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Identification and Management of Wireworms and Slugs

James Dwyer
Crops Specialist
University of Maine Cooperative Extension

Feeding damage on potato tubers that appear as holes can be caused by several different creatures and one should not always assume that holes in tubers were caused by only wireworms.

Wireworms are the larval form of the click beetle. There are several species of wireworms associated with potatoes grown in Maine. Wireworms tend to be more of a problem for potato growers on land that is being brought back into production after being out of crop production for three or more years. Wireworm feeding damage on potato tubers will many times appear as a small round hole up to about a ¼ inch in diameter that many times extends deep into the flesh of the tuber.

Wireworms associated with potatoes in Maine tend to be yellow-orange in color, hard bodied which is wire-like and can vary in size from less than ¼ of an inch to about 2 inches. These larvae will have three pairs of thoracic legs and nine segments. Depending upon the species it may take 1 to 6 years for the wireworm to complete its life cycle. The adult form of this insect is the click beetle, so named because of its ability to create an audible “click” sound. Upon close examination of the adult one can see a spine-like projection on the prosternum of the thorax which it can fit into a notch on the mesosternum and by manipulating these, it can jump to escape predators or right itself if on its back.

If a grower is in a situation where ground is going to be brought back into production after being out of any type of production for three or more years, one should assume that wireworms are an issue. One should also plan ahead to bring that ground back into production.

Growers expecting to plant potatoes of a piece of ground that has been out of production for more than three years may want to:

- A. summer till, the season prior to planting potatoes
- B. plant cover crop in fall to prevent soil erosion
- C. plant this field last, the year it is to be planted to potatoes, to allow soil temperatures to rise in spring
- D. Consider using wireworm traps, but be aware of the trap's limitations.
- E. Check seed pieces for wireworm activity prior to emergence.
- F. Consider using a soil insecticide (read the pesticide label, timing and placement is very specific. Broadcast treatments tend to be more efficacious.)

In 2011 with the extremely wet weather, some growers saw another type of tuber feeding damage. These were comparatively large feeding galleries. Some of these feeding sites were up to ½ inch in diameter and some holes extended rather deep into the flesh of the tuber. These holes also appeared more rounded or cup shaped within the gallery, indicating a larger sized individual causing the feeding damage. This type of feeding damage was caused by slugs, which are not insects but mollusks.

In 2012 growers will want to monitor those areas where slugs were active in 2011. Slug activity can be spotted by the tell-tail slime trail left behind as the slug moves. The slime trail will appear a silvery line on the ground or plant. Traps containing dog food or beer have also been effective for collecting adult slugs. When scouting for slugs looking in protected areas is important such as under plants or under any plant residues.

Fields which have a significant amount organic trash are considered to be at higher risk. Tillage operations to bury the trash make the site less favorable for the slugs. Dry conditions have a negative impact on slugs also. Two pesticides are registered for slug control, metaldehyde and iron phosphate. If considering using one of these products please read and follow the label instructions carefully.

Flea beetle larval feeding can also create damage on potato tubers, which can easily be confused with wireworm feeding damage. Potato flea beetle adults can lay their eggs near the soil surface of potato plants. When the eggs hatch the larvae can follow the stalk down and feed upon the developing tubers. Many times these holes will appear about a ¼ inch in diameter but in contrast to the wireworm hole, these holes will only be about 3/8 of an inch in depth. Many times there will be a cluster of holes on the tuber surface where multiple larvae have attacked the tuber.

Managing the flea beetle population can prevent this type of damage from occurring. The economic threshold for potato flea beetles is based on foliar damage when there is an average of 15 “shot” holes per terminal leaflet on the potato plant.

Both cutworms and white grub can also feed on tubers and create damage. Damage from these insects tends to be rather large feeding galleries.

When encountering tuber feeding damage close examination of the tubers can reveal uniqueness in the feeding sites that may reveal which creature may have caused the damage.

Aphids: The New Face of an Old Enemy

Andrei Alyokhin, Ph.D.
Assistant Professor of Entomology
MAFES

Potato virus Y (PVY) is an increasingly important potato disease in North America. Recent years have been characterized by both growing infection rates on commercial potato farms, as well as by an increase in the incidence of strains that cause tuber necrosis. Unfortunately, PVY spread has proven to be a very difficult problem to contain.

The reason for the seeming unpredictability of PVY infection is that a good part of the disease cycle may occur outside of the tightly managed environment of a potato field. PVY is moved from infected onto uninfected plants by aphids. However, the three aphid species living within potato fields (the green peach aphid, *Myzus persicae*, the potato aphid, *Macrosiphum euphorbiae*, and the buckthorn aphid, *Aphis nasturtii*) often play only a minor role in its transmission. Instead, most spread is done by at least 50 other aphid species that breed outside of the fields because they cannot deal with the toxins contained in potato foliage.

Non-colonizing aphids landing on potato plants probe them with their beaks, and then move on looking for a more acceptable host. PVY transmission is non-persistent, which means that virus particles do not enter the aphid body, but simply contaminate the surface of aphid mouthparts when aphids briefly probe infected plants. Contaminated aphids immediately become capable of spreading the disease. The entire transmission process takes a few seconds, but the infectivity is lost after several probes.

Influx of non-colonizing aphids to potato fields is subject to large fluctuations. During the 2011 growing season, we monitored aphid flight by deploying three yellow sticky cards on potato plots at the Aroostook Research Farm. There was a sharp increase from an average of about 25 aphids per trap to almost 2,500 aphids per trap in the numbers of non-colonizing aphids on August 15. It was mostly due to the influx of the black bean aphids, *Aphis fabae*, from Lamb's quarters. Only three days after the peak, aphid captures dropped down to their usual range.

Even the most effective insecticides take minutes, if not hours, to kill exposed aphids. As a result, they often fail to suppress PVY spread by non-colonizing aphids. Furthermore, intoxication might actually encourage aphids to leave plants of their residence and erratically probe adjacent plants in search of a more suitable place to settle. Also, overspraying potato fields might promote aphid build-up on surrounding non-crop vegetation by killing off their natural enemies.

Not only is PVY transmitted by a wide variety of aphid species, but it is also capable of infecting approximately 120 plant species in at least five different taxonomic families. This includes many common weed species found within and near potato fields. In a recent survey of 18 uncultivated plant species (see the December 2011 issue of Spudlines

for more information), four of them tested positive for PVY. On one of the farms, up to 90% of collected dandelions contained the virus. Although this certainly provides serious grounds for concern, it is also worth noticing that on most of the surveyed farms we detected no PVY in any of the sampled vegetation.

Good control of potato-colonizing aphids within potato fields and planting of certified PVY-free seed remain to be very important for PVY suppression. The growers need to put extra effort into preventing the damage that they can control in order to compensate for the damage that they cannot control. However, using such an approach will not always guarantee acceptable levels of plant protection.

Since killing non-colonizing species with insecticides is not a feasible option, the growers should consider creating barriers to their transmitting the virus to and among potato plants. One possible approach is regular applications of crop oils. Unlike insecticides, crop oils do not necessarily kill exposed aphids (although some mortality, most likely from drowning, should be expected). However, they interfere with PVY transmission, presumably by washing virus particles off aphid mouthparts. Therefore, they may provide a useful tool in protecting potatoes from PVY infection.

Another possible way to minimize PVY transmission by non-colonizing aphids is to plant narrow strips of other crops around perimeter of potato fields. Aphids landing on these crops will probe them with their beaks, flushing the virus out in the process. Such border crops should not be PVY hosts themselves, and should not support large aphid populations. Spring wheat and other cereals might be good candidates to consider.

Yet another potential approach to curtailing PVY transmission is ensuring good weed control within or near potato fields. Obviously, it is impossible to extirpate every single dandelion on the farm. Nevertheless, eliminating alternative PVY hosts in the immediate vicinity of potato plants is likely to reduce the probability of virus transmission.

VFDs – Operation and Maintenance

Stephen Belyea

Maine Department of Agriculture, Food and Rural Resources

VFDs / VSDs (frequency drives) are fairly sophisticated electronic devices. Though sophisticated, they typically need minimal maintenance to perform reliably over an extended service life. Major life threatening conditions for the VSDs are similar for any other electronic device – moisture / water, power surges, and excessive heat.

Whenever possible, install the VSD in a separate room out of the fan room and out of the humid storage atmosphere to minimize the effects of moisture. If the VSD must be in the fan room or storage environment, protect the VSD from dripping and condensation.

Power surges have probably been the most common cause of VSD failures. Lightning strikes and accidental surges from the power company occur all too frequently. Install a surge protector on the electrical entrance panel or on the line feeding the VSD.

VSDs are not 100% efficient in their use of electricity. Much of the lost power is converted to heat inside the cabinet. Fans inside the cabinet move cooling air through the cabinet to provide cooling. Excessive heat buildup results from the lack of cooling air flow through the VSD cabinet. Depending on the VSD design, cooling fans may be located on the top or bottom of the cabinet. Screens on the cooling air intakes keep out larger debris and protect the interior components from accumulations. Air intake screens should be cleaned as part of normal maintenance, at least annually and possibly more often if the VSDs are located outside a control room. Periodic cleaning of the inside of the cabinet and electronic components with compressed air is a good idea as well.

VSDs have proven themselves to be a valuable tool for reducing potato storage ventilation electricity cost. The table below summarizes the relationships between fan motor operating speed, fan output, and electricity use.

VFD Speed – Hz -	% of Full Speed	% Airflow	% Static pressure	Static Pressure - in. w.c. -	% Electricity Used
60	100	100	100	1.25	103
45	75	75	56	0.7	45
30	50	50	25	0.3	13
15	25	25	6	0.08	2

Effects of Changing Fan Speed on Fan Performance

The reduction in fan speed comes with an equal reduction in airflow and a notably greater reduction in electricity use. The major trade-off is the fan's significantly reduced capacity to develop static pressure. Without enough static pressure in the ventilation system, there is a high probability that air distribution in the distribution ducts and bin will be uneven. Storage managers should pay close attention to pile temperatures when operating the fans at slow speeds and be watchful for indications of uneven air distribution.

Seed Treatments and Late Blight

Dave Lambert, Ph.D.
Assoc. Professor of Plant Pathology, UM

Although capable of dramatic spread during the growing season, the late blight pathogen faces bottlenecks in surviving from one season to the next. Improved management, particularly in cull disposal and seed quality and treatment have reduced or eliminated initial outbreaks of blight in Maine since the epidemics of the 1990's. When blight has spread from isolated sources, most growers have not been affected until canopy development has slowed, allowing adequate spray coverage. Limiting blight sources has also contributed to the prevention of oospore production and soil-borne blight, which might develop with a mixture of *Phytophthora* mating types. However, we now face an increasing risk of early-season blight development. The diversity of blight strains in North America, has increased nationally, and both mating types were found in Maine in 2011. New strains appear to have been introduced to the East on western-grown seed. A shift from dry Mancozeb-containing seed treaters to liquid formulations without materials effective against late blight also increases the risk of blight spreading as spores or mycelium in cut seed. Fortunately, most of the *Phytophthora*-specific, systemic fungicides currently used on foliage are adequate to prevent the spread of blight in seed when added to a standard liquid formulation. This approach was used successfully in Montana this past year with a Section 18 allowance of Revus for seed growers. A more general Section 24C for Revus Top is currently being pursued in Maine. *Phytophthora* spores are quite sensitive to most systemic fungicides. Infection of healthy seed pieces by pathogen mycelium is less sensitive, particularly to protectant-type fungicides.

Production of High Quality Barley for Malting

Steven B. Johnson, Ph.D.
Crops Specialist
University of Maine Cooperative Extension

Barley growers are looking for sustainability in their production and their returns. Crop losses from Fusarium head blight have caused some growers very low or negative returns. Fusarium head scab is caused by the fungus, *Fusarium graminearum*. The pathogen may infect heads of small grain (oats and rye, but most notably wheat and barley) from flowering through kernel development and can result in serious yield losses. The majority of the infection occurs during flowering or heading. Conditions of high rainfall and long periods of high humidity during grain flowering and early grain fill provide an ideal environment for the pathogen to infect barley. Field symptoms include premature bleaching of individual spikelets, some of the head or all of the head. Infected kernels are shriveled. There are no resistant varieties, but some do show more tolerance than others. Severe cases of Fusarium head scab may show a salmon-colored mass of the pathogen at the base of some glumes. The disease will reduce yield and test-weight. Crop losses from Fusarium head scab may be compounded by a mycotoxin called deoxynivalenol, more commonly known as vomitoxin. Vomitoxin is highly toxic and poisonings can occur both in humans and animals. The need for a better understanding of Fusarium head scab and deoxynivalenol levels has increased owing to the FDA deoxynivalenol advisory levels. Contamination of food products has become a near overwhelming challenge for today's food producers.

While the presence of Fusarium head scab does not guarantee the presence of vomitoxin, one can expect high levels of vomitoxin in grain with high levels of Fusarium head scab. Humans and animals can get sick from eating grain or grain products with vomitoxin present. Vomitoxin can cause feed refusal in animals and additional problems in lactating or breeding animals. Anyone eating or feeding grain should have the grain tested, as varying end uses have varying advisory levels for vomitoxin.

Maine barley growers need a better understanding of Fusarium head scab and vomitoxin as buyers are starting to reject loads based on vomitoxin levels. Malt-grade barley must have vomitoxin levels less than 2 ppm for acceptance. Barley growers that produce vomitoxin levels over 2 ppm stand to lose over \$1.00 per bushel or perhaps complete rejection of their crop.

Late Blight in 2012: A Strategy for Our Industry

Steven B. Johnson, Ph.D.
Crops Specialist
University of Maine Cooperative Extension

The keys to keeping blight in check for 2012 involve the pathogen, the host, and the environment.. Potato late blight is caused by *Phytophthora infestans*, a fungus-like organism that overseasons in infected tubers, cull piles and in infected volunteer plants. The pathogen is an obligate parasite where it cannot survive in the absence of a host; it cannot survive in soil or dead plant debris. This organism will not survive long in soil or away from association with a living host.

Late blight is a community issue and those in the growing community need to be part of the solution. Planting only late blight-tested seed and knowing the source of your seed are a good beginning of season-long late blight control. Good seed handling, avoiding holding cut seed and treating seed with a fungicide effective against late can contribute to a late blight control. Cool, moist environment favors the pathogen. Initiating fungicide applications and scheduling fungicides based on severity values is the most efficacious control strategy. Maintaining protective fungicide coverage on new growth with a calibrated sprayer is a host strategy to reduce late blight. Performing regular field observations and working with and training employees for late blight detection further this cause. Late blight prevention extends into harvest as potatoes should be killed in a timely manner to insure good skin set. Fields with late blight or fields suspected to have late blight should be thoroughly dead before harvest. Minimizing bruising and skinning during harvest will minimize the tuber-to-tuber transmission of the pathogen. Tuber infection can also occur at harvest when there is contact between tubers and spores. This typically occurs when tubers come into contact with infected green foliage. Skinning of the tubers during harvest greatly increases the risk of infection. Tuber-to-tuber contact during loading and handling as the tubers are entering storage are also possible avenues for tuber infection. Under proper storage management, tuber-to-tuber spread of late blight is minimal, if it all.

Recent strategy changes have coupled environmental factors with fungicide strategy and potato growth. The potato growth season is broken down into five periods: <7/01, 7/01 – 7/15, 7/16 – 8/15, 8/16 – 8/31 and >8/31. As the potato plant changes during these growth periods, so do control tactics change. One control tactic is fungicide selection. As the growth rate of potato plants changes from the beginning of the season to the middle and then to the end of the season, fungicide selection changes from systemic to translaminar to contact materials. During these fungicide selection changes, the timing of applications based on environmental factors remains unchanged.

Potato Late Blight Risk Manager is a new tool for the 2012 season for fine-tuning fungicide applications. Days are coded as green, yellow, or red with respect to risk and the numeric cumulative risk for the previous seven days is given.

Preventative Sprayer Maintenance

George McLaughlin
Agricultural Engineer, MPB

Our spraying season has a very demanding impact on current crop production. How you maintain your equipment can reduce your expenses and keep your equipment working efficiently. Included within this presentation there are simple measures used when cleaning, winterization, as well as service and startup tips to keep your sprayer equipment working properly. Today's equipment has a much higher cost and many more components than what was used 30 years ago. Simple measures can be utilized to keep it working properly.

Simple measures include:

1. Read your owners manual and follow the manufacturers recommendations.
2. Clean your equipment thoroughly.
3. Clean and flush the liquid systems. Use a solution approved for your equipment.
4. Remove and clean all strainers, flow meters and end caps.
5. Flush out the distribution lines.
6. Clean nozzles and screens.
7. Grease and lubricate wear points.
8. Clean and check wiring for corrosion.
9. Inspect hydraulic hoses and components.
10. Inspect tires for wear and inflation.
11. Replace damaged or missing decals.
12. Touch up scratches, or rusted metal with a protective coating.
13. Winterize your equipment according to your manufactures recommendations.

Today's chemical application is a significant part of your current operation. Keep your equipment working properly and avoid high operating costs.

Tuber Rots: Leak, Pink Rot and Bacterial Soft Rot

Dave Lambert, Ph.D.

Assoc. Professor of Plant Pathology, UM

With unusually high rainfall during the growing season, tuber rots were serious problems in 2011. Heavy rains and saturated soil create pathways for mobile pathogens, including those causing late blight, pink rot and bacterial soft rots. Anaerobic conditions reduce tuber resistance, produce swollen lenticels more prone to invasion, and kill tuber tissue. Damp conditions at harvest also increase the potential for these diseases as well as *Pythium* leak. Reductions in pink rot incidence with Presidio applied in-furrow have averaged 80% over the past 5 years' inoculated trials. Further trials with natural inoculum are desirable. *Pythium* leak is almost always associated with wounds to potatoes harvested and stored under warm conditions. While mefenoxam applied in-furrow at planting is still effective against this disease, resistance is a potential problem and is present in Columbia Basin production areas. Bacterial soft rot often resembles leak in producing an internal tuber rot with dark borders. The bacteria responsible for this disease are commonly present in soil and can infect through eyes, lenticels, fungal infection sites and wounds. Any practices causing excess moisture to accumulate on tubers - soil flooding, washing, fungicide sprays going into storage, inadequate drying, poor ventilation or breakdown from other tuber diseases contribute to soft rot.

Transgenic Potatoes: Status Today and Tomorrow

John Jemison
Extension Professor: Soil and Water Quality
University of Maine Cooperative Extension

Potato breeders introduce traits or characteristics into potato cultivars that specific markets identify as important. For example, processing potato growers require high yielding varieties that also meet specific fry color and solid content. Tablestock growers require attractive, scab-resistant lines. Industrial potato processors may require a potato with a low amylose starch composition. When breeders cross lines to enhance a specific trait, undesirable characteristics often come in the breeding process that must be bred back out of the lines, or growers have to accept the imperfections. Potatoes are particularly difficult to breed due to their tetraploid genetic makeup. While breeders have produced lines with excellent disease resistance (e.g. Defender or Jacqueline Lee), failures generally greatly outnumber successful efforts.

Researchers using transgenic breeding techniques take genes that confer specific properties and transfer them into plants to get desired characteristics. Initially, genes capable of effecting the specific plant process were taken from any source and put into plants. The transgenic process and other consumer concerns led several companies to not accept transgenic potatoes. Other public concerns included food safety, patenting of germplasm, and lack of regulatory oversight. While the growth and development of transgenic crops has proceeded onward with corn, soy, and cotton, transgenic potatoes have lagged behind.

Increasingly researchers are looking for traits within a given genus that provide specific characteristics. For example, if a gene could be found and introduced to potato that confers a rougher, hairy characteristic in a plant within the *Solanum* genus, aphid caused disease issues could be reduced. Similarly if a gene could be transferred to provide potato resistance to late blight, billions of dollars could be saved worldwide on pesticide applications, and the amount of carbon dioxide produced by agricultural production could be significantly reduced. Benefits of the transgenic process include speeding up the breeding process because there is no need to backcross unwanted characteristics, and theoretically, no other functions are changed within the plant.

Examples of successful transgenic potato efforts include an all amylopectin starch potato for industrial uses. Other efforts from the University of Wisconsin and at Wageningen University in the Netherlands to confer late blight resistance to potatoes have also shown success. Halterman and others showed success transferring the RB gene from *Solanum bulbocastanum* to late blight into different potato varieties. They provided resistance to late blight in the foliage, but not in the tuber. I conclude the presentation with a discussion of potatoes and climate change, and discuss efforts needed to develop potato lines that perform well in a likely warmer, wetter Maine climate.

Late Blight and Homeowner IPM

Griffin Dill
IPM Professional
UMaine Cooperative Extension

Home gardening has been booming in recent years as the current economic climate forces people to look for innovative ways to save money. While this trend can benefit the home gardener's wallet, it can also negatively impact the commercial grower's bottom line. The movement of pests from home gardens to commercial potato fields is a growing concern. Late blight spores, in particular, can travel long distances through the air or be transmitted by land through the movement of infected plant material. Upon transmission to a potato plant, spores can also be washed through the soil to infect potato tubers. Because late blight can spread so readily and rapidly, it is important that everyone who grows susceptible hosts is able to identify late blight and knows how to control it. University of Maine Cooperative Extension is developing ways to pass on pertinent late blight information not only to commercial growers, but to the home gardener as well. Informing both commercial and home growers about the threats associated with late blight is crucial in protecting Maine's potato crop.

Assessing Maine's Agricultural Future – 2025: Emphasis potatoes

John Jemison, Stephanie Welcomer, Damon Hall, and Jane Haskell
University of Maine Cooperative Extension

With support from the University of Maine Board of Trustees, the University of Maine Cooperative Extension held 15 focus group sessions with Maine farmers in 2011 to assess what farmers think about the future of Maine agriculture. We skewed invitations to younger farmers, but sessions were open to all interested in participating. We met with all commodities, including potatoes, and held four sessions with mixed farmer groups. In total, we met with 199 farmers and crop advisors. Based on demographic information provided, farmers' travel and in-kind support amounted to over \$8500 for this project.

We asked farmers a number of key questions: what are they optimistic and concerned about a future in farming, what changes are they making on their farm with respect to changing weather and energy prices, what should the state do to grow Maine agriculture, where do they get their information, and what is their vision of agriculture in 2025. Their responses to these questions were recorded, transcribed and analyzed using qualitative analytical software.

Key Sources of Optimism and Concerns Expressed by Potato Growers:

Farmers were please to see so many young people talking about their future at the potato growers group. They spoke of the benefits that new technologies (smart phones and GPS) have brought to their commodity. They were excited about the opportunity for available land to expand their operations.

“For young farmers, there's room to grow your businesses because a lot of people are getting out of farming, and (they have no plan) for succession. While it's sad to see, it does create opportunity.”

Potato growers were concerned about increasing controls being put on water resources for irrigation. Other chief concerns included increasing cost of production, concern over food safety and traceability issues, and maintaining soil quality. They felt the state could do a lot more to advertise Maine potatoes, create market opportunities, and help farmers get on the land.

Vision for 2025

Many farmers felt that large farms would continue to expand and there would be fewer growers in 2025. The lack of people with knowledge about how to grow food at a time when food is becoming increasingly important was problematic. Aroostook county should be increasingly important as food systems become increasingly regionalized due to higher fuel costs. Growers prepared to take advantage of interest in local foods will likely benefit greatly.

Managing Cutworms in Potatoes and Rotation Crops

James D. Dwyer
Crops Specialist
University of Maine Cooperative Extension

The incidence of cutworm for potato producers and the producers of rotation crops has dramatically increased within the state of Maine during the recent years. This increased insect activity has been noted in potato, canola and grain crops including corn. Isolated populations of these insects have been significant and at times, created dramatic crop loss situations.

The cutworm population in Maine appears to be comprised of primarily two different species, variegated and black cutworms; however, several other species are also present. Both species can be destructive to crops. The black cutworm typically cuts plants off at the soil surface and the variegated cutworm typically climbs and cuts leaves off. Canola and corn growers need to be aware that these insects also have the ability to feed underground and can be active during times when it can be difficult to differentiate between feeding damage and uneven plant emergence.

Growers are encouraged to scout corn, canola, potato and grain fields carefully as these crops emerge and continue scouting through the early growth stages. Growers are also strongly encouraged to carefully inspect any areas with emergence problems especially in corn and canola. Cutworm damage during this time frame can mimic emergence problems and carefully digging in the affected area may be necessary in order to discover the presence of these insects. In potatoes, cut-off leaves or wilted portions of plants may indicate cutworm activity. Digging near the base of the affected plant may reveal the presence of cutworms. Most surface activity will occur at night, however, when large populations are present surface activity can be noted during the day.

Growers should be aware that cutworms can create significant damage in many crops and growers should be actively scouting for cutworms especially early in the season. Growers should also be aware that the neonicotinyl insecticides do not provide cutworm control. Cutworms tend to be nocturnal so late afternoon applications of control products tend to provide better suppression of these insects. As growers select products for cutworm control, be sure that the product chosen is labeled for the target crop. Products such as dipel, endosulfan, spinosyn and synthetic pyrethroids can provide suppression of these insects.

Neonicotinoid Resistance and CPB Management

Russell Groves, Ph.D.
Extension Vegetable Specialist, UW

Most insecticides used for control of Colorado potato beetles (CPB) in the Northeast and Midwest US have ultimately failed because of resistance that has developed in populations of this problematic insect. Increasingly, growers rely heavily on a single class of insecticides called the neonicotinoids (i.e.: imidacloprid, thiamethoxam, clothianadin, dinotefuran) for control of CPB (NASS 2006). Imidacloprid resistance appeared in NY in 1997, and is now common in the northeast and appeared in the Michigan in 2004 and in Wisconsin in 2007. Growers in these regions of the United States are experiencing serious control problems, including multiple locations in Maine, Michigan, and Wisconsin. This erosion of control with the neonicotinoids threatens the continued effectiveness of current CPB control programs and may seriously alter the economics of potato production. We now also know that CPB resistant to imidacloprid also expresses resistance to new insecticides. The mechanisms of how this resistance has emerged, the extent of this resistance statewide, and the association of this resistance with observation of delayed emergence or extended diapause seems to be of critical importance for the state and the region and further investigation for more practical and long-term CPB control.

Moreover, the CPB has been credited with being largely responsible for creating the modern insecticide industry. Since 1864, hundreds of compounds were tested against this pest, and application equipment was specifically invented to aid their delivery. Currently, insecticides still remain the foundation of the CPB control on commercial potato farms. More than 30 active ingredients are currently registered for use against this pest in the United States. Not surprisingly, high selection pressure eventually resulted in a large number of insecticide-resistant CPB populations, with resistance rapidly progressing since the middle of the last century. Potato growers continue to struggle to control this problematic insect pest, and maintaining control of this insect remains at the forefront of our efforts to protect potato from damaging insect pests.

A high predisposition to resistance development is probably caused by a number of factors. First, plants in the family Solanaceae have high concentrations of toxic glycoalkaloids in their foliage resulting in the requisite development of the physiological capability to detoxify or tolerate poisons. Next, high beetle fecundity not only increases the probability of random mutations, but also ensures the rapid build-up in resistant mutants once mutations have occurred. Thirdly, the beetles have a narrow host range and a limited dispersal range, such that both larvae and adults feed on the same host plants and often in a very discrete geographic area. And finally, growers rely almost exclusively on insecticides for adequate beetle control because other control techniques often provide insufficient levels of control. Taken together, these factors increase the selection pressure towards resistance within this species.

Delayed Diapause and Relationships to Resistance. Another important and recent observation surrounding the emergence of neonicotinoid resistance is the concept of

extended emergence, or delayed diapause. Diapause is a genetically determined behavior of an insect's lifecycle designed to synchronize its biology with seasonal variation in the environment. Insects inhabiting more dynamic or unstable environments with unpredictable resources may extend diapause for longer periods, resulting in delayed emergence. Portions of Wisconsin's resistant CPB populations may be temporally avoiding the highest titers of in plant insecticide by emerging later. Emergence and colonization over longer periods of time will result in extended egg deposition, resulting in multiple resistant life stages present simultaneously in the crop. Anecdotal evidence suggests several of Wisconsin's insensitive populations are smaller, less fit, and may emerge over a longer period. Acceleration of resistance will occur as later emerging portions of populations are exposed to sub-lethal systemic insecticide doses. Population scale selection for later emergence will coincide with reduced in-plant insecticide levels. Over time, the continual exposure of late emerging insects to sub-lethal doses will produce even greater resistance issues. If true, rapid natural selection may fix the protracted emergence trait in the gene pool. Long term impacts of protracted emergence will compromise the efficacy of current and future systemic registrations. Exploitation of phenotypic fitness costs with judicious, reduced risk insecticide application, altered use patterns, and cultural controls will significantly reduce fixation of multiple resistance mechanisms in Wisconsin.

Mechanisms for Resistance in CPB. Known mechanisms of Colorado potato beetle resistance to insecticides include enhanced metabolism involving esterases, carboxylesterases and monooxygenases, target site insensitivity, as well as reduced insecticide penetration and increased excretion. Resistance mechanisms may be highly diverse even within a relatively narrow geographical area. Cytochrome P450 is involved in the metabolism of internal hormones and lipids in insects, and also participates in the metabolism of xenobiotic compounds such as pesticides. In the Colorado potato beetle, the P450 dependent monooxygenase system is the most common mechanism of resistance across many populations from diverse geographical origins. Of significant importance, the pre-treatment by an oxygenase inhibitor, piperonyl butoxide (PBO), has previously been demonstrated to reduce resistance of adult beetles resistant to organophosphates, carbamates, and synthetic pyrethroids. Importantly, imidacloprid-resistant beetles from Long Island, New York showed greater than a 3X reduction in resistance with PBO treatment. Specifically, the insect metabolism of imidacloprid leads to the production of an olefin metabolite that is less toxic to the insect than the parent compound and this phenomenon has been observed in both susceptible and resistant strains, but to a greater extent in the resistance strains.

European Corn Borer in 2011

James D. Dwyer,
Crops Specialist
University of Maine Cooperative Extension

James Dill
Pest Management Specialist
University of Maine Cooperative Extension

Andrei Alyokhin
Associate Professor of Entomology
University of Maine

Gary Sewell
Senior Scientist
University of Maine

European corn borer has been an issue for Aroostook County potato growers since the late 1970s. The insect lays its eggs on the stalks and leaflets of potato plants. When the eggs hatch, the larvae feed on the outside of the plant for about three days. After feeding on the leaves, the larvae enter the potato plant stalk. Many times the stalk is weakened by the feeding, and it may break or become infected with bacteria.

It appears that, historically, foliar insecticides applied to control Colorado potato beetles in June and July may have been unknowingly suppressing European corn borer populations. Anecdotally, it appears that when aldicarb, known as Temik, a systemic insecticide applied at planting, was utilized in the 1970's, its application eliminated the use of foliar insecticides for Colorado potato beetle. European corn borer then became an issue for Aroostook potato growers. When Temik was removed from the market and foliar applications resumed, European corn borer stopped being an issue. In the 1990s when imidacloprid (sold as Admire) was introduced as a systemic insecticide applied at planting, foliar applied materials stopped; and the European corn borer again became a problem.

According to University of Maine Cooperative Extension survey information, approximately 92% of Maine potato growers use some type of neonicotinoid material at planting for insect control. This has dramatically reduced the foliar-applied Colorado potato beetle control materials and increased the opportunity for European corn borer in potatoes.

As part of a monitoring program for European corn borer, University of Maine Cooperative Extension's Potato IPM program has been using primarily an Iowa-strain pheromone for trapping moths, with some New York pheromone placed at selected locations. Iowa-strain moths have accounted for approximately 99% of the moths

collected in the heliothis-style traps. Incidentally, Iowa-strain moths are the strain predominately caught in the Maine Sweet Corn IPM program conducted in the central and southern portions of the state..

A perplexing question has always been why European corn borer is a problem in Aroostook County, but is not an issue for potato growers in central Maine. Is there a unique strain in Aroostook? Another nagging issue is that periodically there have been situations when the pheromone trap does not collect moths, yet we find European corn borer larvae in the field. Again, why?

To address these questions, in 2011 we placed the following on five different farms: a heliothis trap with Iowa pheromone; a second heliothis trap, 100 yards away, with New York pheromone; a third heliothis trap, 100 yards farther away, with Trece's hybrid European corn borer pheromone; and a black-light trap, placed at least 100 yards away from any other trap. The traps were spaced so as to minimize any possible interaction. With these traps in place, we felt that we could successfully monitor any European corn borer populations on these farms. The pheromone traps should collect the common known strains and the black-light traps should collect all European corn borers, no matter what strain. One must also take into consideration that the pheromone traps will collect only male moths, and the black light will collect both male and female moths.

The traps were established in early June and operated until September 1, 2011. Only trace numbers of the New York strain of European corn borer moths were collected during the season, with four of these moths captured, and only seven hybrid-strain moths were collected. The Iowa strain was the principle strain collected using pheromone traps: 261 Iowa-strain moths were collected from the five farms from early June to September. The black-light traps collected 1,919 moths during this same time frame of which approximately 960 were male moths..

Bartles demonstrated in 1999 that pheromone traps can capture as many male moths as black-light traps can. Considering this, it is extremely interesting that there were occasions when the pheromone traps collected one moth, while the black light collected almost 400 male moths in the same area during the same seven-day period. Clearly this was not owing to discrepancies in trap efficiency.

In all locations, the black-light traps outperformed the pheromone traps in terms of the number of individual moths collected. It is interesting to note that for the Iowa moths, peak moth flight occurred at 806 modified growing degree days (MGDD), while peak moth flight for the black-light moths occurred at 673 MGDD. This indicates that the peak moth flights were about eight calendar days apart.

An eight-day difference in peak moth flight, and therefore peak egg-laying, is significant and could mean the difference between timing a successful suppression treatment or not.

It does appear that there may be a strain difference in some of the European corn borer populations in Aroostook, based upon the differences in response between pheromone-

based trapping and black-light-based trapping. In addition, the disparity in the timing of moth emergence and peak moth flights indicate the possibility of a difference within the population.

How might these potential differences affect management strategies for European corn borer in potatoes? Timing is the most important aspect. When will peak moth flight and peak egg-laying occur?

Previously, we have felt that in most years, peak moth flight can be expected to occur at approximately 900 MGGD. This number can vary by as much as 10 calendar days. We have also found that peak moth flight during some years will be at approximately 700 MGGD. This can be explained by the fact that the fall and spring weather have an effect upon the expression of univoltine or multivoltine characteristics in the population. The difference between 700 and 900 MGGD can also vary by 10 to 15 calendar days, depending upon the season. From a monitoring standpoint, discrepancies such as these should be supported by an effective trapping and scouting program that indicates when peak moth flight is occurring thereby confirming model predictions.

The difference of 10 days when applying an insecticide to manage European corn borer in potatoes can mean the difference between success and a miss. The University of Maine Cooperative Extension Potato IPM program will integrate black-light trapping for European corn borer into the program in order to provide a more comprehensive look at the corn borer population for future seasons. This information should allow growers to select and time suppression strategies for optimum control.

As we try to discover more information on strain differences, the University of Maine Cooperative Extension Potato IPM Program will continue pheromone trapping with the most common Iowa pheromone as well as operating several black light traps. Trapping results will continue to be posted at www.maine potato ipm.com and published in the Pest Alert newsletter so that growers will know when peak moth activity is occurring in Aroostook County.

University of Maine Cooperative Extension would like to thank the Maine Potato Board for assisting in the funding of the project.

Split Applications of Fertilizer

Gregory A. Porter and Paul Ocaya
Department of Plant, Soil & Environmental Sciences
University of Maine, Orono, ME 04469

Fertilizers have become increasingly expensive in recent years and, consequently, there has been increased interest in improving the efficiency of fertilizer use in potato systems. Some fertilizer nutrients, especially nitrogen (N) and potassium (K), have strong effects on both yield and tuber quality. It is important to supply adequate amounts of these nutrients, since shortages in N and K can decrease yields and quality. Excess N and K can also decrease yield and quality though responses differ among potato varieties. In general, the most effective means of increasing K and phosphorus (P) efficiency is to make effective and consistent use of a good soil testing program. Nitrogen fertilizer use efficiency varies a lot among potato varieties and N recommendations are typically specific to the variety being grown and the intended market. Fields differ a lot in their ability to supply N to a potato crop. Sandy soils tend to supply less N as do drier fields that are higher on the landscape. Fields that have been in legume crop rotations or that have received recent compost and/or manure applications will also tend to supply more N to the potato crop. Growers can improve their N fertilizer use efficiency by making use of N supplied by the soil following legume crops or when a field has relatively high N supplying capability due to its inherent characteristics or recent management history.

Split fertilizer applications with a portion applied at or before planting and a portion applied during the growing season are commonly used in many parts of North America. This approach has been shown to increase fertilizer use efficiency, particularly in areas with sandy soils and long growing seasons. Sandy soils are more prone to leaching of N from the root zone and delaying a portion of the N fertilizer helps prevent early-season leaching. Potato soils in Maine are typically loamy with a relatively strong ability to hold both water and nutrients. Consequently, potatoes grown in Maine are less likely to respond positively to split fertilizer applications. Fields that are sandier than the typical Caribou loam would be more prone to N and K leaching and more likely to benefit from split fertilizer applications. Our relatively short growing season also favors at-planting fertilizer applications over split applications. An early-vine-killed, seed potato crop is much less likely to benefit from split fertilizer applications than an early-planted Russet Burbank processing crop that needs to be kept alive until late in the growing season.

Over the past 25 years, experiments comparing at-planting versus split N and K applications have been conducted at Aroostook Research Farm in Presque Isle, ME. The soil type used has typically been a Caribou gravelly loam. In general, our experiments have failed to show any consistent yield or quality advantage for split N applications compared to at-planting N applied at the recommended rate. N applied too late in the season can result in poorer yields and poorer quality than the at-planting program. Side-dressed N applications may be more useful for sandy soil types. Side-dressed N can also provide some yield benefit when applied early in the year to a potato crop that is N deficient due to a low rate of at-planting N application or severe early-season N leaching;

however, we have not been able to show that a side-dressed N program provides any consistent yield benefit over an at-planting program that is not N deficient. Despite the lack of yield advantage, split N applications may provide flexibility to growers' fertilization programs, allowing them to adjust their total N application rates while maintaining a simpler, more consistent at-planting fertilizer rate. Our research suggests that application early in the season is very important. Supplying the N too late in the season can lead to poor uptake, as well as reduced yield and quality.

Split K applications can be used to reduce the total amount of banded fertilizer on fields that require a high rate of K fertilizer. The concern is that very high rates of potash (K_2O) fertilizer could have a strong salt effect and damage the roots and seedpieces early in the growing season. This would particularly be a concern if fertilizer placement is too close to the seed and/or on sandier fields. Our general recommendation is that no more than 180 lbs/A of potash be applied in the fertilizer band. The remaining K can be applied either before or after planting. Uniform application is critical and the applications should be made early in the season to assure that the extra K is available when the crop needs it.

Phosphorus (P_2O_5) fertilizer applications rates should be based on soil test P levels. Because of P fixation by Al and Fe in our soils, a minimum banded application of 60-80 lbs/A P_2O_5 is needed on most soils testing MH to H in soil P. The banded application minimizes soil contact, delays fixation, and maximizes availability to the crop. Split applications of P fertilizers are not recommended.

Micronutrients in Potato Production

Bruce Hoskins
Assistant Scientist
University of Maine

The micronutrients boron (B), zinc (Zn), Iron (Fe), manganese (Mn), and copper (Cu) are all essential for normal growth of all plants. Proper management these nutrients consists of balancing ongoing soil supply with the relative small requirements of most crops. Boron is naturally low in Maine soils unless supplemented through chemical fertilizers, compost, or manure. With certain exceptions, our native soil mineralogy supplies ample amounts of zinc, iron, manganese, and copper under most potato production systems.

Boron is the most leachable and therefore most easily lost of the essential micronutrients. The boron requirement of potatoes and most rotation crops is relatively low, so severe boron deficiencies are infrequent. Boron availability decreases slightly as soil pH increases. Boron uptake is also limited by drought conditions. Higher soil organic matter levels improve boron availability. Boron toxicity is of equal or greater concern than deficiency in potato production. Overapplication from poor sprayer calibration or from multiple applications can easily impact crop yield by damaging foliage. Boron applications should not exceed 0.5 to 1 lb actual boron/acre/year. One or two foliar applications of ¼ lb actual B/acre before mid-season can sometime give a yield response if soil and/or foliar levels test low.

Zinc is another micronutrient that can sometimes have limited availability. Unlike boron, zinc level will build in the soil from year to year with successive applications. Potatoes require somewhat less zinc than does corn and soybean. Zinc availability decreases with increasing soil pH. Phosphorus and zinc can have an antagonistic relationship, where a very high level of one can interfere with availability and uptake of the other. This is not a problem if both nutrients are within their optimum ranges. Foliar damage and yield loss from zinc toxicity can occur from overapplication of foliar sprays or from concentrating too much zinc in a fertilizer band. The safest and most cost-effective way to correct a low zinc test level is to broadcast and till in 4-5 lb actual zinc/acre (12 lb zinc sulfate/A). This should supply sufficient zinc for one or more rotations. Monitor for zinc buildup by soil testing before further applications.

Iron and manganese are very abundant in Maine soils. Availability is primarily controlled by soil pH and organic matter. An increase in soil pH will rapidly limit iron availability and more slowly limit the availability of manganese. Manganese often maintains availability at higher pH levels if soil organic matter is high. Manganese availability can also increase dramatically – sometimes to toxic levels - if the soil becomes saturated for an extended period. Under certain circumstances iron and manganese can be mutually antagonistic. A very high level of one can interfere with the availability of the other, though this is rare in most cropping systems in well-drained soils. Potatoes have a high tissue content and therefore a greater requirement for manganese than for iron. Deficiency of either iron or manganese is exceedingly rare, but possible in soils directly

on limestone ledge with $\text{pH} > 7$. Spot deficiencies are best treated with foliar applications (1 % iron sulfate or 1 % manganese sulfate @ 15-30 gal/A). Soil applications of either nutrient in western states have proven to be ineffective.

Copper is required in exceedingly small amounts by potatoes and rotation crops. Due to its very high affinity for soil humus, applied copper will remain in the soil for decades. Potato growing areas in production for 100 years or more commonly contain 5 – 20 times the Cu levels of other areas in Maine, due to the historic use of copper sulfate/ Bordeaux mix. Monitoring of soil copper level is most important where these materials are still used for Blight control. Copper toxicity from an excessive soil level most often manifests as an induced iron deficiency, due to interference with iron uptake. Overapplication of foliar copper can also result in yield loss due to direct damage to foliage.

All micronutrients are needed in relatively small amounts and cases of deficiency are quite rare in potato production systems. Toxicity from too frequent or too heavy application is of greater concern than deficiency. Proper management of soil pH and organic matter level is the best foundation for managing the availability of micronutrients. Foliar applications are best used during the season where tissue testing shows a genuine deficiency.

Bruise Detection Technology

George McLaughlin
Agricultural Engineer, MPB

This presentation of Bruise Detection Technology will try to touch on several aspects of what is currently being provided to help potato growers here in Aroostook County and to get feedback from growers on what they would like to see in the future.

Currently the Maine Potato Board manages and provides anti bruise inspection services for growers during the harvest period. During the fall of 2011 the Maine Potato Board employed three full time inspectors and provided services to approximately 75 different operations. The three inspectors evaluated 748 grab samples on 40 different varieties in comparison to 549 grab samples on 35 varieties in 2010.

Historical detection methods include: Conducting a 10 lb. grab sample and evaluation using a reactant agent. The potatoes are evaluated for skinning, slight bruise, moderate bruise, and serious or severe bruise.

What other methods are available to help minimize bruise?

- Harvester Calibration
- Electronic Potato Evaluation
- Hot Box Evaluation

Is bruise a concern for your operation?

Does bruise have an impact on your operational income?

Is what we are doing working or does it need changes?

Variety Trial and Breeding Program Results

Gregory A. Porter and Paul Ocaya
Department of Plant, Soil & Environmental Sciences
University of Maine, Orono, ME 04469

The goal of our potato variety improvement research programs is to identify new potato varieties that could be useful to Maine seed, fresh market, and processing growers. We are working hard to develop new potato varieties that will provide marketing opportunities and solve production problems for Maine potato growers and the broader potato industry. Our activities range from breeding new potato varieties to helping facilitate commercial-scale trials of promising new varieties from a range of breeding programs.

In Maine, we conduct research-scale variety trials in three locations each year (Presque Isle, Exeter, and St. Agatha). The range of conditions provided by these test locations helps us do a better job selecting varieties that will consistently perform well over time and among locations. Each year, we evaluate hundreds of test clones and identify a few that have enough desirable characteristics to warrant further development efforts. We provide three test sites and furnish the seed potatoes for the NE1031 regional potato variety trial program. This program evaluates candidate potato varieties from Maine, New York, USDA-ARS and elsewhere. Test locations for this trial network include sites in FL, NC, VA, MD, PA, NY, OH, ME, NB, and QC. Once the most promising candidate varieties have been identified in the research-scale trials, we facilitate 10 to 20 commercial-scale trials per year in Maine or in states where we sell seed potatoes. The goal is to identify varieties that have enough merit for commercial seed growers, processors, and fresh market growers to pick up and take over production, marketing, and development.

Finally, our programs participate in national research efforts designed to speed identification of improved new chipping and French fry processing varieties. The chipping effort is partially funded by the U.S. Potato Board (USPB). Maine provides one of 10 national test locations for promising chipping varieties as part of the USPB/SFA National Chipping Trials. We typically also contribute 1-2 promising chipping varieties to this testing program each year. These national varieties trials typically evaluate a total of 10-20 candidate chipping varieties each year. Our program also contributes ~20 candidate chipping clones per year to the National Chip Processing's Trial. In this USPB-funded trial program, ~150 to 200 candidate clones are evaluated at 8 sites scattered around the U.S. Similarly, we contribute ~20 candidate French fry processing clones to the National Fry Processing Trials (NFPT). Each candidate clone was evaluated at three locations (ID, ND, and WA) during 2011 as part of this USPB- and industry-funded effort. Additional grant funding obtained during 2011, will allow expansion to five test locations during 2012 (ID, ME, ND, WA, WI). The goal is to more rapidly identify candidate varieties with processing characteristics that will benefit the frozen French fry industry nationwide.

In this presentation, I will provide a brief summary of 2011 potato variety trial results and recent progress being made by our potato breeding program. I encourage you to stop by our booth at the trade show to see samples of promising clones and to provide input on the programs. Below you will find information on four promising advanced clones from our breeding program. Seed of these clones is currently available from the Maine Seed Potato Board, Maine seed growers, and/or Aroostook Research Farm. Additional clones in each marketing class are also available and/or will become available over the coming years. For more information on these clones, seed availability, or research results please contact Greg Porter; 5722 Deering Hall, Room 114; University of Maine, Orono, ME 04469-5722; (207)581-2943; porter@maine.edu

AF0338-17 (AF303-5 x SA8211-6), a widely-adapted, mid-season, high yielding, round white for out-of-field chipping and fresh market. It has performed well in the S.E. and mid-Atlantic states with U.S.#1 yields averaging 96% of Atlantic. Specific gravity has averaged 4 points lower than Atlantic. AF0338-17 has chipped well from the field and has had much lower incidence of internal defects than Atlantic. It is moderately susceptible to scab, but has verticillium resistance. Seed Availability: certified Maine seed, see seed directory; Maine Seed Potato Board field-grown seed and disease-free plantlets or minitubers; ~30 cwt of University of Maine seed.

AF3001-6 (Silverton Russet x AF1668-60), a widely adapted, late maturing, long-white with netted skin, very good fry color, and high yields. AF3001-6 is very good baked, boiled, and mashed. U.S.#1 yields have averaged ~127% of standard russeted varieties (usually Russet Burbank) in Maine trials. Specific gravity is moderate (average of 1.086 in ME trials) and fry color from storage has been excellent. It is moderately susceptible to scab, but has good verticillium resistance. Seed Availability: Maine Seed Potato Board seed and disease-free plantlets or minitubers; ~20 cwt of University of Maine seed.

AF3317-15 (AWN86514-2 x Reeves Kingpin), a long russet with late blight resistance and potential for fresh market and processing. AF3317-15 is very good baked and mashed. AF3317-15 has very late vine maturity and long tubers with russeted skin. It can yield well when given a long growing season, but needs a lot of time to develop and mature tubers. Specific gravity is moderate (average of 1.085 in ME trials) and fry color from storage has been fair to good. It has resistance to late blight, common scab, and pink rot. Seed Availability: Maine Seed Potato Board disease-free plantlets or minitubers; ~14 cwt of University of Maine seed.

AF3362-1 (Reeves Kingpin x Silverton Russet), a mid-season, long russet with good yields, processing potential, and fair to good appearance. AF3362-1 is very good baked and mashed. U.S.#1 yields have averaged ~110% of standard russeted varieties (usually Russet Burbank) in Maine trials. Specific gravity is moderate (average of 1.084 in ME trials) and fry color from storage has been mostly good. It has moderate scab resistance. AF3362-1 is susceptible to internal heat necrosis and should not be grown in the S.E. states or other areas where this defect is frequently observed. Seed Availability: Certified Maine Seed (see ME seed book), Maine Seed Potato Board field-grown seed and disease-free plantlets or minitubers; ~20 cwt of University of Maine seed.