2006
Integrated Pest Management Program for Insects and Mites in Oregon and Washington Potatoes

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PURPOSE

Potato growers in 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 recommendations as to how potato insect pests in Oregon and Washington can be cost effectively controlled. .

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.

Volunteer Potato Management and Outlook for 2006

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Volunteer potatoes are a significant weed problem most years in the Columbia Basin potato-growing region. Managing volunteer potatoes in crop rotations requires integration of numerous techniques and practices in order to prevent yield and quality losses and to prevent new tuber production that perpetuates the problem in the rotation. A new WSU extension bulletin (EB1993) is available for purchase that covers the biology and management options for volunteer potatoes. The bulletin can be downloaded free at http://cru.cahe.wsu.edu/CEPublications/eb1993/eb1993.pdf.

Many potato tubers left in the soil after harvest may have been killed by cold soil temperatures throughout the Columbia Basin this winter. Potatoes normally are killed when they reach temperatures ≤ 28° F. Data from numerous AGWeatherNet weather stations with buried thermocouples indicated that soil temperatures reached a minimum on December 19, 2005 throughout the region.

Minimum soil temperatures at the 8-inch depth recorded at AGWeatherNet stations near Quincy and Royal City, WA reached 27.8 F and 26 F, respectively. However, minimum soil temperatures in December recorded at 4 and 8 in. at Prosser, Hermiston, and Odessa did not drop below 29 F. In addition, minimum soil temperatures in December recorded 8 in. deep near Othello and Paterson (100 Circles) did not drop below 31 F and 29 F, respectively. Minimum soil temperatures at the ARS Paterson research farm in December were 26.6 F at 4 in. deep and 29.1 F at 7 in. deep, which has the potential to eliminate the majority of the tubers left in the soil. Differences in soil temperatures throughout the region are likely due to differences in air temperatures, snow cover, soil moisture, aspect, and amount of crop residues. Due to variation in soil temperatures from site to site, examination of potato fields should be done to accurately determine the extent of winter kill. Tubers killed by cold temperatures are soft and often leak fluids under pressure, although internally appear relatively normal after cut open. Viable tubers that have escaped cold injury are firm. Tubers that are firm on the underside and soft and leaking on the upper side can often be found which mark the depth that killing temperatures reached.

We estimate more tuber mortality than occurred in 2005, but certain areas of the Columbia Basin will still be faced with significant volunteer potato problems in 2006.

Recommendations for Volunteer Potato Control

Growers should minimize the number of tubers left in the field during potato harvest (see EB1993). Newberry and Thornton (2004) demonstrated that deep fall tillage (mold board plow) that buries tubers deeper prior to cold winter temperatures should be avoided. Previous studies comparing tillage practices indicated that plowing following a deep penetrating frost could be beneficial by exposing deeper buried tubers to additional freezing events (Thomas and Smith, 1983). However, weather patterns are not always conducive to make this practice effective and field access in winter months is often limited.

Control measures should strive to minimize competition with rotational crops and formation of new daughter tubers that can persist and cause problems in subsequent crops. Several components of volunteer potato management that growers can implement in this year's rotational crops are listed below.

- On higher value crops with nematode problems such as carrot or onions, spring fumigate with metham sodium (Vapam, Busan, and others) and 1, 3,-dichloropropene (Telone II). Field studies indicate about 70-75% of tubers are killed by a combination of Telone II at 10 GPA applied with shanks plus Vapam at 30 GPA applied by center pivot. Lower rates of fumigants are less effective in killing tubers. Follow labels for proper rates, soil temperatures, soil moisture, and time required between fumigation and planting of subsequent crop.
- If possible, delay planting of the rotation crop to allow maximum early volunteer potato emergence and apply glyphosate (Roundup) or remove with tillage.
- Use herbicides that are active in reducing volunteer potatoes in rotation crops. Several herbicides can be very effective in killing potato plants and reducing daughter tuber weight, including mesotrione (Callisto), fluroxypyr (Starane), atrazine (Aatrex, Atrazine), glyphosate (Roundup), dicamba + diflufenzopyr (Distinct), dicamba (Banvel, Clarity), and imazamox (Raptor). Repeated applications of contact herbicides such as, oxyfluorfen (Goal), carfentrazone (Aim), fomesafen (Reflex), pyridate (Tough), glufosinate (Rely), and paraquat (Gramoxone) can also be effective. Follow labels closely for labeled crops, proper rates, timing of applications, and crop rotation restrictions.
- When possible, apply postemergence herbicides when potatoes are just beginning to initiate tubers on stolons. If applications are made earlier, mother tubers often resprout and the volunteer plants will require additional herbicide applications. If applications are made later, yield loss may have already occurred and many new tubers will have already formed which will infest next year's crop.
- Previous USDA-ARS research demonstrated that cultivation about 1 week after postemergence applications of Starane, Goal, Roundup, and Banvel greatly reduced the number of daughter tubers formed compared to herbicides alone. In corn, Callisto herbicide has reduced new daughter tuber formation greater than other postemergence herbicides. Cultivation after Callisto application may not improve volunteer potato control.

- Select competitive crops and those with effective herbicide and cultivation options like field corn. Crops like carrots have no effective herbicides registered for volunteer potato control, so avoid planting such crops in fields where volunteers will be plentiful. Winter wheat is a very competitive crop and delays volunteer potato emergence in the spring. However, cultivation isn't practical in wheat and there are limited opportunities for timing effective herbicide applications in winter wheat prior to new tuber set on volunteer potatoes.
- Repeated cultivations and hand weeding can control volunteer potatoes, but they are most effective and economical when combined with other control methods.
- Grazing fields with hogs, sheep, or cattle may also reduce the number of tubers available to sprout.

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Management of Wireworm

Wireworms tend to be most damaging in potatoes that follow corn or small grains and on ground just entering cultivation. There are several kinds of wireworms in the Pacific Northwest. Those causing the most damage in irrigated lands are the Pacific Coast wireworm, the sugar beet wireworm, the western field wireworm and the Columbia Basin wireworm. An invasive European wireworm has been detected in northwestern Washington, and could become a problem Wireworm larvae require 2 to 6 years to mature, overwintering at a depth of 12 to 24 or more inches in the soil, only to return 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 degrees F. Later in the season when temperatures reach 80 degrees 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 degrees 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 for wireworm. If one suspects wireworms are present in a field, chemical control is the only management option.

Telone is effective on wireworms that are present at the time of fumigation and within the zone of fumigation. Therefore, it is important that Telone is applied when soil temperature is 50 degrees (or higher) or prior to the movement of wireworms down the soil profile and out of the fumigation zone.

Only two chemical treatments are recommended for control of wireworm; **Telone** and **Mocap**. It is important that Telone be applied when soil temperatures are at least 50 degrees. Mocap, either the liquid or the granular formulation, is effective. Mocap may be applied as a broadcast incorporated application or in furrow at planting time. If the product is broadcast, it is critical that the material is deeply 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 applied as a band that is as wide as possible, ideally 10-12 inches wide. 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.

Planting Time Insecticide Treatments

Based on trials conducted in Idaho, Oregon and Washington, imidacloprid-based products (Admire Pro and Gaucho) and thiamethoxam-based products (Platinum and Cruiser) provide significantly better aphid control than alternatives. Imidacloprid and thiamethoxam applied at planting will provide 80 to 100 days of residual control. Aldicarb (Temik) applied at planting will provide approximately 70-75 days control. Other soil applied systemic insecticides such as phorate (Thimet, Phorate) and Furadan do not provide reliable GPA control beyond 50 days. Use of Temik will increase the likelihood that foliar application of insecticides mid to late season will be necessary. Use of Thimet and Furadan greatly increase the likelihood that foliar application of insecticides will be necessary. **Venom** is a planting time insecticide recently registered by Valent for use on potatoes, at this time, it is not recommended for use in the Pacific Northwest.

Insecticide Seed Treatments

Gaucho MZ or Tops MZ Gaucho. These dry seed treatments control all aphid species, Colorado potato beetle, flea beetle, potato leafhopper, and psyllids in a dust formulation. Gaucho may reduce wireworm damage in seed-pieces. Application rate is 0.75 lbs/cwt., or 20lbs/acre maximum.

Admire Pro. 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 and daughter tubers. 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).

Cruiser (thiamethoxam) 5FS. Cruiser is a seed applied neonicotinoid product recently registered for use on potatoes. Use Cruiser 5FS seed treatment to provide protection against injury from green peach aphid, potato aphid, Colorado potato beetles, flea beetles, and psyllids. Cruiser 5FS will also control wireworms that feed on the seed piece. The rate range is 0.11 to 0.16 fl 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 lb ai/A.

Insecticide In Furrow Treatments

Platinum. Platinum is a soil-applied insecticide providing long residual control in potatoes. Apply Platinum at 5.0 fluid ounces up to 8.0 fluid ounces/acre (0.34 – 0.52 fluid oz./1,000 linear feet in 34 inch row spacing) 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 5.0 fluid ounces/acre or more than 8.0 ounces/acre/season. Do not apply Provado, Leverage or Actara following this application. Alternatively, Platinum may be applied POST plant, pre-emergence as a broadcast application at 5.0 fluid ounces up to 8.0 fluid ounces/acre and watered in with 0.10 -0.25 inches of water. All precautions listed above must be followed.

Temik 15G. Temik 15G is a soil applied granular insecticide/nematicide for control of major foliar insect pests in potatoes including aphid species, Colorado potato beetle, leafhoppers (excluding beet leafhopper), flea beetles, and mites. Temik also controls lesion nematode while suppressing stubby root, Columbia rootknot and northern rootknot nematode. Reducing populations of these pests alleviate detrimental quality and yield problems that result from corky ringspot, net necrosis, and potato early dying. Application rate is 20 lbs/A. Place granules with seed pieces in the planting furrow or apply in a 6-inch band in front of the opening shoe and incorporate into the soil. Tubers cannot be harvested until 150 days after application. Temik may not be used in furrow irrigated potatoes.

Admire Pro. Admire Pro is a more concentrated formulation than Admire and is available for the first time in 2006. It is a soil-applied insecticide providing long residual control of insect pests of potatoes. Admire Pro will control Colorado potato beetles, aphids, potato leafhoppers, 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).

Early Season Potato Program

Use only clean seed tubers with low or no disease content based on winter tests.

Aphid control in early season potatoes

It is important to control aphids on early season potatoes. Uncontrolled aphid populations can contribute to yield reductions, but more importantly, can serve as a significant source of virus-bearing aphids that infest seed and other potato fields. One well-timed application prior to development of winged aphids may be adequate. Aphids should be controlled until vines are dead or as close to vine kill as possible while observing pre-harvest intervals on product labels.

- Use systemic insecticides at planting.

- If growers of early season potatoes do not use a systemic insecticide at planting, it is even more important that foliar aphid insecticides be used later in the season.

- Fields should be scouted at 3 to 4 day intervals before aphid flights begin; at least eight locations in each field should be checked. Scouting should begin based on University recommendations. Application of foliar aphid insecticides should begin when 5 aphids per 100 leaves or 5 aphids/plant are detected. For information on potato aphids in the Columbia Basin, contact the *Aphid Hotline* at *1 888 673 6273*. This hotline (updated every 7-10 days during the main growing season) provides current GPA flights and field status; it is based on surveys of GPA from Umatilla to Moses Lake. For significant additional information on aphid pests of potatoes in Washington, see the website *www.potato.prosser.wsu.edu.* For information on aphids in Idaho, see the web site *www.uidaho.edu/so-id/entomology* and then click on *green peach aphid/leafroll*.

Foliar aphicides that are available for use in early potatoes include the following:

Fulfill. Apply Fulfill at the full label rate of 2.75 ounces per acre using a penetrating surfactant. 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. Avoid the use of Fulfill 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). 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.

Monitor. Follow suggestions for use of Monitor in the section on aphid control in late season potatoes, see below.

Penncap-M. Apply Penncap-M at the full label rate of 4 pints/acre by ground, air or chemigation for aphid control in early season potatoes. Begin applications as soon as aphids are detected. Applications of insecticides should continue until the likelihood of

GPA occurrence has passed. Repeat applications or Penncap-M at 10 -14 day intervals may be required if aphid pressure continues. Penncap-M is not a systemic insecticide and will not protect new vegetative growth. It is important to obtain complete coverage for best results. Apply in a minimum 5 gallons of water by air and a maximum of 0.2 inch/acre by chemigation. Do not apply more than 24 pints/acre Penncap-M per year. Do not irrigate within 24 hours of application. Penncap-M has an REI of 5 days.

Provado. Provado applied at 3.75 ounces per acre may provide control of both aphids and Colorado potato beetle. Provado provides 7 to 10 days of residual control and a second application is recommended in situations involving moderate to heavy aphid pressure or extended aphid flights. It is important to obtain complete coverage. Addition of a silicone or MSO type surfactant has shown to be helpful. Bayer CropScience does not recommend that the product be applied by air when aphids are the target pests. Do not apply this product if the field has been treated this year with Admire Pro, Gaucho, Cruiser or Platinum.

Actara. Actara 25 WG. Apply 3.0 ounces/acre by either ground or by air. A total of 6.0 ounces may be applied per season. Apply Actara in a minimum of 10 gallon of water when application by ground and a minimum of 5 gallon when applying by air. Application of Actara through irrigation systems is on the label but is not recommended by Syngenta for 2006. Avoid the use of Actara with any product containing sticker/binder-type adjuvants (e.g. Bravo Weather Stik, Bravo Ultrex or Dithane Rainshield). Do not apply this product if the field has been treated this year with Admire Pro, Gaucho, Cruiser or Platinum.

Leverage. Leverage is a package mix of imidacloprid (Provado) and cyfluthrin (Baythroid.) It may be applied by ground or chemigation at 3.75 fl oz/A as aphid populations begin to build. Two applications at 7-day intervals may be required to achieve good control. Use ground application equipment for more thorough coverage in dense canopy situations. The addition of a silicone or MSO surfactant may aid in aphid control. Do not apply this product if the field has been treated this year with Admire Pro, Gaucho, Cruiser or Platinum. Leverage-treated areas may be replanted with any crop specified on either an imidacloprid (Admire Pro, Provado) or cyfluthrin (Baythroid) label. For crops not listed on an imidacloprid or cyfluthrin label, or for crops for which no tolerances for imidacloprid or cyfluthrin have been established, a 12-month plant-back interval should be observed. Consult the Leverage label for specific crop listings.

Beleaf (flonicamid). Beleaf is a new insecticide that is expected to be registered during the 2006 growing season for use on potatoes. The registrant, FMC, will release the labeled use pattern once the product is registered for potatoes. Small plot trials indicate that Beleaf is highly effective when applied to the foliage for control of green peach aphid and potato aphid. The product is highly selective and has little or no activity against other insect pests and beneficial organisms. It has a period of residual control of between 14 and 21 days depending on the rate of application. **At the time this document was released Beleaf was not registered for use on potatoes.**

Assail 70WP (acetamiprid). Apply 1.1 to 1.7 ounces/acre by ground, air or chemigation for aphid control in early 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 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) 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, Cruiser or Platinum.

Early Season Colorado Potato Beetle (CPB) 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 kill beneficial organisms and may flare aphid numbers. Foliar applied products available for CPB control in early-season potatoes include Assail, Success, Agri-Mek, Penncap-M, Imidan, Provado, Leverage, Rimon and Actara.

Success. For light larval populations, apply 3 to 4 ounces 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 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 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.

Agri-Mek. Apply 8 to 16 ounces of Agri-Mek 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 Dithane Rainshield). The addition of a nonionic surfactant or organosilicone-based surfactant, at the manufacturer's recommended rate is suggested for optimum control.

Penncap-M. Apply Penncap-M at 3 - 4 pints/acre by ground, air or chemigation for Colorado potato beetle control in potatoes. Begin applications early when the CPB population is primarily in larval the stage and before unacceptable defoliation has occurred. Repeat applications at 10 -14 day intervals may be required if Colorado potato beetle pressure continues. Penncap-M is not a systemic insecticide and will not protect new vegetative growth. It is important to obtain complete coverage for best results. Apply in a minimum 5 gallons of water by air and a maximum of 0.2 inch/acre by chemigation. Do not apply more than 24 pints/acre Penncap-M per year. Do not irrigate within 24 hours of application.

Imidan 70W. 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.

Provado 1.6 Flowable. Apply 3.75 oz/acre; 7 days of residual activity should be expected. It is important to obtain complete coverage. Addition of a silicone or MSO type surfactant has shown to be helpful. Applications can be made by air or ground. Do not apply Provado, Leverage or Actara if Admire Pro, Platinum, Gaucho or Cruiser have been applied as a seed or in furrow treatment.

Actara. Apply 1.5 ounces/acre by either ground or by air. 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 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, Gaucho, Cruiser or Platinum.

Leverage. 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 gpa with 10 gpa recommended. The addition of a silicone or MSO type surfactant may aid in control. Do not apply this product if the field has been treated this year with Admire Pro, Gaucho, Cruiser or Platinum.

Rimon 0.83 EC. 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 a contact insecticide and ovicide, therefore, reapplication at 7 to 14 days is needed to protect new 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 gpa when applying by air; apply a minimum of 10 gpa when applying by ground.

Assail 70WP (acetamiprid). Apply 0.6 to 1.1 ounces/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 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. 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, Cruiser or Platinum.

Desiccation of Early Season Potatoes

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 of potatoes 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 Monitor be used.

Full Season Potato Program (Stored Potatoes)

- Use only clean seed tubers with low or no disease content based on winter tests.
- Control volunteer potatoes and potatoes growing in cull piles. (See section in early season potatoes for information on volunteer potato control.)
- Based on trials conducted in Idaho, Oregon and Washington, imidacloprid-based products (Admire Pro and Gaucho) and thiamethoxam-based products (Platinum and Cruiser) provide significantly better aphid control than alternatives. Imidacloprid and thiamethoxam applied at planting will provide 80 to 100 days of residual control. Aldicarb (Temik) applied at planting will provide approximately 70 to 75 days control. Other soil applied systemic insecticides such as phorate (Thimet, Phorate) and Furadan do not provide reliable GPA control beyond 50 days. Use of Temik will increase the likelihood that foliar application of insecticides mid to late season will be necessary. Use of Thimet and Furadan in a full season potato production system is of minimal value for pest management.
- Fields should be scouted at 3 to 4 day intervals before aphid flights begin; at least ten locations within each field should be checked. Scouting should begin based on University recommendations. In the Columbia Basin, contact the Aphid Hotline at 1 888 673 6273. This hotline (updated weekly during the main growing season) provides current and projected GPA flights and field status; it is based on surveys of GPA from Moses Lake to Umatilla. For significant additional information on aphid pests of potatoes in Washington, see the website www.potato.prosser.wsu.edu. For information on GPA/PLRV in Idaho, see the web site www. uidaho.edu/so-id/entomology and then click on green peach aphid/leafroll.
- 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 PLRV transmission in late season Russet 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 Potato Leaf Roll Virus (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.
- 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, shepardspurse, 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.

Aphid Control in Full Season Potatoes

- Application of aphid insecticides should begin just prior to time of the expected time in decline in performance "break" of the soil or seed treatment insecticides applied at planting or layby or if aphid flights have been forecast for your area. Do not rely on aphid counts to time applications of foliar aphid insecticides as the action threshold based on number of aphids per plant is too low for most scouting programs to detect.

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

Monitor. Apply Monitor at the full label rate of 2 pints of product just prior to the "break" in control of the soil applied insecticide or as soon as non-winged aphids are detected. Winged aphids bearing PLRV are capable of transmitting the virus within minutes of landing, therefore, application of insecticides solely based on detection of aphids in a field may not prevent transmission of PLRV. Applications of insecticides should continue until the likelihood of GPA occurrence has passed. Monitor should be applied according to the following intervals: 14-day intervals when canopy is open, 10-day intervals when canopy is completely closed over and 7-day intervals when canopy becomes compacted. The Monitor label permits a maximum of four applications. A minimum of five gallons of water should be used when applying Monitor by air. Do not apply Monitor via an irrigation system. [Application of Monitor through an irrigation system may be an appropriate choice for locations where aerial or ground applications are prohibited, such as portions of the Tri-Cities area in Washington.]

Fulfill. Apply Fulfill at the full label rate of 2.75 ounces per acre. 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 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 two applications. When applying Fulfill by ground or air use an oil blend adjuvant. Avoid the use of Fulfill 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). 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.

Actara. Apply 3.0 ounces/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. Application of Actara through irrigation systems is on the label but is not recommended by Syngenta for 2003. 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, Gaucho, Cruiser or Platinum.

Beleaf (flonicamid). Beleaf is a new insecticide that is expected to be registered during the 2006 growing season for use on potatoes. The registrant, FMC, will release the labeled use pattern once the product is registered for potatoes. Small plot trials including Beleaf indicate the product is highly effective when applied to the foliage for control of green peach aphid and potato aphid. The product is highly selective and has little or no activity against other insect pests and beneficial organisms. It has a period of residual control of between 14 and 21 days depending on the rate of application**. At the time this document was released Beleaf was not registered for use on potatoes.**

Assail 70WP (acetamiprid). Apply 1.1 to 1.7 ounces/acre by ground, air or chemigation for aphid control in early 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 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) 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, Cruiser or Platinum.

Penncap-M. Apply Penncap-M at the full label rate of 4 pints/acre by ground, air or chemigation for aphid control in full season potatoes. Penncap-M should be applied prior to the “break” in control of a soil applied insecticide or at the very first detection of aphids in the field. Applications of insecticides should continue until the likelihood of GPA occurrence has passed. Repeat applications at 10 -14 day intervals may be required if aphid pressure continues. Penncap-M is not a systemic insecticide and will not protect new vegetative growth. It is important to obtain complete coverage for best results. Apply in a minimum 5 gallons of water by air and a maximum of 0.2 inch/acre by chemigation. Do not apply more than 24 pints/acre Penncap-M per year. Do not irrigate within 24 hours of application.

- Foliar programs should be initiated just prior to the “break” of the systemic insecticides applied at time of planting. 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. Applications of aphid insecticides should be completed by Labor Day.

- Green peach aphid action threshold. To increase the likelihood that aphids have the minimum opportunity to transmit PLRV, the following action threshold is suggested for potatoes destined for storage and in which net necrosis is a concern. Apply a foliar insecticide when aphids (particularly green peach aphid) reach 3 to 5 winged aphids per 100 leaves, an average of 1 winged aphid per plant or upon detection of wingless aphids.

Mite Control in Potatoes

Virtually all economic infestations of mites (two-spotted spider mites) on potatoes occur in the Columbia Basin of Washington and Oregon. Occasionally mite outbreaks on potatoes occur in other regions of Oregon and in Idaho. Mite infestations should be managed in the same manner throughout the Pacific Northwest, 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 miticides (Agri-Mek, Comite and Oberon) should be made upon early detection of mites. All potatoes should be surveyed for the presence of mites and mite eggs starting July 15.

Sampling for mites requires a close visual inspection of leaves from differing levels of the plants. Use of at least a 16x 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 an different miticide should be considered as a resistance prevention strategy. Mites on potatoes have never been demonstrated increased tolerance to miticides; however, two spotted spider mites are well known for its ability to develop resistance and rotation of miticides is desirable.

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 (mode of action) should be considered as a resistance prevention strategy. Mites on potatoes have never demonstrated increased tolerance to miticides; however, the two spotted spider mite is well known for its ability to develop resistance and rotation of miticides is desirable.

Oberon 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 should be applied at 8-16 fluid ounces 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.

Comite is effective against the nymphal and adult stages of spider mites when applied by air, ground, or chemigation. 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.

Cutworm, Armyworm and Cabbage Looper Control in Potatoes

Little is known about the biology and management of worms in PNW potatoes. The economic threshold for when to treat for worms is unknown. In the absence of a threshold, growers should consider the level of defoliation by worms to be approximately similar to that of Colorado potato beetles. CPB rates of development and feeding patterns are different from worms, so do not make predictions of expected damage using your knowledge of beetle outbreaks. Also, different worm species can infest potatoes, so your experience for one field may not be appropriate for another field unless the species, environment and other conditions are the same or similar. It is important to scout for living worms in your fields, rather than applying in response to damage. Sometimes worms are absent by the time damage is noticed.

There are four insecticides recommended for control of worms in a potato integrated pest management program, Success, Rimon and Avaunt (indoxacarb) and Leverage. Applications should be targeted at the incidence of feeding or appearance of small larvae (1^{st} and 2^{nd} instars). Larger larvae may be more difficult to control and may require multiple applications at 7-day intervals.

Success. For smaller sized worms (early instars), apply 4.5 ounces of product per 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 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 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.

Avaunt. Avaunt may be applied by air or ground equipment at 2.5 to 6.0 ounces per acre, with 3.0 ounces being the most common rate applied. The preharvest interval is 7 days and it has a restricted entry interval of 12 hours. A total of 24 ounces can be applied per season. Applications by air require a minimum of 5 gallons of water per acre.

Rimon 0.83 EC. 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 larvae are between egg hatch and second instar. Rimon is a contact insecticide and ovicide, therefore, reapplication at 7 to 14 days is needed to protect new growth. In order for this product to affect larvae it must be ingested. Rimon has no affect on adults. Do not make more than two applications per season. A minimum of 5 gpa when applying by air; apply a minimum of 10 gpa when applying by ground.

Imidan 70W. Imidan may be applied for control of loopers at 1.33 to 2.5 pounds per acre. Apply when worms are first detected and larvae are predominantly small. A rate of 2 to 2.5 pounds is recommended for use against loopers in potatoes. Apply by ground or air in a minimum of 2 gallons of water per acre. Obtain uniform coverage for best results. Do not apply more than two times per season when using the maximum rate of 2.5 pounds per acre per season, do not apply more than 6.66 pounds per season. This product may be applied through irrigation systems. At 1.33 pounds per acre, the preharvest interval is 7 days, at rates above 1.33 pounds, the preharvest interval is 21 days. This product is available for use under Section 24c of FIFRA, make sure you have a copy of 24c label with you when making the application.

Neonicotinoid Resistance Management

The two most significant insect pests of potatoes in the world, Colorado potato beetle and green peach aphid, have developed resistance to many insecticides used for their control. While the Pacific Northwest has largely escaped this problem, the development of insecticide resistance in these pests is still an issue for which the potato industry needs to be prepared. Once resistance to an insecticide is established in a population the utility of the product is largely lost. Avoidance of resistance or resistance management is the best means to preserve the effectiveness of potato insecticides. PNW potato growers will have access to four planting time products, Admire Pro, Gaucho, Platinum and Cruiser and four foliar products, Assail, Provado, Leverage and Actara, 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 elevated levels of tolerance to neonicotinoid insecticides in potatoes potentially jeopardizing the use of this class of insecticides. It is critical that this situation be avoided in the Pacific Northwest.

A simple method exists that can help avoid the development of resistance to these valuable products. If Admire Pro or Platinum are applied in-furrow or as a side dress or if Gaucho, Cruiser are applied as a seed treatment, do not use Assail, Provado, Leverage or Actara in the same field in the same season. This will help prevent subsequent generations of the pests from being exposed to the chemistry.

A second resistance management tactic that can be used is to not treat all potato fields on one farm or in one localized area with products from the neonicotinoid class at one time. 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.

Management of Leafhoppers and Beet Leafhopper Transmitted Virescence Agent in Potatoes

An early 2004 article published in the Washington State Potato Commission's *Potato Progress* describes the most current opinions in managing leafhoppers and BLTVA in potatoes. This report has been revised in 2005 based on 2004 research and field observations.

Management of BLTVA in Potatoes

A serious epidemic of a "potato yellows" disease occurred in many potato fields throughout the Columbia Basin in 2002. The beet leafhopper-transmitted virescence agent (BLTVA), a bacteria-like organism called a phytoplasma, has been shown to be a primary, if not the only, cause of this disease. The only known vector for this disease is the beet leafhopper (BLH), but leafhoppers in one other genus have tested positive for BLTVA. Even though we know little about this disease and its vector(s), potato growers are still faced with the prospect of protecting their crops from this disease. The following article is a summary of our professional opinions on best management options for controlling BLTVA in potatoes.

Minimal data on control of BLTVA-transmitting leafhoppers is available. We are largely relying on information on control of other species of leafhoppers, notably the potato leafhopper, in potatoes in the Midwest, what we know about controlling leafhoppers in other crops, and what we know generally about insecticides labeled for use on potatoes. Prophylactic use of insecticides is the only known means to prevent transmission of BLTVA. Table 1 contains the list of insecticides available for leafhopper control on potatoes in the Pacific Northwest.

Management Considerations

Monitoring. Because potatoes are not a preferred host of the beet leafhopper, in-field sampling is difficult. We recommend monitoring for leafhoppers using yellow sticky cards around field margins. Historically, initial BLH flights of concern to potatoes occur in May and June in the Columbia Basin. We suggest treating potato fields when total catches of leafhoppers on field margins begin to climb, probably in mid May and June. Control measures should start when leafhopper flights begin and fields must be protected for the duration of these flights. The most important period for BLTVA transmission is apparently May and June, but there is some evidence from commercial fields that transmission can occur and cause damage as late as late July.

Action Threshold. Research since 2002 has found that a significant percentage of the BLH in the Columbia Basin is infected with BLTVA. This means that detection of BLH at any level in or near a field, or even knowledge of BLH flights in your general vicinity, should serve as an action threshold for treatment. We hope to generate research information in coming years, which will help growers judge how serious their risk is. Relevant leafhopper sampling results are posted on the potato/aphid web site hosted by Keith Pike (http://www.wsu.edu/~potatoes/) and the Potato Commission's web site at: www.potatoes.com/research.cfm.

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. For example, there is a 4-application restriction (at the high rate) for Monitor. If Monitor is applied for beet leafhopper three times, only a single application will be available for the remainder of the year. Do not apply Assail, Actara, Provado, or Leverage for leafhoppers if you have already applied Admire Pro, Gaucho, Platinum or Cruiser at planting due to resistance management concerns. Pyrethroid insecticides such as Asana, Baythroid, Ambush and Pounce, or Leverage, which contains a pyrethroid, are tempting choices for control of leafhoppers due to good efficacy against leafhoppers, low price, and broad spectrum. 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. Asana, Baythroid, Ambush, Pounce, and Leverage 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. Timing applications based on leafhopper counts in a field is too risky. 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, Sevin, and Guthion, 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. Minimal insecticide screening against leafhoppers in potatoes has been conducted in the PNW; however, work in this area has been carried out in other crops and in other regions on other leafhopper species on potatoes. Based on these bodies of work, leafhoppers are generally considered to be relatively easy to control. Many of the insecticides listed in Table 1 will kill leafhoppers, but other considerations significantly reduce the utility of several of them. For reasons that are not clear, planting time insecticides do not appear to provide beet leafhopper control in potatoes.

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. Temik, Admire Pro, Gaucho, Thimet/Phorate, Platinum, 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. Growers should depend on a foliar insecticide program rather than planting time treatments to provide control of these leafhoppers.

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, methyl parathion, malathion, and **Disyston.** 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.

Guthion. Guthion is not used for leafhopper control in other crops or for leafhopper on potatoes in the Midwest. Products with known efficacy for leafhoppers are more suitable choices.

Foliar Products with Uncertain Utility for Control of Leafhoppers

Furadan, Thiodan/Endosulfan, 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 rot and tuber crops. Its efficacy against leafhoppers in potatoes is unknown.

Foliar Products with a Higher Potential for Use Against Leafhoppers

Asana, Baythroid, Ambush, and Pounce. These four 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.

Provado, Actara and Assail. These products provide good efficacy against leafhoppers and have relatively longer periods of residual activity. Due to concerns

with resistance management neither product should be used if a neonicotinoid insecticide such as Admire Pro, Gaucho, Platinum or Cruiser, has been used at planting time. Do not apply the 1.5 ounce rate of Actara more than four times. Do not apply Provado more than four times at the 3.75 oz rate. Do not apply Assail more than four times at the 1.7 oz rate.

Leverage. This is a prepackage mix containing imidacloprid (Provado) 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 Provado. Leverage is a very effective against leafhoppers.

Monitor. Monitor provides excellent efficacy against leafhopper and has a relatively longer period of residual activity. There is a season limitation on the amount of Monitor that can be used - do not make more than 4 applications at the 2 pint rate or 5 applications at the 1.5 pint rate.

Penncap-M. Penncap-M is effective against leafhoppers. Apply Penncap-M at 3 - 4 pints/acre by ground, air or chemigation. Penncap-M is not a systemic insecticide and will not protect new vegetative growth. It is important to obtain complete coverage for best results. Apply in a minimum 5 gallons of water by air and a maximum of 0.2 inch/acre by chemigation. Do not apply more than 24 pints/acre Penncap-M per year. Do not irrigate within 24 hours of application.

Vydate. 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 Management Recommendations

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

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Potato tuberworm (PTW) was recognized as an insect pest of potatoes in the Columbia Basin in 2003. In each of the following years, it ingcreased its range and damage. Although its host range includes a wide array of solanaceous crops such as tomatoes, peppers, eggplants, tobacco, and nightshade, it has only been found on potatoes in the Pacific Northwest. At the time these recommendations were developed, PTW had 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.

There is much about the biology and management of PTW in the Pacific Northwest that is unknown. The following recommendations represent our best understanding of this pest in potatoes in Washington and Oregon. When possible, the recommendations are based on local research.

PTW is present throughout the growing season; however, early and mid season foliar infestations have been light to moderate. The species is capable of many generations in a year and populations appear to build sharply later in the growing season (August, September and October). Control efforts should be directed toward populations during this time. If PTW populations appear to be building prior to this time, control measures may be necessary.

Non-Chemical Control Considerations

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. Feeding cull potatoes to cattle will not eliminate risk from PTW unless potatoes are consumed immediately.

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 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 apparently 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 research project on PTW and desiccants in Oregon was inconclusive.

How Long Should a PTW Management Program Last? 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 controlling PTW in potatoes. A 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. Application of all insecticides in this trial controlled PTW compared to the untreated check. However, given the preliminary nature of this study, it is recommended that PTW control programs start no later than 4 weeks prior to desiccation/harvest until further research can be conducted on the subject.

Chemical Controls

Products that have been found to be effective for control of PTW in Washington and Oregon – based on one season of testing. 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.

Monitor. Monitor applied by ground and chemigation at 32 ounces (2 pints) was effective when applied at a 7-day interval.

Guthion. Guthion was effective when applied by ground at 7 days. Guthion's use on potatoes has been cancelled; however there is an existing use provision in place. Growers with Guthion that has potatoes still on the label may use the product through September 30, 2006.

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.

Agri-Mek. Agri-Mek was effective when applied by ground at 7 day intervals at 10 ounces.

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.

Furadan. Furadan was effective at a 7-day interval at 2 pints when applied by ground.

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

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

Assail. In a test in Benton County, Washington involving moderate PTW pressure, Assail had activity against PTW when applied by ground at 10-day intervals; however, this product was only moderately effective. It was not effective when applied by chemigation. In another test at Hermiston, Oregon, Assail was not effective when applied by ground or chemigation against a heavy population of PTW. Assail should be applied at 1.7 ounces. Based on the results of this set of trials in 2005, Assail is not recommended for PTW; however use of the product against other insect pests may reduce PTW populations.

Penncap M. Penncap M applied at 4 pints at 10 day intervals by ground was effective against PTW.

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.

Products Considered Ineffective Against PTW. No planting time treatments are known to be effective against PTW including Gaucho, Admire Pro, Cruiser, Platinum, Venom, Temik and Thimet/Phorate.

Foliar Insecticides Considered Ineffective Against PTW. Sevin, Provado, Actara, dimethoate, Fulfill, Comite and Oberon have not demonstrated efficacy against PTW.

Products of Unknown Efficacy Against PTW. Research has not yet determined the efficacy of Ambush/Pounce, Thiodan and Battalion against PTW.

Treatment Intervals and Rates of Application. Research conducted in 2005 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 likely that products can be applied at wider intervals, at lower rates, or at both wider intervals and lower rates than were tested in 2005. Further research is needed to determine the most cost effective rates and timing intervals.

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 pests[1]

	Beet Leafhopper	Colorado Potato Beetle	Green Peach Aphid	Cabbage Looper	Thrips
Monitor	xxx	x	xxx	xxx	xx
Imidan	xxx	xxx		xx	
Penncap M	xxx	xx	xx	xx	x
Guthion	xxx	xxx			
Furadan	xxx	xxx	x		
Success		xxx		xx	x
Assail	xxx	xxx	xx		xx
Leverage	xxx	xxx	x	xxx	
Baythroid	xxx	xxx		xxx	
Asana	xxx	xxx		xxx	
Agri-Mek		xxx			
Lannate	xxx	x	x	x	
Avaunt				xxx	
Rimon		xxx		xxx	

1 An xxx means efficacy against the pest is high, a double x means efficacy is moderate, a single x means efficacy is present but may not be commercially acceptable. A lack of an x means no efficacy data exists. Other factors including cost, length of residual control, impact on secondary pests and beneficals 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 and thrips. Because of these new pests, growers must choose their products carefully. All insecticides have restricted entry interval (REI)l, a preharvest interval (PHI) and a limit on the amount of product that can be used in a single season.

Guthion has a 7-day REI, Monitor has a 3-day REI. 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. Monitor, Agri-Mek and Furadan have 14-day PHIs, while other products have shorter PHIs such as Baythroid (0 day PHI), and Penncap M (5 day PHI).

PRODUCT	REI	PHI	SEASONAL USE LIMITS
MONITOR	72 hrs	14 days	8 pt/acre/season
GUTHION	7 day	7 days	2 apps/season
RIMON	12 hr	14 days	2 apps/crop/season; 24 oz/season
AVAUNT	12 hr	7 days	24 oz/acre/season
AGRI-MEK	12 hr	14 days	32 oz/season for mites; 48 oz/season for leafminer
ASANA	12 hr	7 days	0..35 lb ai/season
LANNATE	48 hr	6 days	4.5 lb ai or 10 apps/season
IMIDAN	24 hr	7 days	6.66 lb/season
SUCCESS	4 hr	7 days	3 apps/30 day interval; 4 apps/crop/season; 21 oz/season
FURADAN	48 hr	14 days	2 apps/season
LEVERAGE	12 hr	7 days	15 oz/acre/season
BAYTHROID	12 hr	0 day	6 apps/season
ASSAIL 70WP	12 hr	7 days	6.8 oz/season; 4 apps/season
PENNCAP M	5 days	5 days	24 pt/season

When Imidan is used at the higher rate (1.33 to 2.5 lbs/ acre) the PHI increases to 21 days.
Guthion will not be registered for use on potatoes after September 30, 2006.

When to Treat. No economic threshold has been established for PTW in the Pacific Northwest. If larval PTW is detected in a potato field at any level, a control program is recommended.

Method of Application. All PTW insecticide research in 2005 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 significant 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. Two organically acceptable chemical control options have been found effective against the insect pest.

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

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 do 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. The species is notorious for its ability to develop resistance to insecticides used for its control and in many locations in the world has developed resistance to virtually everything used for its control. ***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 three 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: Monitor, Guthion, Imidan, Penncap M
2) Rimon
3) Avaunt
4) Agri-Mek
5) Pyrethroids: Asana, Leverage, Baythroid
6) Success, Entrust
7) Carbamates: Furadan, 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	Adult	Activity against larvae in leaf tissue
Monitor		**x**	**x**	**x**
Guthion		**x**	**x**	
Imidan		**x**	**x**	
Penncap M		**x**	**x**	**x**
Rimon	**x**	**x**		
Avaunt	**x**	**x**		**x**
Agri-Mek		**x**		
Asana		**x**	**x**	
Leverage		**x**	**x**	
Baythroid		**x**	**x**	
Success, Entrust		**x**		
Furadan		**x**	**x**	**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 potato tuberworm releases a sex pheromone to attract 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 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 by Connie Smithhisler. These are put in Delta traps and are replaced after 4 weeks exposure in the field. When purchasing pheromone lures from a company, it is important to specify that you need the complete blend of the pheromone. Trece, for example, sells lures that only include one of the two pheromone chemicals, and they sell lures that include both chemicals. The lures with one chemical, referred to as their “California” lure, are expected to be considerably less attractive to the potato tuberworm than the two component lures, referred to as their “International” lure. We have been told by Cam Oeschlager of Chem Tica in San Jose, Costa Rica that their potato tuberworm lures, sold through AgBio, include both chemicals.

We expect to be able to conduct comparative tests this spring, to verify that these and possibly other commercial lures are similar in attractiveness, and comparable to the lures that have been provided by USDA-ARS to the survey project. Both Trece and ChemTika have expressed strong interest in working with us and providing the types of lures that are needed by PNW researchers and growers.

All growers in areas even potentially affected by tuberworm should maintain at least one pheromone trap adjacent to each field throughout the season. 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). 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: www.potatoes.com/research.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 currently plan to conduct the regional tuberworm trapping network again this coming season. Watch the potato commission website for data when it becomes available:

Scouting and Sampling for PTW

Several issues related to scouting have been 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. A thorough 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.

Comparative Efficacy of Insecticides

I, Alan Schreiber, have conducted a series of insecticide screening trials on potatoes in Washington for several years. As a result of these trials and my review of data from other trials and observations of use in the field, I have developed the following table that provides a comparative efficacy guide of for various insecticides registered for use on potatoes.

Insecticide Effectiveness In Potatoes

Prepared by Alan Schreiber, Agriculture Develoment Group, Inc.

Active Ingredient		Aphids	CPB	Cabbage looper	Spider mites	Wireworms	PTW
1,3 dichloropropene	Telone	VP	VP	VP	VP	G	ND
abamectin	Agri-Mek	VP	G	ND	ND	VP	E
actamiprid	Assail	G	E	ND	ND	ND	F
aldicarb	Temik	E	E	F	ND	ND	ND
azinphos-methyl	Guthion	VP	G	G	ND	VP	E
carbaryl	Sevin	VP	G	ND	ND	VP	VP
carbofuran	Furdan	G	G	ND	ND	ND	E
chloropicrin	several	VP	VP	VP	VP	ND	ND
cryolite	Cryolite	VP	ND	ND	ND	VP	ND
cyfluthrin	Baythroid	VP	E	E	VP	VP	E
dimethoate	Dimethoate	G	P	ND	ND	VP	ND
disulfoton	Di-Syston	G	P	ND	ND	ND	ND
endosulfan	Thiodan	ND	ND	ND	ND	VP	ND
esfenvalerate	Asana	VP	E	E	VP	VP	E
ethoprop	Mocap	VP	VP	VP	VP	G	ND
imidacloprid	several	E	E	VP	VP	F	ND
indoxacarb	Avaunt	VP	VP	E	VP	VP	E
malathion	several	ND	ND	ND	ND	VP	ND
metam potassium	K-pam	VP	VP	VP	VP	ND	ND
metam sodium	Vapam	VP	VP	VP	VP	F	ND
methamidophos	Monitor	E	F	G	VP	VP	E
methomyl	Lannate	G	G	G	ND	VP	E
methyl parathion	Penncap-M	F	F	F	P	VP	E
novaluron	Rimon	VP	G	G	VP	VP	E
oxamyl	Vydate	G	G	G	F	ND	ND
permethrin	Ambush, Pounce	VP	E	E	VP	VP	ND
phorate	Thimet, Phorate	E	E	ND	VP	VP	ND
phosmet	Imidan	VP	G	G	VP	VP	E
propargite	Comite	VP	VP	VP	G	VP	VP
pymetrozine	Fulfill	E	VP	VP	VP	VP	VP
spiromesifen	Oberon	NE	NE	NE	NE	E	VP
spinosad	Success	VP	G	G, F	VP	VP	E
sulfur	several	ND	ND	ND	ND	ND	ND
thiamethoxam	several	E	E	VP	VP	F	ND
diazinon	several	F	G	F	VP	F	ND
azadirachtin	several	ND	F	ND	ND	ND	ND

E = Excellent, G = Good, F = Fair, P = Poor, VP = Very Poor or No Effect, ND = No Data