

MANAGEMENT OF APHIDS AND LEAFHOPPERS IN THE NORTH CENTRAL UNITED STATES

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Aphids

The aphid species that most commonly colonize potato in the North Central United States are green peach aphid, *Myzus persicae*; potato aphid, *Macrosiphum euphorbiae*; and buckthorn aphid, *Aphis nasturtii*. Green peach aphid and potato aphid usually are the most abundant colonizers of potato. Buckthorn aphid is more sporadic but can occur in high numbers. Foxglove aphid, *Aulacorthum solani*, also occurs, but usually is rare.

Aphids are of special concern to seed potato producers because they can transmit virus diseases which may lead to rejection of the seed lot. For this reason, growers of seed potatoes generally target insecticidal treatments specifically against aphids hoping to minimize virus spread. Aphids can cause direct injury to potatoes by sap feeding, but their numbers must be very high for this to occur. Therefore, growers producing potatoes for fresh market and processing can tolerate usual aphid numbers without concern.

The most important potato virus diseases transmitted by aphids are potato leaf roll virus (PLRV) and potato virus Y ("PVY" or "mosaic"). Current season infection usually does not greatly reduce yields, but planting seed tubers infected with these viruses can result in severe yield loss. In certain older cultivars, especially 'Russet Burbank', 'Green Mountain' and 'Irish Cobbler', infection with PLRV can result in a tuber phloem necrosis (= "net necrosis").

Green peach aphid is the most efficient vector of both PLRV and PVY, as well as potato virus A, potato virus S, and potato virus M. Potato aphid and buckthorn aphid also transmit PLRV; however, both these aphids are only 1/10 as efficient as green peach aphid. Buckthorn aphid is an efficient vector of PVY, but potato aphid is not. Foxglove aphid can transmit PLRV, but not PVY.

PLRV can only be transmitted by aphid species capable of colonizing potato. This is because PLRV is a phloem-restricted virus. Acquisition of the virus requires feeding probes of extended duration, often of several hours. After ingestion, PLRV passes through the aphid's midgut wall into the blood, then to other tissues. Aphids are not able to transmit PLRV to healthy plants until the virus penetrates the salivary glands. This may take 8-48 hours, depending on temperature. Once acquired, PLRV is retained by the aphid throughout its life, even when it molts.

In contrast, PVY can be transmitted by many aphid species including species incapable of colonizing potato. PVY and all other aphid-transmitted potato viruses except PLRV occur in the sap of all tissues of the plant. Thus, feeding probes of even the briefest duration can be sufficient to acquire or transmit PVY. Ability to transmit PVY is non-persistent and is lost by the aphid within the first few feeding probes after acquisition.

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Many known PVY vectors are cereal aphids including: bird-cherry oat aphid, *Rhopalosiphum padi*; greenbug, *Schizaphis graminum*; and English grain aphid, *Sitobion avenae*. Other common aphids known to transmit PVY include pea aphid, *Acyrtosiphon pisum*; corn leaf aphid, *Rhopalosiphum maidis*; and a thistle aphid, *Capitophorus elaeagni*.

There are three circumstances in which aphid control is justified in potato production: 1) to eliminate virus vectors in seed production, 2) to prevent spread of PLRV in cultivars susceptible to net necrosis, and 3) when previously used insecticides have induced serious aphid outbreaks. However, insecticides should only be applied as needed.

Sweep net sampling is not very useful for monitoring aphid populations as collection efficiency is low, and those that are collected may be crushed and unrecognizable. Counting aphids on randomly selected leaves is the preferred sampling method. Full leaves (not leaflets) should be selected from the lower mid-portion of the plant. A 100 leaf sample usually will give a reliable estimate of the population in the area sampled. Aphid infestations may not be uniform across large fields so it is preferable to take separate samples at different locations.

In Minnesota and North Dakota the recommended threshold for insecticidal treatment is 35 green peach aphids per 105 leaves in production fields. In Wisconsin, the recommended threshold is 100 aphids per 100 leaves. This difference is not as great as it might seem, since, under favorable conditions, populations of aphids on the plants can double in less 2 days.

The threshold concept is of more questionable validity when applied to seed production. Obviously, what is critical, but always unknown, is the incidence of infectivity in the aphid vectors. The rationale for monitoring aphid flights is the assumption that some unacceptable portion of that in-coming population will be capable of transmitting a virus. In potato fields planted with virus-free tubers, this is the only possible source of virus infection.

European seed potato producers have long relied on monitoring aphid flights to make management decisions. Similar methods are used in some parts of North America, but here there seems to be less certainty as to the benefit. Apparently, large flights of summer migrants are more typical in Europe than in most seed production areas of this continent.

New Brunswick uses yellow pan traps to monitor green peach aphid flights. Traps are checked twice a week and when winged aphids (alatae) are first captured growers are notified by telephone. Wingless aphids (apterae) on the potatoes are not sampled. Vine kill is recommended within 10 days once a cumulative total of 5 green peach aphids per trap (field) have been caught. A special "Topkill Committee" of growers, extension specialists and seed inspectors is empowered to mandate vine kill dates for seed producers. Some years captures exceed this threshold before economically acceptable tuber yields are obtained and the crop may have to be harvested as table stock. Similar programs are operated in Maine and Prince Edward Island.

In the North Central United States, seed potato producers usually do not monitor aphid flights. Here, there have been few studies to compare the importance of alatae and apterae in virus spread, but there is increasing evidence, experimental and observational, that within field spread of PLRV correlates best with counts of apterae on the plants. In Minnesota, we have shown a high correlation between control of within field green peach aphid apterae populations and the spread of PLRV from within field source plants.

Alatae and apterae of this aphid do not appear to differ in their efficiency of transmission, but since apterae are much more common on the plants during most of the summer, we assume these account for most within field spread of PLRV. Further, the pattern of spread of PLRV is to plants immediately adjacent to infected source plants, suggesting spread by aphids walking from plant to plant.

Recent research in Minnesota has demonstrated that spread of PLRV can be halted with the use of foliar sprays alone. Use of the presently available soil applied systemic insecticides at planting did not result in improved PLRV control. Timing of the application of foliar sprays can be based on aphid density. For 'Russet Burbank' we recommend application of methamidophos (Monitor) when green peach aphid numbers reach a threshold in the range of 3-10 green peach aphid per 100 leaves. We have evidence that in more PLRV-resistant cultivars this threshold can be elevated without risk.

In contrast, the pattern of PVY spread appears to be essentially random. This suggests that PVY spread is primarily by winged aphids. There is little evidence that insecticidal control measures are effective in preventing the spread of PVY. Even when persistent toxic residues are continually present, as when systemic insecticides are used, alighting aphids are not killed quickly enough to prevent the transmission of a noncirculative virus such as PVY. If the principal source of PVY were from within the field, i.e., from plants grown from infected tubers, suppression of aphids on the crop might reduce spread, but still wouldn't prevent it. In our experiments, it appeared that PVY spread is primarily by aphids originating from outside the field. These migrants may arrive already capable of transmitting PVY, but are equally capable of acquiring and transmitting the virus from point sources within the field before being killed by insecticide residues.

The principal defenses against a nonpersistent virus such as PVY is to plant clean seed, rogue infected plants as they emerge, and isolate seed fields as much as possible from sources of virus and aphids. For small plots of high value, nuclear or early generation seed, we suggest planting borders of soybean. These borders will reduce the apparency of the potatoes to in-flights of aphids and the intercepted aphids will lose the virus charge from their mouthparts when they attempt to feed on the soybean.

Although insecticides are routinely applied in potato production, many give only marginal or unsatisfactory aphid control. Green peach aphid is one of the few species for which resistance to every major insecticide class has been reported. In many parts of the country, insecticide resistance severely limits the options growers have for control of green peach aphid. Insecticide resistance is also common in potato aphid and buckthorn aphid.

The only insecticide currently registered for potato that consistently gives satisfactory aphid control is methamidophos (Monitor). Other insecticides, e.g., endosulfan (Thiodan), methomyl (Lannate, Nudrin), oxamyl (Vydate) may give adequate control early in the season, but may fail upon repeated application. Systemic insecticides such as disulfoton (Di-Syston) and phorate (Thimet) may provide early season control, but after the residual control is exhausted, aphids may increase to greater numbers than on potatoes not treated with any insecticide.

Many other insecticides registered for use on potato, e.g., carbaryl (Sevin), azinphosmethyl (Guthion), methyl parathion (PennCap-M), and esfenvalerate (Asana), can trigger aphid outbreaks. Some of these insecticides give reasonably good control of aphids on first application, but repeated use of the same insecticide or of others of similar mode of action rapidly selects for an insecticide-resistant aphid population.

Virtual immunity can sometimes develop with just two or three spray applications. This resistance coupled with the elimination of natural enemies can trigger spectacular increases in aphid populations necessitating control to prevent direct injury to the crop. Direct stimulation of reproduction also occurs with certain pesticides.

Usually when insects develop resistance there is initially some loss of fitness; however, with green peach aphid, reproduction is actually enhanced. Insecticide resistance has been attributed to duplication of a gene which codes for carboxylesterase production in green peach aphid. In highly resistant variants, carboxylesterase may account for 3% of total body protein. When insecticide pressure is removed, resistance remains stable in green peach aphid populations for 10-27 generations, then spontaneously reverts to complete susceptibility within approximately 4 generations.

Leafhoppers

Two leafhoppers are commonly found on potatoes in the North Central United States. The most important species in terms of yield reduction is the potato leafhopper, *Empoasca fabae*. The other common leafhopper is the aster or six-spotted leafhopper, *Macrostelus quadrilineatus*. Both leafhopper species overwinter in the southern U.S. These leafhoppers usually arrive in the North Central States before potatoes have emerged and it is their progeny that colonize potato. Potato leafhoppers build up in alfalfa and other early season hosts; aster leafhoppers develop on grasses and small grains, especially oats.

Potato leafhopper overwinters only in the coastal region of the Gulf States. Each spring, the adults are transported northward from the Gulf on upper level airstreams. Wisconsin often bears the brunt of such influxes. Subsequent wind events may bring potato leafhoppers, perhaps the summer progeny from elsewhere in the mid-west.

Potato leafhopper adults are wedge-shaped insects, about 1/8 inch in length. The potato leafhopper's body is a vivid lime green to yellow green with no dark markings. At rest, the adults fold their wings over their body. The adults are highly mobile, flying readily, and are difficult to sample without a sweep-net. The immatures (nymphs) resemble the adults, but lack wings. When disturbed, nymphs tend to run across the leaf in a curious sideways fashion. Nymphs can be easily sampled by plucking leaves and examining the under surface. Eggs are laid singly and embedded in plant tissue and cannot be seen. The eggs take about 10 days to hatch and development of the nymphs another 3 weeks.

Potato leafhopper is one of the most damaging insect pests of potato. The injury caused in feeding impairs the vascular tissues that conduct the products of photosynthesis from leaves to other parts of the plant. Feeding injury results in loss of that conducting capability. Margins of the leaf beyond the point of feeding yellow and roll; eventually the whole leaf turns brown and dies. The resulting leaf damage is termed hopperburn. Yield loss occurs even before the development of obvious symptoms. Leafhopper feeding impairs efficiency of photosynthesis and greatly increases respiration, depleting the plant's food reserves.

Both adults and nymphs of the potato leafhopper feed on potato foliage. Immatures are actually much more destructive than the adults, and generally more numerous, so action thresholds are based on nymphs. Insecticidal sprays are recommended when potato leafhopper densities exceed 1 nymph per 10 leaves. Nymphs are more injurious than adults, but if adults are abundant, e.g., more than 1 per sweep, immediate control is warranted. Because yield loss occurs at very low populations of nymphs, effective management requires weekly scouting. Sampling 25-35 leaves in each of 3-5 locations

per field will generally give a good estimate for nymphs. Potato leafhopper has not been implicated in the transmission of any plant disease.

It has been suggested that early maturing potato cultivars generally are more susceptible to both hopperburn and early blight. We found that the early maturing 'Norland' sustained much greater foliage loss than did the late-season cultivars 'Red Pontiac' or 'Russet Burbank'. However, tuber yield reductions were proportionately less in 'Norland' than in the other two cultivars, because the early and rapid tuber-bulking of that cultivar reduced the effective duration of pest exposure.

Potato leafhopper infestations commonly occur on potato synchronously with other insect pests and diseases that reduce yield. Therefore, much of our recent research has been to quantify these interactions. We found that the interacting effects of potato leafhopper, early blight, and *Verticillium* wilt all resulted in yield reductions that were statistically less than additive in their combined effects on yield. This has important implications in potato pest management because the expected benefit of control of one pest is reduced by damaging levels of other pests. This result appears to be the consequence of competition among pests for green leaf tissue. To achieve the optimum benefit of controlling any one pest the other two must also be controlled.

Action thresholds for potato leafhopper need not be adjusted for the water status of the potato crop. This is contrary to the widely held view that potato leafhopper injury is more severe under conditions of water stress. We examined interacting effects of potato leafhopper and water stress on 'Russet Burbank' tuber yields. Resulting slopes for the negative regression of yield on potato leafhopper numbers (i.e., yields decreased in linear relationship with increasing potato leafhopper numbers) were either not significantly different between the high and low water treatments or were less negative in the low water treatment.

Because action thresholds for potato leafhopper on potato are very low, it is experimentally difficult to establish the dynamics of the yield loss function. Consequently, most thresholds that have been proposed either do not take into account growth stage-specific changes in plant susceptibility or use empirically established threshold ranges. As an alternative to field experiments, we coupled effects of potato leafhopper feeding to a potato growth model developed specifically for pest management problems. Our goal in this research was to develop a better understanding of the dynamics of the potato leafhopper/yield loss function.

The potato growth model we used accumulates and partitions dry matter into leaves, stems, roots and tubers based on inputs of solar radiation, temperature, and soil water potential. Potato leafhopper affected yield by reducing the efficiency of use of captured solar radiation and loss of green leaf area to hopperburn. Intensity of potato leafhopper effects on potato growth were logarithmically related to the density of nymphs on midplant leaves. Removal of the nymph population, e.g., by insecticides, allowed efficiency of use of solar radiation to return to normal after about three days. Our model incorporates a response function that estimates feeding intensity of nymphs within leaf age classes. This response function includes terms for leaf and crop physiological age as well as an interaction term. Inclusion of the response function resulted in improved predictions of tuber yields and hopperburn development.

Overall, the model reasonably explained yield reductions observed in three seasons of field trials. Approximately 900 simulation runs were completed using this model. Given the same economic assumptions used in our previous experiments, the model predicted that at the time of tuber initiation (when the crop is most susceptible to injury) a

cumulative population equivalent to 126 nymphs per 105 leaves was sufficient to reduce yields by 1%. The most important conclusions from simulation experiments with this model were that potato shows a relatively constant sensitivity to potato leafhopper damage from about full bloom to 2 weeks before harvest, but is relatively insensitive to damage for the first month after plant emergence. We also found that maximum yield loss sensitivity to potato leafhopper occurs at a later stage of growth and for a longer period of time than yield reductions caused by defoliation.

Simulation results with the model also showed reduced sensitivity of potato to yield loss during periods of moisture stress and increased sensitivity before or after moisture stress; i.e., potato was most sensitive to potato leafhopper when conditions were otherwise optimal for photosynthesis and tuber-bulking. Simulation analysis using yield loss criteria of 2% yield reductions for dryland potatoes and 1% on irrigated potatoes yielded action thresholds generally in the range of those previously published.

Aster leafhoppers do not reproduce on potato and cause only minor direct injury. However, this insect is the principal vector of the aster yellows mycoplasma-like organism (AY-MLO), causal agent of potato purple top. Purple top symptoms develop only when aster leafhopper pressure is severe, but AY-MLO is of concern to processors because infected tubers can yield discolored chips. Aster leafhoppers cannot acquire AY-MLO from potato, but become infected feeding on other susceptible host plants during migration from ripening small grains to potato.

Aster leafhoppers overwinter primarily in northern Texas, eastern Oklahoma, Arkansas, and western Missouri. Grasses are the preferred hosts of aster leafhopper and enormous populations can build up in small grains, particularly oats and wheat. As these cereals mature, huge influxes of aster leafhopper can be transported into the North Central States on upper air streams. Populations of immigrant origin can reach damaging levels 5-6 weeks before locally overwintered aster leafhoppers develop damaging populations. As local cereals ripen, aster leafhopper move to other hosts, including potato.

References

- Preston, D. A. 1993. Insects Infesting Potatoes: a Field Guide. Red River Valley Potato Growers Association. Copies available for \$5.00, write RRVPGA, P.O. Box 301, East Grand Forks, MN 56721.
- Radcliffe, E. B., D. W. Ragsdale, and K. L. Flanders. 1993. Management of aphids and leafhoppers, pp. 117-126, in: *APS Plant Health Management in Potato Production*, R. C. Rowe [ed]. Amer. Phytopath. Soc.
- Radcliffe, E. B. and D. W. Ragsdale. 1993. Insect pests of potato in the Red River Valley, pp. 77-85, in: *Potato Production in North Dakota*, N. Dakota State Univ., Agricultural Extension Bulletin 26 (Revised), AG-BU-6109-S.
- Radcliffe, E. B., K. L. Flanders, D. W. Ragsdale, and D. M. Noetzel. 1991. Pest management systems for potato insects, pp. 587-621, in: *CRC Handbook of Pest Management, second edition*, Vol. III, D. Pimentel [ed.]. CRC Press, Boca Raton, Fl.