at the end of this section.) A minimum of five gallons of water should be used when applying Fulfill by air. Fulfill can be applied via irrigation systems. The Fulfill label permits a maximum of only two applications. When applying Fulfill by ground or air use an oil blend adjuvant. Always use a

penetrating adjuvant when used with other products that contain sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield. Examples of appropriate adjuvants include crop oil concentrates (COC) (e.g. Herbimax), methylated seed oils (MSO) (e.g. Dynamic), ethylated seed oils (ESO) (e.g. Hasten) and organosilicone (OS) blends (e.g. Aerodynamic). Note, there is no quick knock down of aphid populations with Fulfill; the product causes aphids to cease feeding, with actual death occurring in 3-5 days. Do not rotate Fulfill (9B) directly with Beleaf (9C) for resistance management reasons.

Beleaf (flonicamid, Group 9C). Apply Beleaf at 2.0 to 2.8 oz/acre. The product may be applied by ground, air or chemigation for aphid control. This product will only control aphids. Apply no more than 3 applications per season. Beleaf has a 7 day pre harvest interval. Always use a high quality organosilicone blend surfactant with Beleaf. Do not rotate Beleaf (9C) directly with Fulfill (9B) for resistance management reasons.

Torac (tolfenpyrad, Group 21a). Apply at 17 to 21 fluid ounces per acre by ground, air and chemigation for control of aphids. Use the higher rate or heavier pest infestations or applying by chemigation. When applying by ground use at least 20 gallons of water per acre, when applying by air use at least 5 gallons of water and when applying by chemigation refer to the specific label language. Do not apply more than 2 applications per cropping season. Torac has a 14 day pre harvest interval and a 14 day retreatment interval. A total of 42 fluid ounces can be applied during a single cropping season.

Movento (spirotetramat, Group 23). Movento may be applied by air, ground or chemigation for control of aphids. We do not recommend this product be applied to potatoes by chemigation. Apply Movento at 5.0 oz of product per acre; there is a seasonal limit of 10 oz per acre Movento requires up to 14 days to become fully effective in the plant. If following an application of a neonicotinoid at planting/cracking, apply Movento at 14 days prior to expected “break” of the planting time insecticide. Research has shown that the most effective means of controlling psyllids, aphids and other pests is to apply Movento consecutively twice with a 10 to 14 day treatment interval. For resistance management purposes, do not allow more than 21 days between applications of Movento unless an insecticide with a different mode of action is applied between the two applications. If a planting time insecticide has not been made, apply Movento 14 days prior to the appearance of aphid. The product is more effective when applied earlier in the outbreak cycle due to its systemic properties and efficacy against eggs and nymphs. Use of Movento requires inclusion of a penetrating surfactant, such as a MSO. One feature of consequence for Movento is that there is a 30 day plant back restriction after the the last application for all crops. Since this product would almost always be applied more than 30 days before harvest, there are functionally no plant back restrictions for Movento.

Preharvest Interval, Restricted Entry Interval and Seasonal Limits for Potato Insecticides					
Brand Name		Common Name, Group Number	PHI (days)	REI (hours)	Seasonal Limit
Assail 70WP	UPI	Acetamidiprid, 4A	7	12	7
Belay 50 WG	Valent	Chlothianidin, 4A	14	12	3 app
Beleaf	FMC	Flonicamid, 9C	7	12	3 day
Fulfill	Syngenta Crop Protection	Pymetrozine, 9B	14	12	11 oz
Movento	Bayer CropSciences	Spiromesifem, 23	7	24	10 oz
Transform WG	Dow AgroSciences	Sulfoxaflor, 4C	7	24	8.5 fl oz
Actara	Syngenta Crop Protection	Thiamethoxam, 4A	14	12	6 oz
Sivanto	Bayer CropScience	Flypyradifurone, 4D	7	7	28
Torac	Nichino	Tolfenpyrad, 21A	14	12	42 oz

A cautionary note: The above information is based on work conducted in eastern Washington, in the Columbia Basin and has focused on control of aphids vectoring PLRV in table stock/processing potatoes. This information is thought to be applicable to control of aphids vectoring PVY. However, many conditions between Idaho, Oregon, northwest Washington and the Columbia Basin are different. Virtually no research has been carried out on control of virus vectoring aphids in seed potatoes in western Washington. Please use the above information with the understanding there may be differences in the application of this information for different seed growing areas.

Two-Spotted Spider Mites

The only place in the U.S. potatoes that have mite problems (two-spotted spider mites, Figure 8) is the PNW. Mite infestations should be managed in the same manner throughout the PNW, however, the decision of whether and when to scout for mites on potatoes outside of the Columbia Basin must be based on local conditions and risk of mite outbreak. All potatoes in the Columbia Basin should be sampled for mites. Applications of most miticides (Comite, abamectin, Acramite, Onager, and Oberon) should be made upon early detection of mites. Movento must be applied prior to outbreak of mite populations. All potatoes should be surveyed for the presence of mites and mite eggs starting July 15.



Figure 8. Two-spotted spider mite and eggs on potato leaf. The mite is less than 0.05 inch long.

Sampling

Sampling for mites requires a close visual inspection of leaves from differing levels of the plants. Shaking suspected infested leaves above a piece of white paper helps to determine the presence of mites. They will dislodge from the leaves and the tiny spots moving on the paper (mites) are easy to see. The use of at least a 10x hand lens is important for detecting mites in low numbers. There are no registered miticides available that will provide full control or serve as rescue treatments once mite populations reach outbreak levels. Application of miticides should begin before populations reach 2 mites per leaf; this is close to the detection limit for the pest. Thorough coverage is essential for good control. Foliage should be dry at the time of application. Do not irrigate potatoes for 24 hours after application if possible.

In most cases, a single application of a miticide will suffice for a growing season; however, in about 10% of mite outbreaks a second application of a miticide is required. Retreatment with a different miticide should be considered as a resistance prevention strategy. Mites on potatoes have never been demonstrated to have increased tolerance to miticides; however, two spotted spider mite is well known for its ability to develop resistance and rotation of miticides is desirable.

Based on research supported by the Washington State Potato Commission inclusion of surfactants that improve coverage has been shown to significantly improve efficacy of miticides. Miticides are commonly applied via chemigation, when doing so, it is important to use minimal water volumes, ideally in the 0.1 to 0.15 acre inch volumes.

Acramite (bifenazate Group # unknown) is a miticide that may be applied by air, chemigation or ground. Acramite should be applied at 16 to 24 oz/acre. Apply the higher rate to higher populations of mites. Use at least 20 gallons of water when applying by ground and at least 5 gallons of water when applying by air. Up to two applications can be applied per season. The preharvest interval is 14 days. In research conducted in 2010, Acramite applied at 16 oz by chemigation provided 35 days of residual mite control in a light mite infestation situation.

Oberon 4SC (spirotetramat Group 23) is a broad-spectrum miticide that may be applied by air, ground, or chemigation equipment. Good coverage of the foliage is necessary for optimal control. An adjuvant may be used to improve coverage and control. For best results the treatment should be made when mite populations begin to build and before a damaging population becomes established. Oberon is most effective against the egg

and nymphal stages of mites. Control should be directed at these stages. Oberon can be applied at 4-8 fluid oz per acre. Apply when mites first appear and prior to leaf damage or discoloration. Apply in adequate water for uniform coverage with ground or aerial application equipment, or by chemigation as per the use label. If needed, repeat an application of Oberon at a 7- to 10-day interval. There is a limit of two applications per season. Applications of Oberon at the 4.0 oz rate are not recommended by air or chemigation except for situations where mite pressure is low or when applied sequentially as a split application following higher rates of Oberon as needed. Based on observations of field applications, applications via chemigation have been more effective than by air. In research conducted in Washington in 2010, Oberon applied by chemigation at 8 oz provided 35 days of residual control in a light mite infestation situation. Do not apply Oberon after Movento unless a miticide of a different mode of action such as Comite, Onager or Acramite has been made.

Comite (propargite, Group 12C) is effective against the nymphal (6 legs) and adult (8 legs) stages of spider mites when applied by air, ground or chemigation. Chemigation is permitted in Washington and Oregon only under a Section 24c (possession of the 24c is required for this type of application.) Comite is applied at 1.5 to 2.5 pints product as a foliar treatment. Do not exceed two applications per season. The preferred method of application is by air or ground. Aerial applications of Comite should be applied in a minimum of 10 gallons of water. The addition of an adjuvant has been shown to improve coverage. Comite has a 14-day retreatment interval for Washington, Oregon, and Idaho.

Onager (hexythiazox, Group 10) is effective against mite eggs and immature mites. It may be applied by air or by ground at 16 to 24 ounces per acre. When applying by air, use a minimum of 5 gallons of water. The product may only be used in Idaho, Oregon and Washington. Do not apply within 21 days of harvest. It is critical to use Onager prior to adult mite buildup as the product will not control adult mites. Use higher rates on moderate to high mite infestations or for larger plants with a dense canopy. Do not plant rotational crops other than those on the Section 3 label within 120 days of this application. Research conducted in Washington in 2010 documented that in a light mite infestation situation, Onager applied by chemigation very early in the mite outbreak cycle provided 43 days of residual control. In this situation, Onager was applied 8 days earlier than other standard miticides.

Agri-Mek SC (abamectin (Group 6). Apply 1.75 to 3.5 fl oz of Agri-Mek SC by air with 5 gallons of water per acre. Avoid the use of Agri-Mek with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or DithaneRainshield). The addition of a nonionic surfactant or organosilicone-based surfactant, at the manufacturer's recommended rate is suggested for optimum control.

Movento (spirotetramat, Group 23). Movento is not recommended for use as a rescue treatment for mites in potatoes. The product does not have lethal activity against adults and requires between 7 and 14 days to become active. However, application of Movento for other potato insect pests such as aphids or psyllids may result in prevention or delay of mite outbreaks. Refer to Movento use pattern described in the aphid section. Do not apply Movento after Oberon unless an application of an insecticide with a differing mode of action has been made.

Two-spotted spider mite resistance management. While the species of spider mite attacking PNW potatoes has demonstrated the ability to readily develop resistance to miticides, there appears to be no evidence of this problem developing in our area. However, with the availability of new miticides, potato growers should consider taking some basic steps that could prevent or delay onset of resistance in mites. If growers apply more than one miticide per season, consider applying a different miticide for the second application. The six miticides registered for use on potato belong to five modes of action (Movento and Oberon are in the same class; the rest are in distinct classes) and can be rotated with each other. While research has shown some differing levels of efficacy among the products, all products have been shown to provide commercially acceptable levels of control when applied early enough in the outbreak cycle.

Cutworm, Armyworm and Looper

Little is known about the biology and management of worms in PNW potatoes. The economic threshold for when to treat for worms is also unknown; however potatoes can tolerate some worm defoliation without loss in marketable yield. The period of full bloom is the most sensitive plant growth stage, but even then defoliation on the order of 10% appears to cause little if any yield loss. For pests like worms that usually do not develop huge populations over the course of the season (as CPB will do), it may sometimes be best to allow a little defoliation and save insecticide applications. This not only saves money but also may preserve beneficial insects and spiders. It is important to scout for living worms in your fields, rather than applying treatments in response to damage. Sometimes worms are absent by the time damage is noticed. Also, some species have nocturnal habits and may not be easily found during the day.

There are six insecticides recommended for control of worms in potatoes; Success, Blackhawk, Radiant, Rimon, Avaunt, and Coragen. Applications should be targeted at the incidence of feeding or appearance of small larvae (1st and 2nd instars). Larger larvae may be more difficult to control and may require multiple applications at 7-day intervals.

Success SC (spinosad, Group 5). For smaller sized worms (early instars), apply 4.5 fluid oz/acre by air, ground or chemigation. Time applications to target egg hatch or young larvae. For larger (later instar) larval populations, apply 5 to 6 fluid ounces of product per acre. Applications by chemigation at either rate should be made with 0.25 acre-inches of water or less. If the plant is actively growing, applying 3 or 4 fluid ounces of product per acre in sequence may be more effective than applying 6 ounces singularly. Acidic (< 6 pH) spray solutions may shorten the residual activity of Success and should be avoided. The pH of spray solution should be checked prior to adding Success into the tank and adjusted, if necessary. Acidifying products such as boron should be avoided. In addition, prior to adding Success to a tank it is recommended to conduct a compatibility test.

Blackhawk (spinosad, Group 5). Apply 2.25 to 3.5 oz of Blackhawk per acre to potatoes for control of worms on potato. Begin at first signs of infestations. Use the lower rate for relatively small worms and the higher rate for larger worms. Very large worms are difficult to control at any rate with any insecticide. Follow resistance management recommendations on the product label.

Radiant SC (spinetoram, Group 5). Apply 6 to 8 fluid oz of Radiant per acre by air, ground or chemigation. Time applications to target egg hatch or young larvae. For heavy larval populations, repeat applications may be necessary but follow resistance management guidelines. Applications by chemigation at either rate should be made with 0.25 acre inches of water or less. Acidic (< 6 pH) spray solutions should be avoided. The pH of spray solution should be checked prior to adding Radiant into the tank and adjusted, if necessary. Acidifying products such as boron should be avoided. In addition, prior to adding Radiant to a tank it is recommended to conduct a compatibility test.

Avaunt (indoxacarb, Group 22). Avaunt may be applied by air, chemigation or ground equipment at 2.5 to 6.0 oz per acre, with 3.0 ounces being the most common rate applied. When applying by chemigation, apply with minimal amount of water, perhaps 0.1 to 0.15 acre inches. As with other insecticides targeting worms, the best efficacy is achieved when targeting early instars. The preharvest interval is 7 days and it has a restricted entry interval of 12 hours. A total of 24 oz can be applied per season. Applications by air require a minimum of 5 gallons of water per acre.

Rimon 0.83 EC (novaluron, Group 15). Rimon may be applied by air, chemigation or ground equipment at 9 to 12 fl oz/acre. Applications should be made when the majority of larvae are between egg hatch and second instar. Rimon is an insect growth regulator type insecticide which must be ingested by larvae or applied either

over or under eggs to act as an ovicide, therefore, reapplication at 7 to 14 days is needed to protect new plant tissue during periods of active foliar growth. In order for this product to affect larvae it must be ingested. Rimon has no effect on adults. Do not make more than two applications per season. Use a minimum of 5 gpa when applying by air; and a minimum of 10 gpa when applying by ground. Rimon has a 12 hour restricted entry interval and a 14 day preharvest interval. Apply no more than 24 ounces per acre per season.

Coragen (rynaxypyr, Group 28). Coragen may be applied for control of worms at 3.5 to 5.0 oz/acre by ground, air or chemigation. Use 1% MSO with broadcast applications. Make no more than four applications or 15.4 ounces per acre per season. Do not apply more than twice within a 30 day period. Coragen may be applied by ground, air or chemigation. If applying by chemigation, refer to specific instructions on the label in a section outside of the potato section. The preharvest interval is 14 days. The restricted entry interval is 4 hours.



Figure 9. Armyworm.



Figure 10. Cabbage looper.



Figure 11. Spotted Cutworm.

Management of Beet Leafhopper and Beet Leafhopper Transmitted Virescence Agent in Potatoes

A serious epidemic of a “potato yellows” disease, also called purple top, occurred in potato fields throughout the Columbia Basin in 2002. The beet leafhopper-transmitted virescence agent (BLTVA), a bacteria-like organism called phytoplasma, has been shown to be the cause of this disease. The only known vector for this disease is the beet leafhopper (BLH).

BLTVA can cause a wide range of symptoms in potatoes, including leaf curling and purpling, aerial tubers, chlorosis, and early senescence (Figure 12). Most BLTVA infection occurs early in the season, during May and June, although some evidence suggests damaging infections occur in July. Potato is not a preferred host for BLH and it will not spend much time on the crop (however it does spend enough time to transmit BLTVA.) Beet leafhoppers live and reproduce mostly in weeds on nonirrigated ground. Favorite food plants include wild mustards, kochia, and Russian thistle. BLTVA is transmitted to potatoes every year but is extremely severe in years when beet leafhopper numbers are highest.



Washington State Potato Commission

Figure 12. Two adjacent plants with purple top symptoms.

Monitoring with yellow sticky traps

Because potatoes are not a preferred host of the BLH, in-field sampling is difficult. We recommend monitoring for leafhoppers using yellow sticky cards (AlphaScents, brand name of recommended sticky cards) around field margins. At least two traps should be deployed per field. This is because BLH populations can be very spotty. More traps make it more likely that an infestation will be detected.

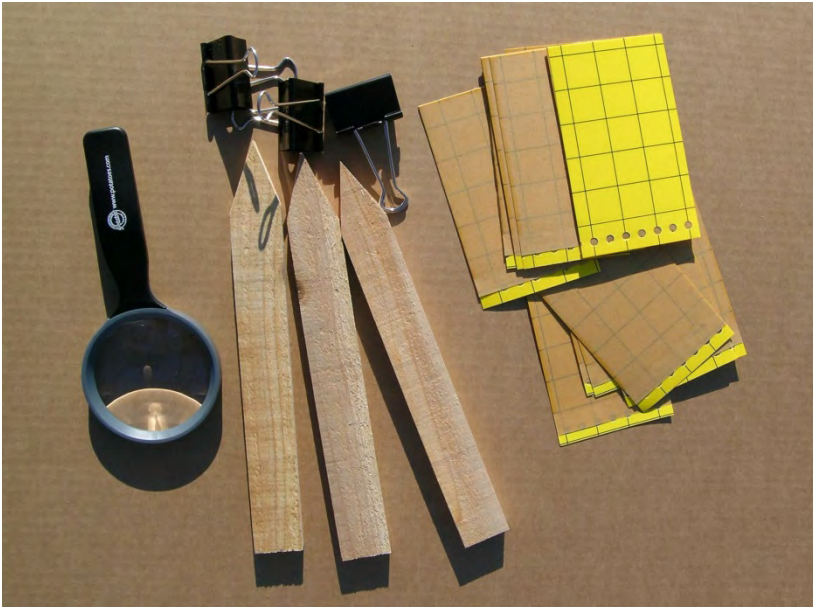


Figure 13. Supplies needed for BLH trapping.

Supplies needed. Trapping supplies include double-sided 4X6" yellow sticky cards, wooden stakes, large binder clips to secure the cards to the stakes, and a magnifying glass for counting BLH on the cards (Figure 10). The magnifying glass is essential to correctly identify BLH, and sometimes even picking leafhoppers out from all the other insects caught on a card requires a magnifier.



Figure 14. Proper mounting for yellow sticky card trap. Both sides of the trap should be used.

potato fields where annual weeds predominate. Perennial grass or native shrub habitats are not good places for BLH traps.

How to deploy traps. Yellow sticky cards should be set up as shown in Figure 14. It is important to keep the traps low to the ground as shown because BLH move about very close to the ground. Even with a very low mount like shown in Figure 11, the bottom half of the trap will often catch almost all the BLH on the trap.

Where to place traps. BLH occur in almost all kinds of habitats we see near potato fields. There are, however, habitats that they prefer such as unirrigated low weedy vegetation composed of mustards and grasses (during early spring) or kochia and Russian thistle (during late spring, summer, and fall). When monitoring for BLH with yellow sticky traps, the traps should be placed outside potato fields in unirrigated weeds. When siting your traps, focus on the more disturbed areas around

Checking the traps. Traps should be checked and changed once a week, or whenever they become covered in insects, dirt, feathers, fur, dead lizards and mice, etc. **If you read the traps on site, use a magnified lens (10-20X).**

Counting beet leafhoppers. Here is the tricky part. The first step is recognizing the leafhoppers from amongst all the insects that yellow sticky cards catch. Figure 15 shows many of the leafhopper species we catch near potato fields.



Figure 15. A multitude of leafhopper species. Leafhoppers are elongate and tapered from head to tail, hold their wings roof-like at rest, and vary in size from about 3 to 10 mm long. BLH are marked in the figure.

Figure 16 shows a sticky trap with many BLH, little dirt and debris, and few other insects. If only all sticky cards were this easy to count. Figure 17 shows a trap that will be much harder to count. Figure 18 demonstrates what a little magnification can do.

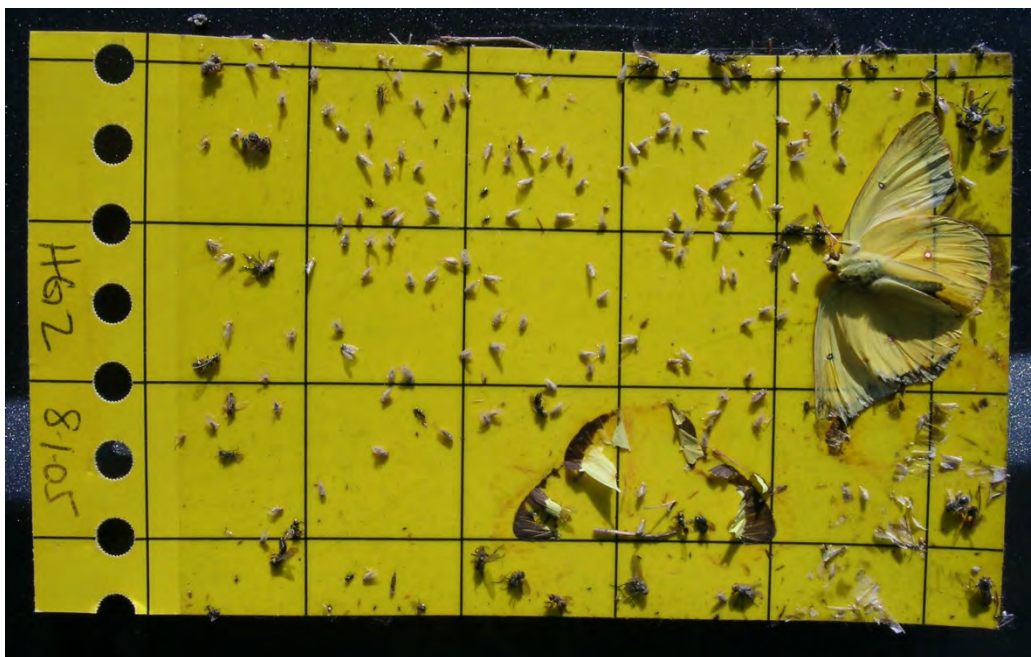


Figure 16. Good BLH catch.



Figure 17. Messy leafhopper trap.

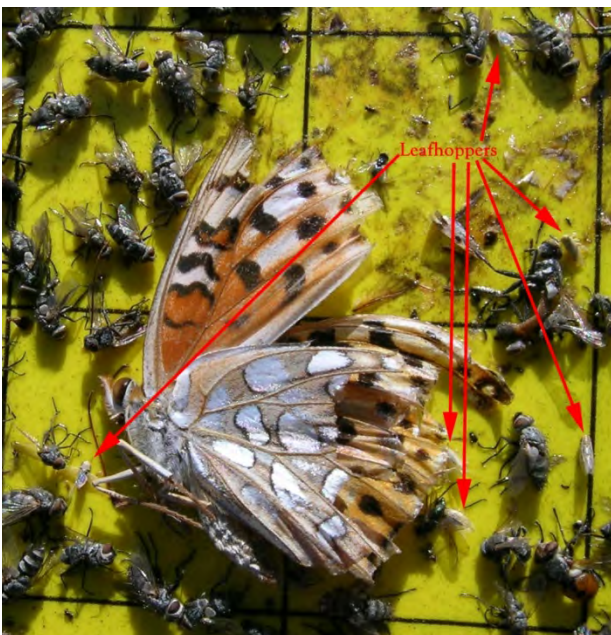


Figure 18. A piece of Figure 17 magnified a little, about what a magnifying glass will do.

Spotting the leafhoppers is easy in Figure 18, but which ones are BLH? It is definitely NOT safe to assume that all leafhoppers on sticky cards are BLH. The other species of leafhoppers shown in Figure 15 can be very common. Those other species do not transmit BLTVA to potatoes, or cause any problem for potatoes. Therefore, it is important to know when you are and are not looking at BLH.

Recognition features for beet leafhopper

1. Size. BLH is one of the smaller species on the cards. Most of the straw-colored specimens shown in Figure 16 are BLH. See Figure 19 for some pictures of BLH with other common species to get a feel for relative size.

2. Color. BLH are relatively pale, lacking strong pigmentation on the head and body. See Figure 20 for some information on BLH variation and comparison of pigmentation to other species.

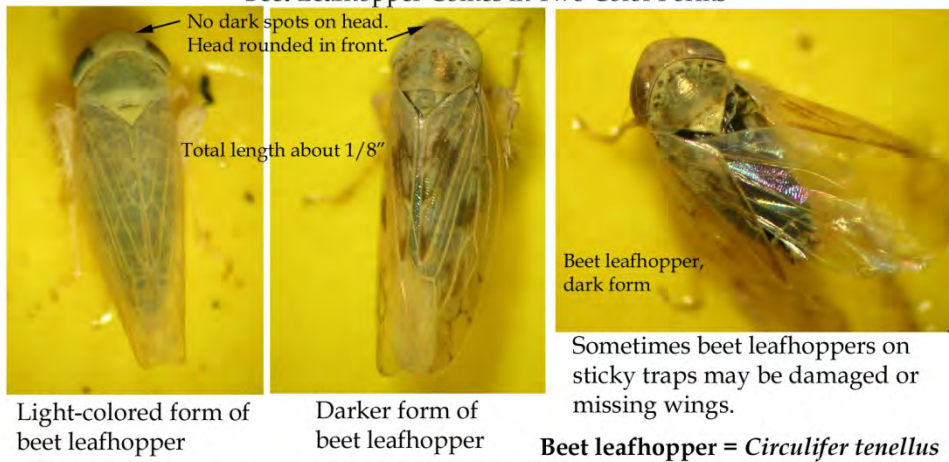
3. Shape. Of the leafhoppers of similar length, BLH is relatively broad in the body. Another critical feature is the gently curved front of the head (as viewed from the top). Some other species have pointed heads, as you can see in Figure 20.



Figure 19. A few common leafhoppers compared to BLH.

Leafhopper Identification on Yellow Sticky Traps

Beet Leafhopper Comes in Two Color Forms

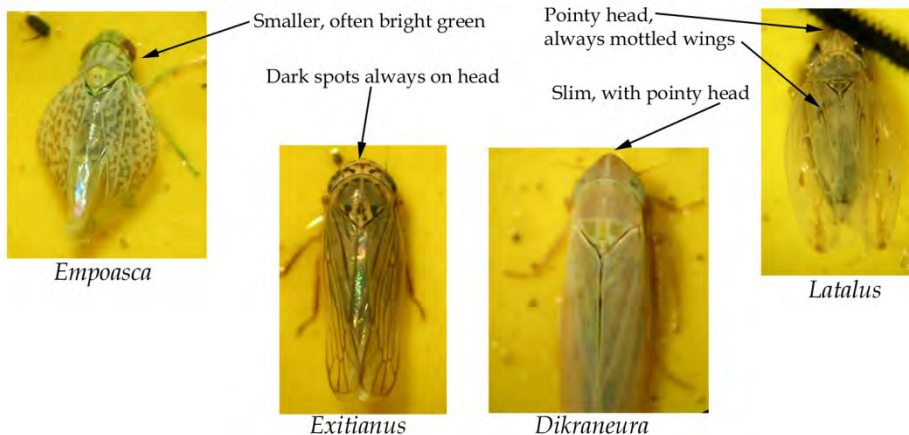


Light-colored form of beetle leafhopper

Darker form of beetle leafhopper

Beet leafhopper = *Circulifer tenellus*

Other Leafhoppers, Which Do Not Transmit Purple Top



Empoasca

Exitianus

Dikraneura

Latalus

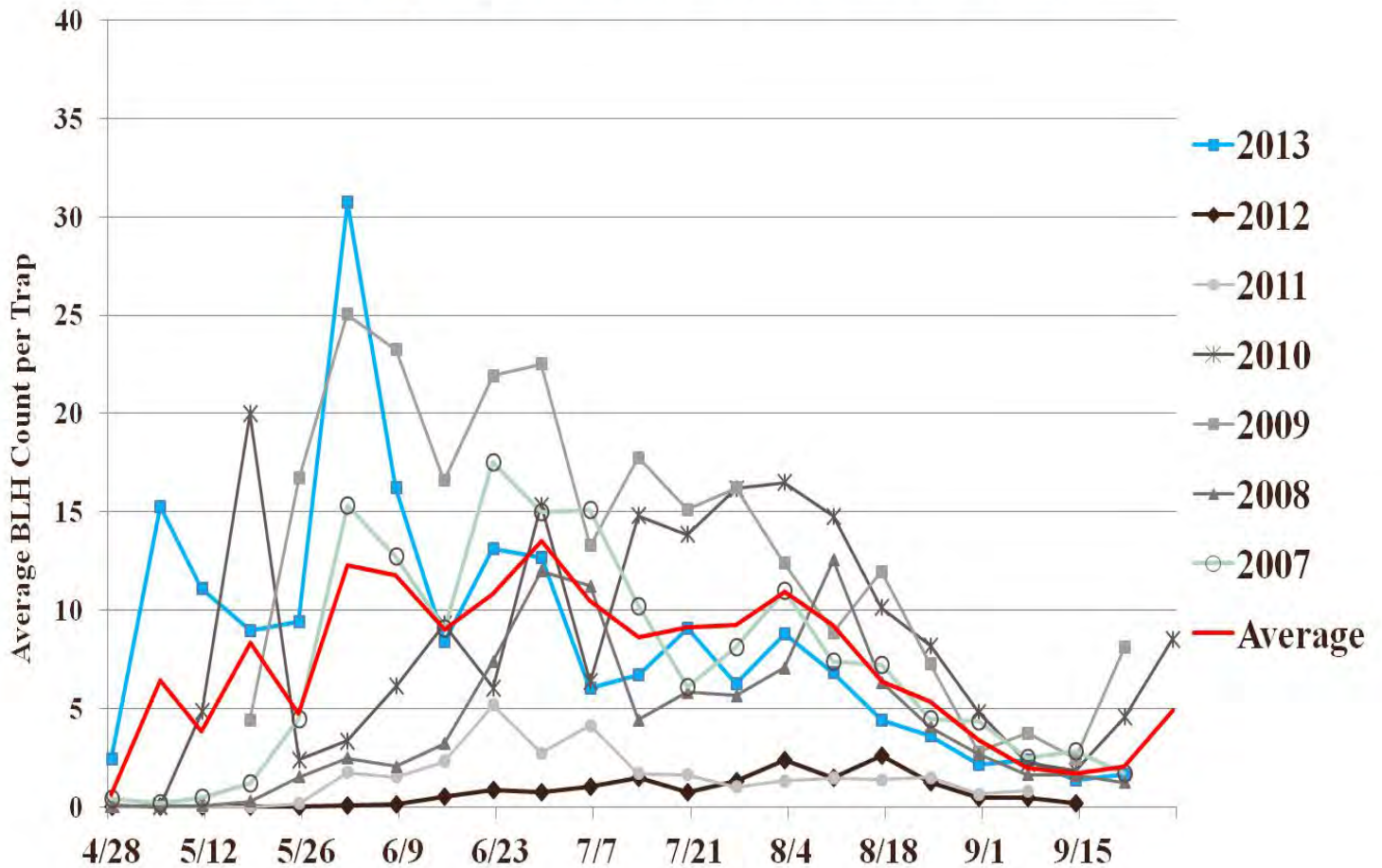
Figure 20. Information on the light and dark forms of BLH, and how they compare to some other common species.

How to Interpret BLH Trap Catch Numbers

Unfortunately, nobody knows how many BLH on sticky traps next to a potato field are enough to warrant treatment of that field. What we do know is that exposure to large populations of BLH during the first 8 weeks or so of plant growth is a bad thing. So all we can do today is offer guidance on what a “large population” is, as detected with yellow sticky cards. We have been conducting region-wide trapping of BLH for several years now, and we can turn to our data for some guidance. Our highest number of BLH caught on a single trap in a week was 471. A more typical weekly catch during a peak of BLH activity is 100. A common scenario for a well-placed trap is to see very few (less than 10 per week) BLH until sometime in mid- or late May. A peak will quickly occur, rising from very low counts to 40 or 50 per week and then to about 100 per week, and then the third week will see very few BLH caught. It is this rapidly peaking flight that is important to detect.

As noted above, it is important to have more than one trap deployed per field, and to check them regularly. When the average catch rate increases toward the equivalent of 40-100 per week, it may be a good time to get worried.

Beet Leafhopper Population Trends in the Columbia Basin of WA Weekly Trapping Data from 2007 to 2013 vs. 7-Year Average



C.H. Wohleb and T.D. Waters, 2013. Sampling Network for Insect Pests of Potato in the Columbia Basin of Washington.

Management of BLTVA in Potatoes

Cultural control.

There is still little research-based knowledge on cultural control techniques for purple top caused by BLTVA. We do know some things about BLH, though, that lead to a few suggestions: favored hosts of BLH during later spring and summer are young kochia plants and Russian thistle. Preventing or eliminating large tracts of these weeds near potato fields will reduce BLH numbers in the area.

Research since 2002 has found that a significant percentage of the BLH in the Columbia Basin are infected with BLTVA (close to 37%). This means that risk from BLTVA infection increases in proportion to the number of BLH.

Insecticidal control.

For the past several years, BLH control programs consisted of foliar applied insecticides. Application intervals should be no longer than 14 days if BLH are active in your area. Intervals less than 7 days are probably not necessary. Early in the season plants can grow very rapidly sometimes doubling in size every 7 days. If BLH flights are occurring during a period of rapid growth, applications should occur at the shorter intervals, particularly for contact insecticides such as pyrethroids.

Consider your overall insect program. Before selecting an insecticide for controlling leafhoppers, think about the impact your selection will have on the rest of your program. Some insecticides have season limits, and use of a product for leafhoppers early in the season may restrict usage later in the season. Most products have a limit on the number of applications that can be made in a season. Often a product can be applied 2 to 4 times, based on its label. Growers should take care not to use all of the applications for a product too early in a season and thereby precluding its use later in the season, and should consider not making more than 2 consecutive applications per season of a product as part of a good resistance management program.

Do not apply Assail, Actara, Endigo, Brigadier, Belay, Admire Pro, or Leverage for leafhoppers if you have already applied Admire Pro, Belay, Platinum or Cruiser at planting due to resistance management concerns. Pyrethroid containing insecticides such as Asana, Baythroid, Ambush and Pounce, or Leverage, Endigo, Hero, Brigadier, and Voliam Xpress, which contain pyrethroids, are tempting choices for control of leafhoppers due to good efficacy against leafhoppers, low price, and broad spectrum. However, broad spectrum products such as pyrethroids also remove beneficial insects that keep pests such as aphids and mites under control. One to three applications of a pyrethroid can result in aphid and mite outbreaks. Pyrethroid containing products have a role in potato insect management programs, but careful consideration should be given to their use for leafhopper control.

Residual Control. BLTVA can be transmitted by a vector that can be difficult to detect, making management of the insect and disease challenging. The greatest likelihood of success in preventing transmission of BLTVA is through the use of longer residual insecticides applied at the beginning of leafhopper flights and maintaining a residue of insecticides on potato foliage that is sufficient to kill leafhoppers. In general, an application should have a period of residual activity of 10 to 14 days, otherwise the number and expense of applications required to maintain control would become prohibitive. Depending on the duration of leafhopper flights and timing of applications, two applications providing 20 to 28 days of control may provide a sufficient interval of control. If plants are actively growing during this time, a contact insecticide, such as pyrethroids, Imidan and Sevin, will not provide control for foliage produced after application. For actively growing plants reduce the intervals of application for a contact insecticide. Because leafhoppers in other cropping systems are considered easy to control, it is tempting to use below labeled rates of insecticides; a not uncommon practice in the Midwest for non-disease transmitting leafhoppers. Reducing the rate of any insecticide will reduce the period of residual activity. Do not use below labeled rates of insecticides for control of leafhoppers potentially transmitting BLTVA.

Efficacy. Leafhoppers are considered to be relatively easy to control. Many of the insecticides listed below will kill leafhoppers, but other considerations reduce the utility of several of them.

Method of Application. In many situations growers choose chemigation to avoid the cost of application; however in this scenario use of chemigation with non-systemic products may result in substantially reduced insecticide levels on the foliage. Due to our lack of knowledge on effect of method of application on efficacy, do not apply insecticides for leafhopper in potatoes via chemigation unless you are confident the application will result in adequate deposition of insecticide residues on the foliage. Obtaining adequate coverage, particularly with contact insecticides, is extremely critical.

Planting Time Insecticides. Admire Pro, Thimet/Phorate, Platinum, Cruiser 5FS and CruiserMaxx Potato and Vydate applied at planting time, all have leafhopper on the label, although none specify beet leafhopper. Based on a review of BLTVA infested fields and a field trial conducted in 2004, planting time treatments did not appear to provide protection against the disease. This observation has at least two different explanations. One explanation is that BLTVA-transmitting leafhoppers probe and feed only briefly on potato, can transmit the disease during this period, and transmission may occur before the insect is killed by the systemic insecticide. A second explanation is that by the time of the season BLTVA transmission occurs, the level of insecticide is insufficient to provide control of the vectoring leafhopper. Based on Alan Schreiber's research, he believes at least 60 to 70 days of control of BLH may be possible with CruiserMaxx, Admire Pro, and Belay. Length of control will vary depending on the rate used, soil and environmental conditions, and insect pressure. It is important to note that the application rate will vary by the number of sacks planted per acre with a maximum use rate of 0.125 lb ai/A. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Endigo Actara, Assail) following this application.

Foliar Products with Limited or No Utility for Control of Leafhopper

M-Pede. This product is thought to have low efficacy; label states product should be used in combination with other insecticides.

Lannate, dimethoate, and malathion. These products will kill leafhopper but have relatively short periods of residual control. Other options exist that have similar efficacy but provide a longer period of control.

Foliar Products with Uncertain Utility for Control of Leafhoppers

Sevin and Imidan. Due to lack of research, it is unclear of the relative efficacy and period of residual activity these products have against leafhoppers. Sevin is registered for use against leafhoppers in other crops such as sugarbeets, cereal grains and several root and tuber crops. Its efficacy against leafhoppers in potatoes is unknown.

Foliar Products with a Higher Potential for Use against Leafhoppers

Asana, Brigadier, Hero, Baythroid, Ambush, Brigade, Mustang Max and Pounce. (Group 3) These products are highly effective against leafhoppers and can provide a longer period of residual control. Additionally, these products will control several other pest species. Use of these products is discouraged in most potato pest management scenarios due to their potential to cause aphid and mite outbreaks. In some situations, these products may be appropriate for control of BLTVA-transmitting leafhoppers in potatoes. Group 3 products have contact activity only and are often applied early in the season when potatoes are rapidly growing, sometimes double in size every 7 days. These pyrethroid insecticides will only control potato foliage present at the time of application. They will not provide control of foliage that appears one or more day after application. For example, in May, most potatoes are growing very rapidly and a potato plant will have significant foliage that is not protected seven days after application of one of these insecticides. If potatoes are rapidly growing, insecticides should be applied at least every seven days to maintain control of leafhoppers.

Admire Pro, Belay and Actara (Group 4a). These products provide good efficacy against leafhoppers and have relatively longer periods of residual activity when applied to the foliage. Due to concerns with resistance management these products should not be used if a neonicotinoid insecticide such as Admire Pro, Belay, Platinum or Cruiser, has been used at planting time. Do not apply the 1.5 ounce rate of Actara more than four times.

Assail 70WP (acetamidiprid, Group 4a). Assail provides effective control of beet leafhoppers and has been shown to reduce the incidence of BLTVA in potato plants. Apply 1.0 to 1.7 ounces/acre by ground, air or chemigation for beet leafhopper control. Control measures should start when leafhopper flights begin and fields

must be protected for at least several weeks following crop emergence to help prevent transmission of BLTVA (causes purple top). A total of 6.8 ounces may be applied per season. Do not make more than 4 applications per season and do not apply more than once every 7 days. Do not apply less than 7 days prior to harvest (7 day PHI). Assail is a systemic insecticide and will move upward in the plant to protect new vegetative growth. Good coverage of the lower portion of the plant is necessary to control pests if present in that area. It is important to obtain complete coverage for best results. Apply Assail in a minimum of 20 gallons of water by ground, 5 gallons by air and a maximum of 0.2 inch/acre by chemigation. When applying Assail by ground or air, use a crop oil adjuvant such as crop oil concentrates (COC), methylated seed oils (MSO), ethylated seed oil (ESO), or use an organo-silicone crop oil blend adjuvant. Avoid the use of Assail with any product containing sticker/binder-type adjuvants when aphid and leafhopper are the target pests. Do not irrigate within 12 hours of an Assail application. There are no rotational crop plant back restrictions for Assail. For resistance management do not apply this product if the field has been treated this year with an at-plant or seed treatment neonicotinoid insecticide.

Transform WG (sulfoxaflor, Group 4C). Apply for control of beet leafhopper by ground, air or chemigation at 1.5 to 2.25 ounces per acre. Refer to the label for specific instructions when applying via chemigation. Transform has a 7 day preharvest interval, a 14 day retreatment interval and a total seasonal limit of 4 applications and a total of 8.5 ounces of Transform per acre per year. Transform can be used during the season if a neonicotinoid (Group 4A) insecticide has been applied at planting as long as an insecticide with a different mode of action has been applied to the target pest prior to the use of Transform. This product does not have a full set of Maximum Residue Limits (MRLs). Use this product with caution if your potatoes have the potential for export. See the section on MRLs at the end of this report for specific MRLs for this product by country.

Leverage 360 (imidacloprid and cyfluthrin, Group 3 and 4A). This is a prepackage mix containing imidacloprid (Admire Pro) and cyfluthrin (Baythroid). Because it contains a pyrethroid insecticide, it is viewed similar to other pyrethroid insecticides. However, because it contains imidacloprid, it does provide a broader spectrum of control and is subject to the same limitations as Admire Pro. Leverage is a very effective against leafhoppers. Do not apply this product if the field has been treated this year with any neonicotinoid (Admire Pro, Belay, Cruiser or Platinum.)

Baythroid XL (cyfluthrin, Group 3). Research in 2007 demonstrated that four applications of Baythroid applied at 2.8 fluid ounces per acre provided excellent control of beet leafhopper and prevented transmission of BLTVA.

Mustang Max (zeta-cypermethrin, Group 3). Research in 2007 demonstrated that four applications of Mustang Max applied at 4 fluid ounces per acre provided excellent control of beet leafhopper and prevented transmission of BLTVA.

Vydate (oxamyl, Group 1B). Based on several anecdotal observations from the 2002 growing season, a program including 3 to 4 applications of Vydate applied in June and July controlled transmission of BLTVA, while adjacent fields without a Vydate program were highly symptomatic and tested positive for the phytoplasma. Based on knowledge of how this product works and experiences from the 2002 growing season, Vydate can be an important tool for control of BLTVA. Careful consideration must be given to timing of the early applications of the product. Applications should begin before or at the very beginning of leafhopper flights.

Potato Tuberworm

These guidelines are intended for Washington and Oregon, but may have utility outside of this geographic area.

There is much about the biology and management of potato tuberworm (PTW) in the PNW that is unknown. The following guidelines represent our best understanding of this pest in potatoes in the PNW. When possible, these guidelines are based on local research. For more information visit

<http://cropandsoil.oregonstate.edu/group/potatoes>.



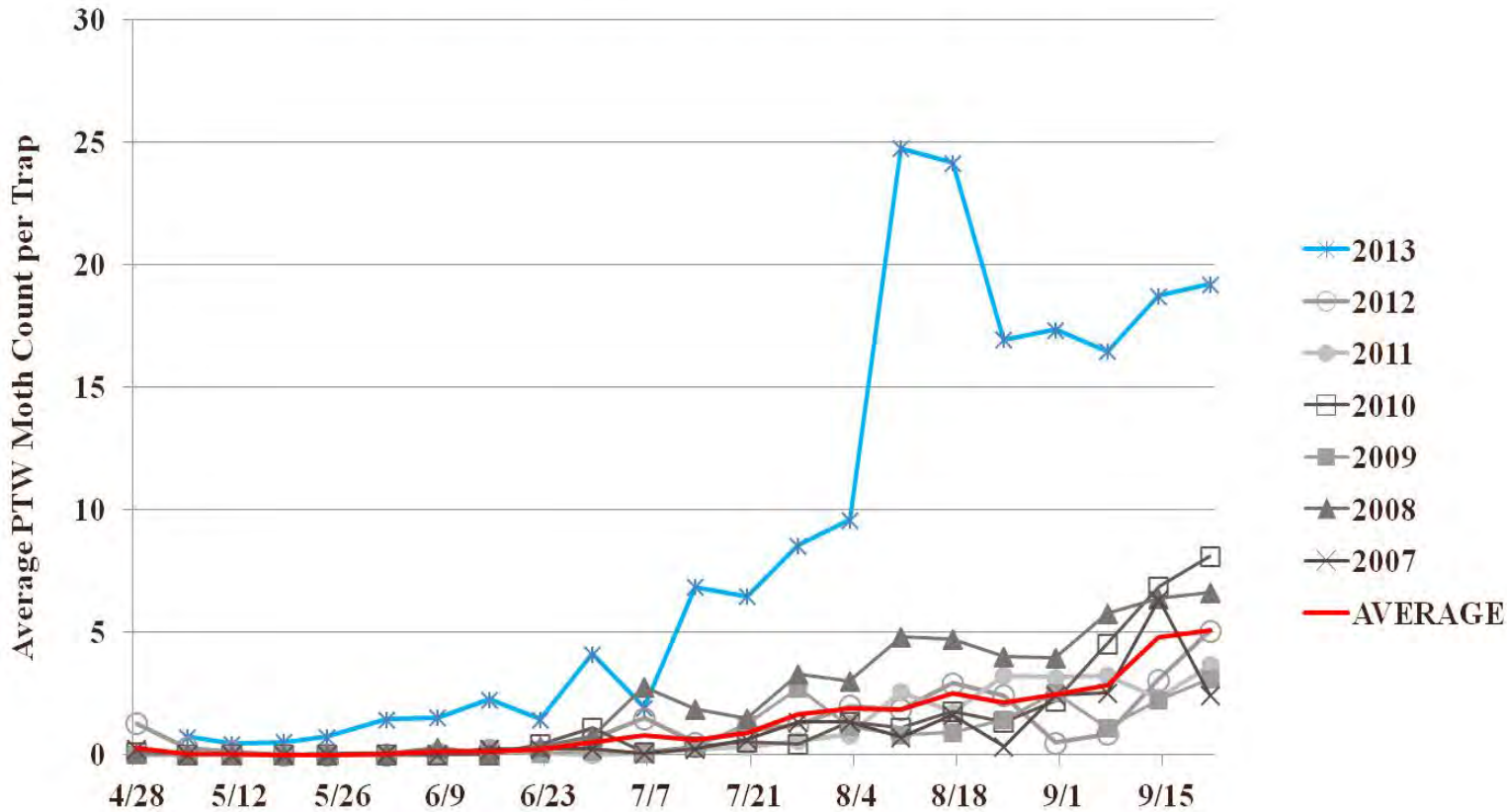
Potato tuberworm, *Phthorimaea operculella* (Zeller), is one of the most economically significant insect pests of cultivated potatoes (PTW, Figure 21). The first significant economic damage to potato crops in the Columbia Basin region occurred in 2002, when a field in Oregon showed high levels of tuber damage associated with PTW; by 2003, the pest was a major concern to all growers in the region after potatoes from several fields were rejected by processors because of tuber damage. Since then, PTW has cost growers in the Columbia Basin millions of dollars through increased pesticide application and unmarketable potatoes. Although the recent

outbreak is the first report of major, widespread damage caused by PTW in the region, there is

Figure 21. Tuberworm larva on damaged tuber.

evidence that PTW has been present in the PNW for a long time. A recent study suggests that locations with higher spring, summer, or fall temperatures are associated with increased trapping rates in most seasons. Moreover, elevation and latitude appeared to play a constraining role since low densities of PTW were associated with higher elevations and latitudes. It remains unclear how severe of a pest PTW will be in the Columbia Basin in the following years but it is highly likely that the species will be with us for the foreseeable future. Probably the most important issue in PTW success is its ability to survive the winter in the pupal stage. Thus far, Franklin, Benton, Walla Walla counties of Washington and Umatilla and Morrow counties of Oregon are likely to be at the highest risk of PTW infestations.

**Potato Tuberworm Moth Population Trends
in the CENTRAL/SOUTH Columbia Basin
Weekly Trapping Data: 2007-2013 vs. 7-Year Average**



C.H. Wohleb and T.D. Waters, 2013. Sampling Network for Insect Pests of Potato in the Columbia Basin of Washington.

Host Range. Although its host range includes a wide array of solanaceous crops such as tomatoes, peppers, eggplants, tobacco, and weeds such as nightshade, it has only been found on potatoes in the PNW. PTW has been detected in all potato growing regions of Oregon and throughout the Columbia Basin of Washington. A limited number of adult PTW have been trapped in western Idaho and far eastern Oregon. No tuber damage has been reported in Idaho.

PTW adults emerge as early as April in the Columbia Basin, and continue to threaten the crop through November. The first years of this outbreak, many crop managers begin insecticide application, either aerial or chemigated, as soon as moths were detected. This practice may have been unnecessary. Although PTW is present throughout the growing season, early and mid season foliar infestations have been light to moderate; however, PTW populations appear to build sharply later in the growing season (September and October) and can cause tuber damage. Thus, control efforts should be directed toward populations during this time. If PTW populations appear to be building prior to this time, additional control measures may be necessary.

Non-Chemical Control Methods

Cull Piles and Volunteer Potatoes. PTW thrives on potatoes. Elimination of cull potatoes and piles and control of volunteer potatoes will reduce your exposure to PTW populations. Feeding cull potatoes to cattle will not eliminate risk from PTW unless potatoes are consumed immediately. Potatoes left unharvested can also be a source of PTW.

Irrigation. During mid to late season, apply irrigation water daily or often enough to keep the soil surface moist. Research in other areas of the world has shown that tuber infestations are greater when the soil is dry. Research conducted in Oregon in 2005 and 2006 showed that irrigating with 0.10 inches daily from vine kill to harvest decreased PTW damage and did not significantly increase tuber rot. It is thought that either the insect cannot reach the tubers as easily in wet soil or dry soil has cracks that result in more exposed tubers.

Desiccation. PTW females prefer to lay eggs on potato foliage. When potato foliage starts to degrade and turn color, the risk of tuber infestation increases greatly. The period between desiccation and harvest is a time of increased risk of tuber infestation. Between 100% vine kill and harvest is the time of greatest risk of tuber infestation. Anything that will reduce the time between desiccation and harvest is thought to reduce the risk of tuber infestation. Selection of desiccant may influence PTW tuber infestation; however a 2005-2006 research project on PTW and desiccants in Oregon found that the rate of vine desiccation did not impact tuberworm damage, and the researchers concluded that the rate of vine-dying is not an important factor, as long as there are green vines in the field.

For more information visit

<https://catalog.extension.oregonstate.edu/sites/catalog.extension.oregonstate.edu/files/project/pdf/pnw594.pdf>

When should insecticides be applied for PTW? PTW tuber infestations increase as the amount of potato foliage in the canopy decreases. In other locations, particularly in California, control programs have targeted the interval leading up to desiccation and harvest. Control programs in Washington and Oregon that have focused on the period of 4 to 8 weeks prior to harvest have been successful in reducing PTW in potato tubers. A 2005 study at OSU Hermiston that examined Monitor, Asana and Lannate applied at regular intervals starting at 1, 2, 3 and 4 weeks prior to desiccation found no difference in tuber infestation, suggesting that control of PTW just prior to desiccation and harvest is critical. The same trend was observed in 2006 and 2007. Application of all insecticides in this trial controlled PTW compared to the untreated check. It is recommended that PTW control programs start no later than 4 weeks prior to desiccation/harvest.

Chemical Controls

Products that have been found to be effective for control of PTW in Washington and Oregon – based on testing in 2004 and 2006. All rates are in formulated product per acre. Unless otherwise noted, the products discussed in this section were found to reduce the incidence of PTW larvae in the foliage to close to zero in a moderate pressure situation or significantly reduce larval populations in a high pressure situation. All treatments began approximately four to six weeks before desiccation.

Rimon 0.83EC. Rimon applied at 9 and 12 ounces provided effective control of PTW when applied at a 10 day interval by ground and chemigation.

Avaunt. Avaunt was effective when applied by ground and chemigation at 7 day intervals at 3 and 5 ounces. Avaunt applied by chemigation at desiccation and 7 days after desiccation was effective at reducing tuber infestation.

Abamectin. Abamectin was effective when applied by ground at 7 day intervals at 10 ounces for an EC formulation. Rates are lower for SC formulations.

Asana. Asana was effective at 4 and 8 ounces when applied by ground and chemigation at 7 to 10 day intervals. There is no indication that the higher rate is more effective.

Lannate. Lannate applied by ground and chemigation at 1 and 2 pints at 5 day intervals was effective at controlling PTW.

Imidan. Imidan at 1.3 and 2.5 pints applied by ground at 10-day intervals was effective against PTW.

Success. Success was effective at 6 ounces when applied by ground at a 7 day interval.

Leverage 360. Leverage applied by ground and chemigation at 10 day intervals at 3.75 ounces was effective against PTW.

Baythroid XL. Baythroid at 1.5 ounces was effective when applied by chemigation at 10-day intervals.

Hero. Hero was effective at 8 ounces per acre at 10 day intervals when applied by ground

Assail. Based on the results of research trials in 2005, Assail is not recommended for PTW; however use of the product against other insect pests may reduce PTW populations.

Dipel (*Bacillus thuringiensis*). Dipel at 1 pound per acre applied by ground in rotation with Entrust at 3 ounces per acre at 10-day intervals was effective in controlling PTW. Entrust was applied first and third and Dipel was applied second and fourth.

Aza Direct. Aza Direct applied at 2 pints per acre at 10 day intervals by ground significantly reduced PTW populations.

Products Considered Ineffective Against PTW. No planting time treatments have been documented to be effective against PTW.

Foliar Insecticides Considered Ineffective Against PTW. Sevin, dimethoate, Fulfill, Beleaf, Acramite, Comite, Onager, Movento and Oberon are considered ineffective against PTW.

Treatment Intervals and Rates of Application. Research conducted in 2005, 2006 and 2007 included treatment intervals at 5, 7 and 10 days and products were tested at the higher end of the range of labeled rates in most cases. In many cases, the products were very effective against PTW. It is possible that products can be applied at wider intervals, at lower rates, or at both wider intervals and lower rates than were tested.

Spectrum of Control. It is likely that growers will have other insect pests present at the same time PTW is targeted. Other pests that require control at the same time as PTW can influence selection of an insecticide for PTW control. Following is a spectrum of control guide for PTW active insecticides. This information is taken from a variety of sources including product labels, discussion with agchem company representatives and my own research and knowledge (Alan Schreiber).

Effectiveness of PTW active products against other potato insect pests¹

	Beet Leafhopper	Colorado Potato Beetle	Green Peach Aphid	Cabbage Looper	Thrips
Imidan	xxx	xxx		xx	
Success		xxx		xx	x
Assail	xxx	xxx	xx		xx
Leverage	xxx	xxx	x	xxx	
Baythroid	xxx	xxx		xxx	
Asana	xxx	xxx		xxx	
Abamectin		xxx			xx
Lannate	xxx	x	x	x	x
Avaunt				xxx	
Rimon		xxx		xxx	
Coragen		xxx		xxx	

- 1 xxx = efficacy against the pest is high; xx = efficacy is moderate; x = efficacy exists but may not be commercially acceptable. A lack of x's means no efficacy data exists. Other factors including cost, length of residual control, impact on secondary pests and beneficials and label restrictions may influence choice.

Important Use Restrictions – Pay Attention!

In recent years, growers have been targeting new insect pests of potatoes such as PTW, beet leafhopper, psyllids and thrips. Because of these new pests, growers must choose their products carefully. All insecticides have restricted entry interval (REI), a preharvest interval (PHI) and a limit on the amount of product that can be used in a single season and plant back restrictions.

Prior to PTW, growers have not had to control insect pests near harvest time. Now selecting products near harvest is critical and significant differences exist in PHI among PTW active insecticides. Abamectin productions have 14-day PHIs, while other products have shorter PHIs such as Baythroid (0 day PHI).

Economic Threshold. No economic threshold has been established for PTW in the PNW.

Method of Application. All PTW insecticide research in Washington and Oregon was conducted via ground or chemigation. Virtually all commercial PTW applications are made using air or chemigation applications. Significant additional work needs to be done to ascertain the best method of application for control of PTW. The majority of PTW larvae are in the top third of the foliage; however a portion of PTW exist in the middle and lower portion of potato foliage. Accordingly, as with many other insect pests, coverage is important. Some products may be more effective when applied by air or chemigation. Regardless of method of application, take appropriate steps to insure adequate coverage of foliage with insecticides.

Organic Potatoes. Growers of organic potatoes can expect a difficult time controlling PTW. One strategy is to harvest as early as possible to avoid the build-up of PTW infestations. Three organically acceptable chemical control options have been found effective against the insect pest; Entrust, Dipel and Azadirect.

Entrust. Entrust, the organic formulation of Success, was effective when applied at 6 ounces by ground at 10 day intervals.

Dipel (*Bacillus thuringiensis subsp. kurstaki*). Dipel at 1 pound per acre applied by ground in rotation with Entrust at 3 ounces per acre at 10 day intervals was effective in controlling PTW. Entrust was applied first and third and Dipel was applied second and fourth.

Azadirect (Group # unknown). AzaDirect applied at 2 pints per acre at 10 day intervals by ground significantly reduced PTW populations.

Pyrethroid Insecticides. Research by Alan Schreiber has conclusively demonstrated that application of pyrethroid insecticides mid and late season will flare aphids and mites in potatoes. Application of insecticides in May and the first half of June does not appear to result in aphid and mite infestations. Pyrethroids should not be applied for PTW after June 15 in the Columbia Basin of Washington and Oregon in order to prevent the flaring of aphids and mites. One exception to this rule is during the two weeks prior to harvest or desiccation. Two weeks prior to harvest or desiccation does not allow sufficient time to flare aphids or mites.

Resistance. PTW has a number of characteristics that have allowed it to develop resistance to insecticides. PTW has developed resistance to insecticides used for its control in several locations around the world. *It is critical that growers prevent PTW from developing resistance in the PNW. To achieve this, the potato industry must incorporate resistance management into PTW control programs from the beginning.*

There are two key components to developing a resistance management program for PTW. First, growers must employ non-chemical control tactics for control of PTW, including irrigation, cultivation and proper hilling of potatoes. Second, growers must rotate insecticidal modes of action, in the same manner as growers currently rotate fungicides in late blight programs. The PNW potato industry is fortunate that we have a large number of insecticides that have demonstrated efficacy against PTW. These products can be separated into 8 different modes of action.

We recommend that growers incorporate different modes of actions in a PTW management program. There is no order in which the products should be rotated. No group is recommended over other groups.

PTW active insecticides grouped by mode of action

- 1) Organophosphates: Imidan
- 2) Rimon
- 3) Avaunt
- 4) Abamectin
- 5) Pyrethroids: Asana, Leverage, Baythroid, Brigade, Brigadier, Ambush, Warrior
- 6) Success, Blackhawk, Entrust, Radiant
- 7) Carbamates: Lannate
- 8) *Bacillus thuringiensis*

If Assail is used during the course of a PTW control program, it would count as a ninth and separate mode of action.

Chart for activity by life stage. This information is based on 2005 research data, information provided by registrations and our knowledge of the products listed.

Product	Egg	Larvae	Activity against larvae	
			Adult	in leaf tissue
Imidan		x	x	
Rimon	x	x		
Avaunt	x	x		x
Abamectin		x		
Asana		x	x	
Leverage		x	x	
Baythroid		x	x	
Success, Entrust		x		
Lannate		x	x	x
Bacillus thuringiensis		x		
Assail		x		

Pheromone Trapping

Prepared by Andy Jensen, WSPC, and Peter Landolt, USDA-ARS

All growers in areas even **potentially** affected by PTW should maintain at least one pheromone trap adjacent to each field starting April 15. This insect can have very localized infestations, and it is risky to conclude too much from traps that are miles away from your field(s).

Like hundreds of other moths, the adult female PTW releases a sex pheromone which attracts males for mating. That pheromone has been identified and is sold for use in traps to detect or monitor changes in the presence of the moth. The pheromone is a blend of two chemicals: (E,Z)-4,7-tridecadienyl acetate and (E,E,Z)-4,7,10-tridecadienyl acetate. These chemicals are absorbed into rubber septa as the lures, which then slowly release the pheromone when placed in a trap. The attractiveness of the lure varies with the amount of pheromone put into the septum, and less so by the ratio of the two chemicals. The numbers of moths captured is also affected by the design of the trap. In order to compare experimental results between sites and years, it is best for researchers to consistently use the same lures and traps. In order to appropriately interpret trap catch data, it is best for growers to use lures and traps that are as similar as possible to those used by researchers.

The multi-year potato tuberworm monitoring project coordinated by Andy Jensen and Carrie Wohleb in Washington and Silvia Rondon in Oregon, uses lures that are loaded with a 1:1 ratio of the two chemicals, with a total load per septum of 200 micrograms. These lures have been made at the USDA-ARS Laboratory near Yakima. These are put in Delta traps and are replaced after 4 weeks exposure in the field.

Pheromone traps should be mounted within or very near the potato fields, close to the ground or canopy (about 12" high). We recommend using a re-usable plastic Delta trap with replaceable sticky liners. These liners should be monitored as often as possible, and replaced weekly. Pheromone lures should be changed every 4 weeks, and kept frozen prior to use. In the Columbia Basin of Washington and Oregon the tuberworm pheromone lure attracts many other species of moth that are not tuberworm and are not pests of potato. Persons uncertain about moth identification are encouraged to have an entomologist confirm the identification of their moths. See also the tuberworm information on the potato commission's website:

<http://www.nwpotatoresearch.com/IPM-Home.cfm>. Moth trap catch information cannot be readily translated into risk of tuber damage, but it is clear that at lower population densities, greater moth catch indicates greater risk. Pheromone traps are especially useful for detecting initial infestations in an area.

We are conducting the regional tuberworm trapping network again this season. Trapping information can be found at <http://www.nwpotatoresearch.com/IPM-Home.cfm>.

Scouting and Sampling for PTW

Prepared by Sandy DeBano, OSU

Several issues related to scouting were examined in Oregon in 2005, including determining the length of time it takes to visually sample whole plants in the field for PTW foliar damage, the accuracy of those counts, and the number of plants that must be sampled to give a reliable estimate of foliar damage in a given area. An examination of the foliage of a single potato plant takes approximately 2 minutes and detects less than 50% of the mines that can be found in a thorough examination in the laboratory. Most mines (56%) are found in the upper third of the plant canopy, suggesting that efficient scouting for foliar damage should focus on the top third of the plant. The number of mines on a plant is correlated with the number of larvae in a plant, but not strongly. This means that while number of mines gives a good indicator of the history of PTW infestation of a plant, it does not necessarily indicate the severity of larval infestation at a point in time. The study also found that reasonably precise estimates of foliar damage for areas of 23 ft x 30 ft can be made by sampling 9 plants. While this information may not be useful for scouting large fields until we understand the pattern of damage in large areas, it should be useful for researchers attempting to quantify foliar damage.

Thrips

Thousands of acres of potatoes treated in Idaho, Washington and Oregon each year for thrips annually.. We estimate that between 10 and 25% of potato acres in Washington are treated for thrips depending on the year. The pest is most commonly a problem in longer season potatoes because the thrips have more time to build up to damaging levels. The actual damage or yield loss that occurs on a per acre basis is unknown.

The distribution of fields treated for thrips ranges from the southern Columbia Basin to north of Moses Lake and the western half of southern Idaho. However, some areas of the Northwest seem to perennially not have problems with thrips, these include western Oregon and Washington, central Oregon, eastern Idaho and the Yakima Valley. Most of these areas either have shorter growing seasons or grow potatoes for shorter periods of time. The leading theory of why thrips have become known as a pest in potatoes is due to a shift in insecticides used on potatoes. Formerly, most potatoes in Washington were treated with carbamate (Temik, Furadan) and organophosphate (Monitor, dimethoate, Di-Syston, etc) insecticides. These products have efficacy against thrips. In the last ten years, product removals (e.g. Di-Syston, Monitor and Furadan), and introduction of new insecticidal products that do not have thrips activity have probably influenced thrips populations. The widespread use of neonicotinoid insecticides, such as Admire, Platinum and Belay and highly selective insecticides such as Beleaf and Fulfill has allowed thrips populations to surge that formerly had been controlled by broader spectrum insecticides.

Based on casual surveys, it has been assumed that the thrips species involved in potato outbreaks are western flower thrips, *Frankliniella occidentalis*. Knowing the species involved is important as differing thrips species have varying susceptibility to insecticides. Based on grower observations that potato fields following onions have thrips outbreaks more often than fields not following onions and some preliminary research by WSU entomologist, Bill Snyder, there is some evidence onion thrips, *Thrips tabaci*, may also occur in some potato fields. According to OSU Entomologist Stuart Reitz onion thrips can be by found in potato fields in Malheur county, but the overwhelming majority are western flower thrips.

Due to its cryptic nature, life cycle characteristics and recent appearance as a pest, virtually no research has been conducted on this species in potatoes. Based on some limited efficacy research funded by the Washington State Potato Commission, products that have been found to have some efficacy against thrips on potatoes are Endigo, Radiant, Lannate, Hero, Mustang Max, abamectin, Athena and dimethoate. Based on multiple field observations in 2012, Radiant demonstrated significant efficacy against thrips.

Understanding the lifecycle of thrips is important to improving control of the insect. Thrips on potatoes have a relatively short lifecycle, have shorter lifecycles when it is warmer and have multiple generations per year. The longer and warmer the potato growing season; the greater potential for high thrips numbers. Thrips grow whenever temperatures are above 46 F and their ideal temperature range is 77 to 90 F. At the higher temperature range, western flower thrips complete a full life cycle in 9 to 13 days.

Thrips often invade fields from adjacent areas, particularly dryland areas. The earlier in the season or the greater number immigrating into the fields, the more likely a field is to have a thrips outbreak.

Thrips eggs are inserted into the leaf tissue, the immature thrips hatch from the eggs and feed on the surface and more commonly on the underneath of the leaf surface. There are two active feeding larval instars. After a few days they will drop off the plant and pupate in the soil. There are two pupal instars. They emerge from the soil and climb or fly up to the potato plant start feeding and then start the cycle over again. A key point to this is that the egg stage and the pupal stage are cryptic and may not be sufficiently exposed to receive a toxic dose of insecticides.

Thrips have a curious characteristic, called thigmotaxis, that causes them to seek out and spend much of their time in tightly enclosed and concealed places on a plant. In particular, the thrips are common in plant flowers and growing points of the plant. This further keeps some insecticides from reaching them. Unfertilized thrips eggs develop into males and fertilized eggs develop into females, which may help the population colonize and build in number more quickly.

The combination of the short lifecycle, multiple generations, one life stage buried in the plant, one life stage is off the plant and their predisposition for not being exposed to pesticides on the plant surfaces make this insect a difficult one to manage. Potato growers can learn something from onion growers who have been dealing with thrips problems for a long time.

- Thrips will rarely be controlled by a single application. A typical onion program will include up to six or more insecticide applications, consisting of different modes of action. A successful thrips program in potatoes may require at least two and more likely up to four applications.
- Better control is achieved by rotating chemistries. Fortunately, the six products that are listed for thrips control belong to five different modes of action (Hero and Mustang Max are both pyrethroids and should be considered identical products in terms of their mode of action).
- Applications should be 7 to 14 days apart depending on pressure. The higher the pressure, the shorter the interval.
- If a product has a rate range use the higher end of the rate range when attempting to control thrips..
- Each of these products control other pests and your decision on which to use may depend on what other pests you have present. Abamectin will also control Colorado potato beetle. Radiant will also control armyworms, cutworms, loopers, potato tuberworm and Colorado potato beetle. Dimethoate and Lannate will also control aphids and leafhoppers. Hero and Mustang Max will also control leafhoppers, armyworms, cutworms, loopers, potato tuberworm and Colorado potato beetle.
- Consider other factors. Hero and Mustang Max will remove most beneficial organisms, including predators of thrips, and increase your risk of flaring aphids and mites. It is not recommended to use pyrethroids between June 15 and two weeks before harvest. Dimethoate and Lannate are relatively short residual products and should not be expected to have residual control longer than 7 days.
- There is no an established economic threshold or action threshold for thrips in potatoes. It is not known when growers should initiate applications. If thrips have built up into high numbers it is probably impossible to reduce the population down to a negligible level. Initiate insecticidal programs prior to the presence of necrotic lesions caused by thrips feeding. Usually thrips build up in very high numbers by August, however in 2012 thrips numbers reached damaging high levels by mid July.

Abamectin SC (abamectin Group 6). 1.75 to 3.5 fl oz of Agri-Mek SC by air with 5 gallons of water per acre. Avoid the use of Agri-Mek with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or DithaneRainshield). The addition of a nonionic surfactant or organosilicone-based surfactant, at the manufacturer's recommended rate is suggested for optimum control.

Radiant SC (spinetoram, Group 5). Apply 6 to 8 fluid ounces of Radiant per acre by air, ground or chemigation. Time applications to target early outbreaks of thrips. Heavy thrips populations may not be control with use of Radiant. Applications by chemigation at either rate should be made with 0.25 acre inches of water or less. Acidic (< 6 pH) spray solutions should be avoided. The pH of spray solution should be checked prior to

adding Radiant into the tank and adjusted, if necessary. Acidifying products such as boron should be avoided. In addition, prior to adding Radiant to a tank it is recommended to conduct a compatibility test.

Dimethoate (Group 1B). The 4E formulation may be used at 0.5 to 1.0 pints per acre. It may be applied by ground, air or chemigation. (There are no data showing efficacy by chemigation.) Dimethoate has a short period of residual activity. Use of the higher rate is recommended. Efficacy may be marginal against higher populations of aphids. It has a 2 day post harvest interval, a 48 hour reentry interval and a 7 day retreatment interval. A total of 2 pints may be applied per season.

Hero (zeta-cypermethrin, bifenthrin, Group 3). Apply at 4 to 10.3 ounces per acre. Applications must be at least 21 days apart, do not apply more than 40.6 ounces of product per acre per season. There is a seasonal limit of two applications per year. Apply by ground or air only, no chemigation application.

Lannate (methomyl, Group 1A.) Apply 1.5 to 3 pints per acre. Apply by ground, air or chemigation. If applied by chemigation apply with 0.1 to 0.2 acre inches of water and refer to the product label for significant additional information on chemigation instructions. There is a 6 day preharvest interval and a 48 hour reentry interval and a season long limit of 15 pints per acre and a maximum of ten applications.

Mustang Max (zeta cypermethrin, Group 3). Apply at 3.2 to 4.0 ounces per acre. Applications must be at least 4 days apart. Apply by ground in a minimum of 10 gallons of water or apply by air in a minimum of 2 gallons of water.



Figure 22. Western flower thrips on potatoes; left is an adult, right is an immature.

A potato thrips program would probably consist of something like Radiant followed by dimethoate, followed by Radiant, followed by dimethoate or abamectin, abamectin, Lannate, Lannate.

There are no nonchemical control methods recommended for use on potatoes to manage thrips. There can be large numbers of predators (pirate bugs, big-eyed bugs, etc.) that can suppress thrips populations. If growers target thrips, select a product like Radiant (rather than dimethoate or Lannate) to help conserve beneficials.



Figure 23. Thrips damage to potatoes in Idaho.

Whitefly

When sampling for potato psyllid in 2014 one could commonly find the adults, nymphs and eggs of greenhouse whitefly later in the season. The eggs and nymphs look similar to potato psyllids. Adults resemble tiny white moths about 0.1 inch long. Immature forms look like scale insects or psyllids and are completely sedentary after the first nymphal instar.

Biology and life history. Greenhouse whitefly is a common pest of many crops and ornamental plants all over the world. Eggs are laid individually on leaves, the immature stages remaining on the same leaf throughout development. Therefore, larger whitefly nymphs will be found on mid-canopy leaves. The final immature stage is much like a pupa, with the adult developing inside the cast nymphal skin. Whiteflies have short generation times, with multiple generations per season.

Adult whiteflies are easy to spot flying within the plant canopy. Whitefly nymphs are much more difficult to measure – a leaf sampling scheme is required since they are not dislodged during beating sheet/tray sampling. There is no established treatment threshold for whiteflies in PNW potatoes. Greenhouse whitefly is not thought to be a pest of potatoes in the Pacific Northwest. At this time, it is recommended to discount the insect as a pest of potatoes. In 2014 efficacy trials in Washington, efficacy data were collected against this insect species. If the insect does become of pest of potatoes, a number of products with efficacy against potato psyllid were found to have efficacy against greenhouse whitefly.



Figure 24. Whitefly adult.



Figure 25. Whitefly immature, which cannot walk.



Figure 26. Whitefly eggs.

Whitefly eggs are often laid in groups and are similar in appearance and shape to potato psyllid eggs; however, they are less orange in color. Whitefly eggs and nymphs often occur in the center of a white scurfy discoloration of the potato leaf. Immature whitefly are flat, relatively opaque and do not move after the first instar, which is hard to see while a potato psyllid immature resembles leafhopper immature and readily moves.

Potato Psyllid and Zebra Chip (ZC)

Alan Schreiber, Agriculture Development Group, Inc., Andy Jensen, Northwest Potato Research Consortium, and Silvia Rondon, Oregon State University

Research conducted in the region indicates that potato psyllid is easier to control when applications start prior to population establishment. Population establishment is defined as potato psyllids successfully laying eggs that lead to development of a nymphal population. Products that controlled psyllids when applications started prior to population establishment were less effective when applied in a rescue situation. It is critical to start psyllid control programs prior to population establishment. Rescue treatments made to established populations of potato psyllids containing the causal agent of zebra chip may not be successful.

The potato psyllid (*Bactericera cockerelli*) is a phloem-feeding insect that reproduces mostly on the potato and nightshade family (Solanaceae) and the morning glory family (Convolvulaceae). Zebra chip (ZC) is characterized by development of a dark striped pattern of necrosis in tubers (Fig 1). The pathogen associated with ZC is the bacterium *Candidatus Liberibacter solanacearum* and is vectored by potato psyllid.

Identification

Potato psyllids pass through three life stages: egg, nymph and adult. All life stages are difficult to detect. The adults look like small cicadas, about 0.08 inch (2 mm) long (Fig. 2A). They are closely related to aphids and leafhoppers and have clear wings that rest roof-like over the body. Although predominantly black, the potato psyllid has white markings. The first abdominal segment shows a broad white band, the last segment has an inverted white "V". Psyllids jump readily when disturbed.



Figure 27. ZC tuber symptoms.

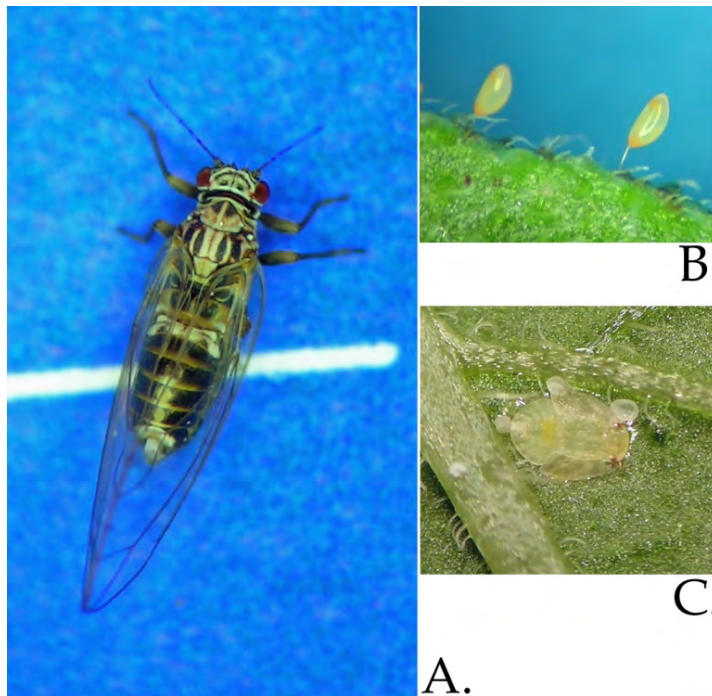


Figure 28. Potato psyllid life stages. A. Adult; B. Egg; C. Nymph.

The football-shaped eggs (Fig. 2B) are extremely small, slightly larger than leaf hairs, and on a short stalk. They are usually on the underside and along the edges of leaves and are usually laid in the upper plant canopy. A 10X hand lens or magnifying glass is required to see them.

Psyllid nymphs (Fig. 2C) look like immature soft scale or whiteflies. Unlike whiteflies, when disturbed, they move readily. They are flat and green with a fringe of short spines around the edge. Immature psyllids go through five stages in as little as 13 days in warm temperatures.

Potato psyllid can damage a plant even if it does not carry the bacterium since these insects feed directly on the plant and may weaken it. As they feed, psyllids inject toxins with their saliva that can cause leaf yellowing or purpling, smaller and fewer tubers, and misshapen tubers. This physiological condition has been dubbed “psyllid yellows” disease (Fig 3) and is generally less damaging than ZC.

The psyllid acquires the bacterium when feeding on an infected plant or from its mother who can transmit the bacterium to her offspring via the egg. Once infected the insect is always a carrier of the bacterium. The disease usually takes about 3 weeks from infection to produce symptoms in the foliage and tubers.



Figure 29. Psyllid yellows foliar damage.

First identified in northeastern Mexico in 1994 and south Texas in 2000, ZC has now been reported from most of western U.S.A. Also, the disease was reported in New Zealand and several countries in Central America. Plants affected by ZC exhibit a range of symptoms that are similar to potato purple top and psyllid yellows, including stunting, chlorosis, leaf scorching, swollen internodes near apical portions, axillary bud and aerial tuber proliferation, necrosis of vascular system, and early death. The name “zebra chip” refers to the characteristic brown discoloration of the vascular ring and medullary ray tissues within the tubers that is enhanced when tubers are sliced and fried into chips or fries.

Potato psyllids will feed on and transmit the disease-causing organism to all varieties of potatoes tested so far. While there are differing susceptibilities across potato varieties, virtually all varieties will express symptoms of ZC.

The bacterium affects the phloem tissue, causing the foliar symptoms described above and higher than normal sugar concentrations in tubers. When cooked, the sugar caramelizes and forms dark brown stripes (Fig. 4). Though not a human health concern, ZC negatively affects the taste of fried products and renders the tubers unmarketable. This disease is not restricted to potato chips (Fig. 4). In addition to causing tuber necrosis, the ZC organism can significantly reduce yields and tuber size.



Figure 30. ZC-affected French fries and chips.

Potato psyllid has infested potato fields in the Pacific Northwest (PNW) for decades but was never considered a pest until the advent of ZC in the region. For many years it was thought to migrate from other regions of the country, but this has not been demonstrated. Research from 2011 to 2014 has proven overwintering of this psyllid in Oregon, Washington and Idaho in association with the perennial weed called bittersweet nightshade (*Solanum dulcamara*), a native to Eurasia. It can be found in fence rows, stream banks, pond margins, low woods and roadsides throughout the PNW. The relative significance of this overwintering life style versus long-range migration is still uncertain. More recently, potato psyllid was found on *Lycium* (boxthorn) in Washington, Idaho, and Oregon.

The potato psyllid is now known to have at least four genetically distinct types in North America (haplotypes), with evidence emerging about variability amongst them in terms of mating and ecology. The importance of these biotypes and whether one or all are relevant to ZC are still not well understood.

The historical lack of ZC in PNW potatoes, even though the insect has long since been present here, is probably due to the insects in previous years not carrying the pathogen. It is possible that psyllids have carried the disease in previous years in the PNW but disease symptoms were attributed to other causes such as viral infections.

Psyllids are typically first detected in PNW potatoes in early-to mid June. Theoretically, the only important psyllids are those that carry the ZC pathogen (*Liberibacter*). It is generally possible to detect *Liberibacter* in psyllids using PCR tests. Recently, however, research has shown that some psyllids that initially test negative for *Liberibacter* may actually carry it in very low concentration. Therefore, much research is underway to determine 1.) the extent to which psyllids can carry extremely low numbers of *Liberibacter* cells, 2.) whether such carriers are important in the field, and 3.) whether new testing methods can be developed to reliably detect extremely low *Liberibacter* levels in psyllids. An additional complicating factor in ZC biology is that there are at least two biologically distinct haplotypes of the *Liberibacter* that infect potatoes. Initial research information suggests that one biotype causes a more severe foliar disease than the other. This information is relevant to growers and IPM.

Monitoring and Management

Special note: Our suggestions for monitoring and management apply to all potatoes in the PNW, including seed potatoes. Although seed potatoes are often grown in isolation from other potatoes, it is still best to monitor for the presence of psyllids and ZC in seed crops.

The most commonly used scouting method for psyllids is yellow sticky traps (AlphaScents brand). Psyllid adults are active flyers and are attracted to yellow, but traps must be placed inside crop fields close to the canopy. This differs from monitoring beet leafhoppers, which feed and reproduce outside potato fields. Psyllids feed specifically on potatoes and are rarely caught on yellow sticky traps deployed outside potato fields to catch beet leafhoppers. Our current recommendation is to place four sticky cards per circle at least 5 feet from the border. There are several native psyllid species that are routinely caught on yellow sticky traps in the PNW, so knowing how to recognize potato psyllid is important. **We highly recommend yellow sticky traps as monitoring tools for all potato growers and market classes.** For detailed information on monitoring psyllids using sticky traps see: <http://www.nwpotatoresearch.com/pr/Insect-Trapping-Guides.cfm>.

Other monitoring methods, including vacuum sampling using an inverted leaf blower (<https://www.youtube.com/watch?v=dLpI3jkCjXQ>) and various leaf sampling schemes, are used by the research and extension community, but are not practical for implementation by most growers. If interested in procedures for these monitoring methods, please contact Andy Jensen at ajensen@potatoes.com or your local extension agent.

Table of Activity for Psyllid Life Stages and Other Potato Insect Pests. Each x indicates the insecticide has activity against that pest and life stage.

	Group #	Psyllid Lifestage			Efficacy Against Other Potato Pests					
		eggs	nymphs	adults	BLH	CPB	GPA	Thrips	Worms	Mites
pyrethroids	3		x	x	x	x			x	
Platinum	4a	x	x	x	x	x	x			
Cruiser	4a	x	x	x	x	x	x			
Belay	4a	x	x	x	x	x	x			
Admire Pro	4a	x	x	x	x	x	x			
Transform	4c		x	x	x		x			
Radiant	5		x			x		x	x	
Abamectin	6		x	x		x		x	x	x
Fulfill	9b		x	x			x			
Beleaf	9c		x	x			x			
Rimon	15		x			x			x	
Torac	21a		x	x		x	x			
Movento	23	x	x				x	x		x
Oberon	23	x	x							x

The guidelines contained herein should be viewed with the caution that products may perform better in a low pressure situation than they would in a higher pressure situation.

Insecticide at planting time followed by foliar applications. Apply a neonicotinoid to the seed piece, in furrow at planting or at cracking, such as Admire Pro, CruiserMaxx, or Platinum. At just prior to the effective decline of the planting time insecticide, initiate a foliar insecticide program. The point at which one decides to make the first application is based on a combination of the pest management professional's aversion to risk and the choice of product. Based on the 2012-2014 field research seasons, neonicotinoid insecticides appeared to provide at least 60 to 90 days of residual control. A foliar program should begin no later than 80 to 90 days after a planting time neonicotinoid application. For resistance management reasons we recommend that no more than 80% of fields on a farm be treated with Group 4 neonicotinoid insecticides at planting/cracking. Neonicotinoids are particularly important against aphids and Colorado potato beetle

Foliar only program. If no planting time insecticides are applied then start a foliar insecticide program at the first detection of potato psyllids in your area (Caution: do not wait until psyllids are detected in a particular field). Apply foliar insecticides with known effectiveness against adult potato psyllids at the beginning of your program. Continue a foliar program until your field has been desiccated or harvested.

Timing of Application. Actively growing potato plants can double in size every 7 days until bloom starts. Application of contact (non-systemic) products such as pyrethroid insecticides will only provide control on the plant tissue that is present at the time of application, necessitating a shorter application interval than when using a highly systemic insecticide. Later in the season when a potato plant is not actively growing above ground, a contact insecticide will provide 14 days or longer residual control, often as long or longer than a systemic insecticide. When a potato plant is fully mature, a systemic insecticide can take up to 2-4 days to become fully translocated throughout the plant.

Method of Application. In many situations growers choose chemigation, however use of chemigation with non-systemic products may result in substantially reduced insecticide levels on the foliage. Due to our lack of knowledge on effect of method of application on efficacy, do not apply insecticides for potato psyllids in potatoes via chemigation unless you are confident the application will result in adequate deposition of insecticide residues on the foliage. Obtaining adequate coverage, particularly with contact insecticides, is critical since the immature stage of the potato psyllids prefers the underside of the leaves.

Planting Time Insecticide Treatments

Imidacloprid (Admire Pro), thiamethoxam (Cruiser) and chlothianidin (Belay) applied at planting will provide 60 to 90 days of residual control of aphids and beetles. Outside of the PNW, these products have provided a shorter period of residual control for psyllids. It is not known if this difference is due to the insect being more tolerant to the insecticide or due to a more rapid breakdown of the product in other regions. Based on information from other states with potato psyllid control challenges, we believe that imidacloprid and thiamethoxam have similar periods of residual control for this pest. Out of an abundance of caution, we recommend that growers assume the period of residual neonicotinoid soil control for potato psyllids to be no longer than 80 to 90 days. Application of these products at cracking/layby is expected to have three weeks shorter period of control. Phorate (Thimet, Phorate) is thought to not provide reliable psyllid control beyond 50 days and therefore is not expected to be of value in psyllid management. Venom is another neonicotinoid insecticide registered for use at planting time on potatoes. This product is not recommended for use in the PNW at planting for psyllid control due to its short period of soil residual control. A new product, Verimark was recently registered on potatoes for at planting time use but its use is not recommended for control of potato psyllids.

Admire Pro, Platinum, Cruiser 5FS, and CruiserMaxx applied at planting time are expected to have efficacy against the potato psyllid. Length of control will vary depending on the rate used, soil and environmental conditions, and insect pressure. For seed piece treatments, it is important to note that the application rate will

vary by the number of sacks planted per acre, with a maximum use rate of 0.125 lbai/A. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Belay, Venom, Endigo Actara, Assail) following applications of Admire Pro, Belay, Platinum, Cruiser 5FS and CruiserMaxx to follow resistance management guidelines established by IRAC for the insecticide group 4A.

Insecticide Seed Treatments

Admire Pro (imidacloprid, Group 4A). Admire Pro is a liquid seed piece treatment offering control of all aphid species, Colorado potato beetle, flea beetle, potato leafhopper, and psyllids with the flexibility of ultra-low volume liquid seed-piece application. Admire Pro may also reduce wireworm damage in seed-pieces. The application rate is 0.17 – 0.35 fl. oz./cwt. of seed-pieces (Note: Based on a 2000 lb/acre seeding rate, this rate range is equivalent to 3.5 -7.0 fl. oz./acre). Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Venom, Brigadier, Endigo Actara, Assail) following this application.

Cruiser 5FS/CruiserMaxx Potato (thiamethoxam, Group 4A). Cruiser is a seed-applied neonicotinoid product recently registered for use on potatoes. Use CruiserMaxx Potato seed treatment to provide protection against injury from aphids, Colorado potato beetles, flea beetles, and psyllids. Cruiser 5FS will also control wireworms that feed on the seed piece. The rate range is 0.19 to 0.27 oz per 100 lbs of tubers, depending on the seeding rate (consult label). Length of control will vary depending on the rate used, soil and environmental conditions, and insect pressure. Use approved application equipment (Spudgun or Milestone barrel treater). It is important to note that the application rate will vary by the number of sacks planted per acre with a maximum use rate of 0.125 lbai/A. This Cruiser Maxx Potato formulation is a combination of Cruiser 5FS, Maxim 4FS and a drying agent. The drying agent dries the seed more quickly aiding in suberization. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Brigadier, Venom, Endigo Actara, Assail) following this application.

Insecticide In-Furrow Treatments

Platinum 75SG (thiamethoxam, Group 4A). Platinum is a soil-applied insecticide providing long residual control in potatoes. Apply Platinum 75SG at 1.67 to 2.67 oz/A in-furrow at planting in a 6-8 inch band with sufficient water for good coverage for the control of aphids, Colorado potato beetle, potato leafhoppers, flea beetles, and potato psyllid. Do not apply less than 1.67 or more than 2.67 oz/season. Do not apply if any neonicotinoid (Group 4A: CruiserMaxx, Belay or Admire Pro) has been applied as a seed treatment. Alternatively, Platinum may be applied POST plant, pre-emergence as a broadcast application at 1.67-2.67 ounces/acre and watered in with 0.10 -0.25 inches of water. All precautions listed above must be followed. Do not apply any foliar neonicotinoid (Admire Pro, Leverage, Brigadier, Venom, Endigo Actara, Assail) following this application.

Admire Pro (imidacloprid, Group 4A). Admire Pro is a soil-applied insecticide providing long residual control of insect pests of potatoes, including psyllids. Admire Pro will control Colorado potato beetles, aphids, wireworms (seed piece only), and psyllids. Application rates are 5.7 to 8.7 fl oz/A applied as an in-furrow spray at seeding or as a side dress to both sides of the hill after planting (treated areas of both hillsides should be covered with approximately 3 inches of soil).

Foliar Insecticide Psyllid Treatments

Do Not Use These Products for Psyllid Control. dimethoate, Regent, Mocap, Avaunt, Comite, Acramite, Coragen and malathion. These products have very short residual or no efficacy against potato psyllids; other options exist that have better efficacy and/or longer periods of control.

Method of Application. Limited data generated in 2013 indicated that control of potato psyllid by chemigation was poorer than when applied by ground. Based on limited data, application of insecticides by chemigation for control of potato psyllid is not recommended despite this use pattern being contained on many products with this insect pest on the label.

Lannate (methomyl, Group 1B.) Apply 3 pints per acre. Apply by ground or air. There is a 21 day preharvest interval and a 48 hour reentry interval and a season long limit of 15 pints per acre and a maximum of ten applications.

Vydate, (oxamyl, Group 1B). Research conducted in Oregon in 2012 indicated that an insect program that included Vydate at planting at 4.2 pints in furrow followed by Vydate applied bi-weekly at 800 degree days for seven foliar applications at 2.1 pints per acre applied via chemigation significantly reduced expression of zebra chip. DuPont has released a 2ee label describing this use pattern, which is effective for Washington, Oregon and Idaho.

Pyrethroid Insecticides (Group 3): Asana, Athena, Brigadier, Hero, Baythroid, Ambush, Brigade, Mustang Max, Warrior II and Permethrin. These products have activity against potato psyllids. Additionally, these products will control several other insect pests such as Colorado potato beetle and beet leafhopper. Use of these products is discouraged in most potato pest management scenarios due to their potential to cause aphid and mite outbreaks. *Potato psyllids are closely related to aphids and share several characteristics with them. Experiences in controlling psyllids in Texas potato fields found that overreliance on pyrethroid insecticides tended to flare potato psyllid populations thereby creating unacceptable losses.* In some situations, these products may be appropriate for control of potato psyllids in potatoes. We strongly recommend against use of pyrethroid insecticides between June 15th and two weeks before desiccation. If pyrethroid insecticides are applied prior to June 15th, applications should be made every seven days if plants are actively growing. Make no more than two applications, spaced seven days apart before rotating to a new mode of action of insecticides. If a field is within 14 days of harvest or desiccation, a pyrethroid insecticide can be an effective tool and would also serve as an important resistance management tool. Many pyrethroid insecticides have short preharvest intervals making them suitable end of season choices. Most package mixes contain a pyrethroid insecticide. Statements made for products containing pyrethroid insecticides also apply for package mixes that contain a pyrethroid insecticide. A study from Texas showed that psyllids exposed to pyrethroids produced 30% more eggs before they died from the insecticides than did psyllids not exposed to insecticides.

Transform WG (sulfoxaflor, Group 4c). Apply for control of potato psyllid by ground, air or chemigation at 2.0 to 2.25 ounces per acre. Refer to the label for specific instructions when applying via chemigation. Transform has a 7 day preharvest interval, a 14 day retreatment interval and a total seasonal limit of 4 applications and a total of 8.5 ounces of Transform per acre per year. Transform can be used during the season if a neonicotinoid (Group 4A) insecticide has been applied at planting as long as an insecticide with a different mode of action has been applied to the target pest prior to the use of Transform. If a 4A (neonicotinoid) or a 4D (Sivanto) insecticide has been previously applied, apply an insecticide with a different mode of action (different group number) prior to the use of Transform. This product does not have a full set of Maximum Residue Limits (MRLs). Use this product with caution if your potatoes have the potential for export. See the section on MRLs at the end of this report for specific MRLs for this product by country.

Sivanto 200SL (flupyradifurone, Group 4D). Apply at 10.5 to 14.0 fluid ozs per acre by ground or by air for psyllid control. Use the higher rate under conditions of heavy pest pressure, dense foliage and/or by application by air. Transform has a preharvest interval of 7 days and a 7 day interval between applications and a seasonal crop limit of 28 fluid oz per acre. Do not make more than two consecutive applications. If a 4A (neonicotinoid) or a 4C (Transform) insecticide has been previously applied, apply an insecticide with a different mode of action (different group number) prior to the use of Sivanto. This product does not have a full set of Maximum Residue Limits (MRLs). Use this product with caution if your potatoes have the potential for export. See the section on MRLs at the end of this report for specific MRLs for this product by country.

Fulfill (pymetrozine Group 9B). Apply Fulfill at the full label rate of 5.5 ounces per acre using a penetrating surfactant. Use the higher rate when treating psyllid populations. This product should be applied just prior to the “break” in control of soil applied insecticide or at the very first detection of potato psyllids in the field. A minimum of five gallons of water should be used when applying Fulfill by air. Fulfill can be applied via irrigation systems. The Fulfill label permits a maximum of only two applications. When applying Fulfill by ground or air use an oil blend adjuvant. Always use a penetrating adjuvant when used with other products that contain sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or DithaneRainshield). Examples of appropriate adjuvants include crop oil concentrates (COC) (e.g. Herbimax), methylated seed oils (MSO) (e.g. Dynamic), ethylated seed oils (ESO) (e.g. Hasten) and organosilicone (OS) blends (e.g. Aerodynamic). Note, there is no quick knock down of psyllid populations with Fulfill; the product causes psyllids to cease feeding, with actual death occurring in 3-5 days.

Beleaf (flonicamid Group 9C). Apply Beleaf at 2.0 to 2.8 ounces per acre. The product may be applied by ground, air or chemigation for aphid control. This product will only control aphids and potato psyllids. Apply no more than 3 applications per season. Beleaf has a 7 day pre harvest interval. Always use a high quality organosilicone blend surfactant with Beleaf

Radiant SC (spinetoram, Group 5). Apply 6 to 8 fluid ounces of Radiant per acre by air, ground or chemigation. Time applications to target egg hatch or young nymph. For heavy larval populations, repeat applications may be necessary but follow resistance management guidelines. Applications by chemigation at either rate should be made with 0.25 acre inches of water or less. Acidic (< 6 pH) spray solutions should be avoided. The pH of spray solution should be checked prior to adding Radiant into the tank and adjusted, if necessary. Acidifying products such as boron should be avoided. In addition, prior to adding Radiant to a tank it is recommended to conduct a compatibility test.

Blackhawk (spinosad, Group 5). Apply 3.5 oz ounces of Blackhawk per acre to potatoes for control of potato psyllid by ground. Begin at first signs of infestations. Due to the occurrence of multiple generations in a growing season, repeated applications may be required. Under moderate to high pest pressure, do not extend application interval beyond 7 to 10 days. Follow resistance management recommendations on the product label.

Entrust 2SC (spinosad, Group 5). Apply at 6 to 10 ounces per acre by air, ground or chemigation. Do not apply more than 2 Group 5 products per acre consecutively (Success, Blackhawk, Entrust, Radiant) in a season. The application interval and the preharvest interval are both 7 days. There is a seasonal limit of 4 applications and 21 ounces of products than can be applied.

Agri-Mek SC (abamectin (Group 6). Apply 1.75 to 3.5 fl oz of Agri-Mek SC by air with 5 gallons of water per acre. Avoid using Agri-Mek with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or DithaneRainshield). The addition of a nonionic surfactant or organosilicone-based surfactant, at the manufacturer's recommended rate is suggested for optimum control. Agri-Mek has activity against adult psyllids.

Knack (pyriproxyfen, Group 7c). Apply Knack by ground at 8 fluid ounces at 20 to 40 gallons of water. Knack is an insect growth regulator and has no activity against adults. Its primary activity is against immature stages and may have some activity against eggs. Potatoes do not appear on the Section 3 label but it is registered for use in Washington via supplemental labeling (a similar registration is pending in Oregon). Knack has a 3 day preharvest interval and a 14 day interval between applications and seasonal limit of two applications and 16 ounces total. Knack has a 30 day plant back restrictions for several crops.

Rimon 0.83 EC (novaluron, Group 15). Rimon may be applied by air, chemigation or ground equipment at 9 to 12 fl oz/A. Applications should be made before psyllid populations reach adulthood. Rimon is an insect growth regulator type insecticide which must be ingested by nymphs or applied either over or under eggs to act as an ovicide; therefore, reapplication at 7 to 14 days is needed to protect new plant tissue during periods of active foliar growth. It will not control adult psyllids. Do not make more than two applications per season. Do not apply to two successive generations in the same growing season. Use a minimum of 5 gallons per acre when applying by air; apply a minimum of 10 gallons per acre when applying by ground. Rimon has a 12 hour restricted entry interval and a 14 day pre harvest interval. Do not apply more than 24 ounces per acre per season.

Onager (hexythiazox, Group 10) is effective against eggs and immature psyllids. It may be applied by air or by ground at 16 to 24 ounces per acre. When applying by air, use a minimum of 5 gallons of water. The product may only be used in Idaho, Oregon and Washington. Do not apply within 21 days of harvest. It is critical to use Onager prior to adult psyllid buildup as the product will not control adults. Use higher rates for larger plants with a dense canopy. Do not plant rotational crops other than those on the Section 3 label within 120 days of this application.

Oberon 4SC (spiromesifen Group 23). May be applied by air, ground, or chemigation for control of psyllids. Application of Oberon by chemigation is not recommended due to lack of data demonstrating efficacy. Good coverage of the foliage is necessary for optimal control. An adjuvant may be used to improve coverage and control. For best results the treatment should be made at first occurrence of psyllids and before a damaging population becomes established. Oberon is most effective against the egg and nymphal stages of psyllids. Control should be directed at these stages. Oberon can be applied at 4 to 8 fluid ounces per acre. Apply when psyllids first appear and prior to leaf damage or discoloration. Apply in adequate water for uniform coverage with ground or aerial application equipment, or by chemigation as per the use label. If needed, repeat an application of Oberon at a 7- to 10-day interval. There is a limit of two applications per season.

Movento (spirotetramat, Group 23). Movento may be applied by air, ground or chemigation for control of psyllids. The manufacturer of Movento recommends air or ground application of the product when treating for psyllids. Apply Movento at 5.0 ounces of product per acre. There is a 10 ounce per acre per season limit. Movento requires up to 14 days to become fully effective in the plant. If following an application of a neonicotinoid at planting/cracking, apply Movento at 10 days prior to expected "break" of the planting time insecticide. Research has shown that the most effective means of controlling psyllids, aphids and other pests is to apply the product twice with a 10 to 14 day retreatment interval. For resistance management purposes, do not allow more than 21 days between the two applications of Movento and always rotate to an insecticide with a different mode of action following the two Movento applications. If a planting time insecticide has not been made, apply Movento at the first appearance of potato psyllid. The product is more effective when applied earlier in the outbreak cycle due to its systemic properties and efficacy against eggs and nymphs. Use of Movento requires inclusion of a penetrating surfactant, the manufacturer of Movento recommend use of an MSO. One use feature for this product is that there is a 30 day plant back restriction after the last application for all crops. Since this product would almost always be applied more than 30 days before harvest, there are functionally no plant back restrictions for Movento.

Torac (tolfenpyrad, Group 21a). Apply at 17 to 21 fluid ounces per acre by ground, air and chemigation for control of potato psyllid. Use the higher rate or heavier pest infestations or applying by chemigation. When applying by ground use at least 20 gallons of water per acre, when applying by air use at least 5 gallons of water and when applying by chemigation refer to the specific label language. Do not apply more than 2 applications per cropping season. Torac has a 14 day pre harvest interval and a 14 day retreatment interval. A total of 42 fluid ounces can be applied during a single cropping season.

Organic Control of Potato Psyllid.

Research conducted in 2013 demonstrated that organic products provided significant control of potato psyllid. While there are no organic at planting time controls of psyllids, foliar products did provide control comparable to that of conventional products. Apply products at first detection, apply products at higher rates, at seven day intervals and to improve efficacy, apply products as tank mixes. Although there is limited data to support, addition of sulfur to psyllid treatments appeared to improve efficacy.

Entrust 2SC (spinosad, Group 5). Apply at 6 to 10 ounces per acre by air, ground or chemigation. Do not apply more than 2 Group 5 product per acre consecutively (Success, Blackhawk, Entrust, Radiant) in a season. The application interval and the preharvest interval are both 7 days. There is a seasonal limit of 4 applications and 21 ounces of products than can be applied.

Aza-Direct (azadiractin, Group # Unknown). Apply at a rate of 3.5 pints per acre by air, ground or chemigation. When applying Aza-Direct via chemigation refer to the label for significant other instructions as application of this product through water requires a set of conditions that are critical for successful outcome. For example forbids application of Aza-Direct via chemigation if the pH of water exceeds 7 which commonly occurs with surface water used for irrigation.

Storage

- Little information is available on the biology of the disease in storage; however, there is research that shows asymptomatic tubers produced by potato plants infected late in the season may later develop ZC symptoms in storage.
- Experience with this disease in other locations suggest that infected tubers do not rot in storage.
- Tubers with symptoms put into storage will maintain those symptoms.

Preharvest Interval, Restricted Entry Interval and Seasonal Limits for Potato Insecticides					
Brand Name		Common Name	PHI (days)	REI (hours)	Seasonal Limit
Abamectin SC	Syngenta, others	abamectin	14	12	10.25 fl oz
Assail 70WP	UPI	acetamidiprid,	7	12	7
Acramite 4 SC	Chemtura	bifenazate	14	12	24 oz
Sevin	TKI	carbaryl	7	12	6 qt/yr
Belay 50 WG	Valent	clothianidin	14	12	3 app
Baythroid XL	Bayer CropSciences	cyfluthrin	0	12	16.8 oz
Dimethoate	Several	dimethoate	2	2	2 pints
Asana XL	DuPont	esfenvalerate	12	7	0.35 lb ai
Beleaf	FMC	flonicamid	7	12	3 day
Sivanto 200 SL	Bayer CropSciences	Flypradifurone	7	4	28 oz
Onager	Gowan	hexythiazox	21	12	24 oz
Avaunt	DuPont	indoxacarb	7	12	24 oz
Lannate, Annihilate	DuPont Chemtura	methomyl	6	48	4.5 lbs/ai
Rimon 0.83 EC	Chemtura	novaluron	14	12	24 oz
Vydate L-CV	DuPont	oxamyl	7	48	1.6 gallons
Vydate L	DuPont	oxamyl	7	48	4.5 gallons
Imidan 70W	Gowan	phosmet	7	24	6.66 lb*
Comite	Chemtura	propargite	14	48	80 oz
Fulfill	Syngenta Crop Protection	pymetrozine	14	12	11 oz
Knack	Valent	pyriproxifen	3		60 oz
Coragen	DuPont	rynaxypyr	14	4	15.4 fl oz
Radiant SC	Dow AgroSciences	spinetoram	7	4	32 oz
Success SC	Dow AgroSciences	spinosad	7	4	21 oz
Blackhawk	Dow AgroSciences	spinosad	7	4	14.4 oz
Entrust SC	Dow AgroSciences	spinosad	1	4	29 oz
Movento	Bayer CropSciences	spiromesifem	7	24	10 oz
Oberon 4 SC	Bayer CropSciences	spiromesifem	7	12	16 oz
Transform WG	Dow AgroSciences	sulfoxaflor	7	24	8.5 fl oz
Actara	Syngenta Crop Protection	thiamethoxam	14	12	6 oz
Torac	Nichino	tolfenpyrad	14	12	42 oz
Mustang Max	FMC	zeta-cypermethrin	1	12	25 oz
Voliam Flexi	Syngenta Crop Protection	thiamethoxam, chlorantraniliprole	14	12	8 oz
Hero	FMC	zeta-cypemethrin, bifenthrin	21	12	13 oz
Voliam Xpress	Syngenta Crop Protection	lambda-cyhalothrin, chlorantraniliprole	14	24	27 oz
Endigo	Syngenta Crop Protection	lambda-cyhalothrin, chlorantraniliprole	14	24	10 oz
Leverage 360	Bayer CropSciences	imidacloprid, cyfluthrin	7	12	15 oz
Brigadier	FMC	imidacloprid, bifenthrin	21	7	25.6 oz/a

Comparative Efficacy of Insecticides in Potatoes

Recent insecticide efficacy evaluations conducted from 2003-14 by Agriculture Development Group, Inc., (Alan Schreiber) indicate the general effectiveness of a variety of insecticides registered for use in potatoes for a number of insect pests. Use these products against these pests at your own risk.

Insecticide Effectiveness for Nine Potato Insect Pests

Prepared by Alan Schreiber, Agriculture Development Group, Inc.

Active Ingredient		Aphids	CPB	Worms	Spider mites	Wire-worms	Thrips	PTW	BLH	Psyllid
1,3 dichloropropene	Telone	NE	NE	NE	NE	E	NE	NE	NE	NE
abamectin	Agri-Mek	VP	G	ND	ND	VP	G	E	ND	E
actamiprid	Assail	G	E	ND	ND	ND	F	F	E	G
azadirachtin	several	ND	F	ND	ND	ND	ND	ND	ND	G
bifenazate	Acramite	NE	NE	NE	E	NE	NE	NE	NE	NE
bifenthrin	several	VP	E	G	G	ND	ND	E	E	G
carbaryl	Sevin	VP	G	ND	ND	VP	ND	VP	ND	G
chloropicrin	several	VP	VP	VP	VP	ND	NE	ND	NE	NE
clothiniadin	Belay	E	E	NE	NE	NE	F	G	G	G
cryolite	Cryolite	VP	ND	ND	ND	VP	ND	ND	ND	ND
cyfluthrin	Baythroid	VP	E	E	VP	NE	F	E	E	ND
cyazypyr	Exirel	E	E	ND	NE	NE	ND	ND	ND	E
dimethoate	Dimethoate	G	P	ND	ND	VP	ND	ND	P	G
esfenvalerate	Asana	VP	E	E	VP	VP	F	E	E	G
ethoprop	Mocap	VP	VP	VP	VP	G	NE	ND	NE	NE
fipronil	Regent	NE	NE	NE	NE	E	NE	NE	NE	NE
flupyradifurone	Sivanto	E	ND	NE	NE	ND	ND	ND	ND	E
imidacloprid	several	E	E	VP	VP	F	ND	ND	E	G
indoxacarb	Avaunt	VP	VP	E	VP	VP	ND	E	NE	NE
lambda cyhalothrin	Warrior	G	E	E	VP	NE	F	E	E	G
malathion	several	ND	ND	ND	ND	VP	ND	ND	ND	ND
metam potassium	K-pam	VP	VP	VP	VP	ND	NE	ND	NE	NE
metam sodium	Vapam	VP	VP	VP	VP	F	NE	ND	NE	NE
methomyl	Lannate	G	G	G	ND	VP	G	E	P	G
novaluron	Rimon	VP	G	G	VP	VP	ND	E	NE	G
oxamyl	Vydate	G	G	G	F	ND	ND	ND	E	G
permethrin	Ambush, Pounce	VP	E	E	VP	VP	ND	ND	E	G
phorate	Thimet, Phorate	E	E	ND	VP	VP	ND	ND	P	NE
phosmet	Imidan	VP	G	G	VP	VP	ND	E	NE	G
propargite	Comite	VP	VP	VP	G	VP	NE	VP	NE	NE
pymetrozine	Fulfill	E	VP	VP	VP	VP	NE	VP	P	E
renaxyapyr	Coragen	NE	NE	E	NE	NE	NE	E	NE	NE
spinetoram	Radiant	NE	E	E	NE	NE	E,G	ND	NE	E
spinosad	Blackhawk	VP	G	G, F	VP	VP	G	E	NE	G
spiromesifen	Oberon	NE	NE	NE	E	NE	ND	VP	NE	E
spirotetramat	Movento	E	NE	NE	F	NE	F	NE	ND	E
sulfoxaflor	Transform	E	NE	NE	NE	NE	NE	NE	E	E
sulfur	several	ND	ND	ND	ND	ND	ND	ND	NE	ND
thiamethoxam	several	E	E	VP	VP	F	ND	ND	E	E
tolfenpyrad	Torac	G	E	NE	NE	NE	ND	NE	ND	E
zeta cypermethrin	Mustang Max	VP	E	G	VP	NE	G	E	E	G

E = Excellent, G = Good, F = Fair, P = Poor, VP = Very Poor or No Effect, ND = No Data, NE means product has no effect on the pest

Potato Maximum Residue Limits Table (MRLs)

The below information is from the USDA Foreign Agricultural Service Maximum Residue Database. More information from more countries is available at the USDA FAS MRL Database. This information is current as of February, 2014.

Terms of Use

Users are advised that international regulations and permissible Maximum Residue Levels (MRL) frequently change. Although this International MRL Database is updated frequently, the information in it may not be completely up-to-date or error free. Additionally, commodity nomenclature and residue definitions vary between countries, and country policies regarding deferral to international standards are not always transparent. This database is intended to be an initial reference source only, and users must verify any information obtained from it with knowledgeable parties in the market of interest prior to the sale or shipment of any products. The developers of this database are not liable for any damages, in whole or in part, caused by or arising in any way from user's use of the database.

MRL values in *italics* are more restrictive than U.S. and indicates that if your potatoes could be destined to that market, one should exercise care when using that product.

All numeric values listed are in parts per million (ppm), unless otherwise noted

--- (dashes) indicate that no specific MRL for the commodity or relevant crop group is established. A default MRL may apply for countries that have default MRLs (see Default MRLs section below). Additionally, inadvertent or extraneous MRLs are not included in the database; and the database does not indicate substances that are banned in a country or exempt from requiring an MRL.

Section 18, Time-Limited, or Regional: indicates that the US MRL is a temporary Section 18, Time-Limited Tolerance, or Regional Tolerance.

Brand name	Common Name	U.S.	Codex	Brazil	Canada	Chile	China	Hong Kong	Japan	Korea	Mexico
Abamectin	Abamectin	0.01	0.01	{0.005}	0.01	0.01	---	0.01	0.01	0.01	0.01
Assail	Acetamiprid	0.01	---	0.5	0.01	0.01	---	---	0.3	0.1	0.01
Acramite	Bifenazate	0.1	---	---	---	{0.01}	---	---	{0.05}	0.1	0.1
Brigade	Bifenthrin	0.05	0.05	{0.03}	---	0.05	---	0.05	0.05	0.05	0.05
Sevin	Carbaryl2	---	{0.1}	{0.2}	{0.05}	{1}	---	{0.1}	{0.2}	2	
Coragen	Chlorantraniliprole	0.3	{0.02}	{0.01}	{0.01}	{0.02}	---	{0.02}	{0.02}	{0.05}	0.3
Belay	Clothianidin	0.3	---	{0.03}	0.3	{0.05}	---	---	{0.25}	{0.1}	0.3
Baythroid	Cyfluthrin	0.01	0.01	---	---	0.01	---	0.01	0.1	0.1	0.01
Trigard	Cyromazine	0.8	---	{0.1}	0.8	0.8	---	---	0.8	{0.05}	0.8
Deltamethrin	Deltamethrin	0.04	{0.01}	{0.01}	0.04	{0.01}	---	{0.01}	0.05	{0.01}	0.04

Dimethoate	Dimethoate	0.2	{0.05}	---	---	{0.05}	0.5	{0.05}	1	{0.05}	0.2
Venom/Scorpion	Dinotefuran	0.05	---	---	---	---	---	---	0.2	0.1	0.05
Asana	Esfenvalerate	0.02	---	{0.01}	---	0.02	0.05	---	0.05	---	0.02
Mocap	Ethoprop	0.02	0.05	0.05	---	0.05	0.02	0.05	0.05	0.02	0.02
Regent	Fipronil	0.03	{0.02}	0.05	---	{0.02}	---	{0.02}	{0.01}	{0.01}	0.03
Beleaf	Flonicamid	0.2	---	---	0.2	---	---	---	0.3	0.3	0.2
Onager	Hexythiazox	0.02	---	---	---	---	---	---	0.2	0.3	0.02 Regional
Admire Pro	Imidacloprid	0.4	0.5	0.5	0.4	0.5	---	0.5	0.5	{0.3}	0.4
Avaunt	Indoxacarb	0.01	0.02	0.05	---	0.2	---	0.02	0.2	0.05	0.01
Malathion	Malathion	8	---	---	{0.5}	{0.5}	{0.5}	---	{0.5}	{0.5}	8
Lannate	Methomyl	0.2	{0.02}	{0.1}	---	{0.02}	---	{0.02}	0.3	{0.1}	0.2
Rimon	Novaluron	0.05	{0.01}	{0.02}	0.05	{0.01}	---	{0.01}	0.05	{0.01}	0.05
Vydate	Oxamyl	0.1	0.1	---	0.1	0.1	---	0.1	0.1	0.1	0.1
Permethrin	Permethrin	0.05	0.05	---	0.05	0.05	1	0.05	0.05	0.05	0.05
Thimet	Phorate	0.2	0.3	{0.05}	---	0.3	{0.01}	0.3	0.2	0.2	0.2
Imidan	Phosmet	0.1	{0.05}	---	0.1	{0.05}	---	{0.05}	{0.05}	{0.05}	0.1
Comite	Propargite	0.1	{0.03}	---	---	{0.03}	---	{0.03}	0.1	0.1	0.1
Fulfill	Pymetrozine	0.02	---	{0.01}	0.02	0.02	---	---	0.1	0.2	0.02
Knack	Pyriproxyfen	0.15	---	---	---	---	---	---	---	0.2	0.15
Radiant	Spinetoram	0.1	---	{0.01}	{0.04}	---	---	---	---	{0.05}	0.1
Success/Entrust	Spinosad	0.1	{0.01}	{0.01}	{0.02}	{0.01}	---	{0.01}	{0.02}	0.1	0.1
Movento	Spiromesifen	0.02	---	---	0.02	---	---	---	0.02	0.05	0.02
Oberon	Spirotetramat	0.6	0.8	---	0.6	0.8	---	0.8	1	0.8	0.6
Transform	Sulfoxaflor	0.05	{0.03}	---	---	{0.03}	---	{0.03}	---	0.05	0.05
Actara/Platinum	Thiamethoxam	0.25	0.3	{0.02}	{0.15}	{0.1}	---	0.3	0.3	{0.1}	0.25
Torac	Tolfenpyrad	0.01	---	---	---	---	---	---	0.05	---	0.01