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In This Issue:

IPM – the first line in resistance management

Newer pesticides are usually less harmful to the environment, mammalian health and other living organisms compared to older ones. These pesticides are economical yet effective to manage agricultural pests. Coupled with these desirable attributes and advances in genetic engineering, crops now have the ability to tolerate some of these pesticides while the pests are susceptible to them. Such benefits have led farmers to depend on these tools in order to increase their productivity. However, repeated use of these same tools has led to the evolution of pests that are resistant to the technology, whether it be a pesticide or a pest-tolerant crop capable of combating pests.

> *A goal of IPM is to provide sustained levels of crop protection while taking the health of the ecosystem into consideration.*

One of the goals of integrated pest management is to provide sustained levels of crop protection while taking the health of the ecosystem, its flora and fauna, into consideration. In the process, pesticide use is allowed but only to complement other management efforts so that the risks are minimized. Potential risks include adverse effects to human health and the environment, injury to non-target organisms and development of pesticide-resistant pests. In an effective IPM program, appropriate non-chemical approaches are included, and pesticides are used only when threshold levels have been reached.

It is a knowledge-intensive process and takes into consideration the cropping sequence, biology of pests and potential interactions between pest groups. Preventative, chemical, cultural, mechanical and biological strategies are used to different extents in a successful IPM program.

Integrated pest management can also be resource-intensive, demanding higher levels of human and material resources during implementation. Threshold levels of certain pests are well-established, but others are not yet determined. Certain pests, such as the herbicide-resistant biotype of palmer pigweed *(Amaranthus palmeri)* are capable of producing close to a million seeds per plant, which sometimes calls for zero-tolerance in certain row crops. Other pests, such as the brown marmorated stink bug *(Halyomorpha halys)*, require broad-spectrum insecticides, which can affect years of IPM implementation in specialty crops. Unpredictable weather patterns and frequent periods of high precipitation make it challenging to forecast the onset of certain devastating diseases, such as fire blight *(Erwinia amylovora)*; successful IPM depends largely on accurate prediction models and reduced pesticide application. These challenges make it difficult to implement IPM in commercial

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Fall cleanup and modified cultural operations reduce losses from plant diseases

During a rainy and humid growing season, many crops suffer losses from plant diseases. Pathogens from these infected tissues can overwinter. This is specifically true for foliar diseases, and it provides an avenue for continuation of the disease from one crop to another. For example, early blight and Septoria leaf spot of tomato are major foliar diseases caused by fungal pathogens *Alternaria solani* and *Septoria lycopersici*, respectively, that can be a recurring problem in the tomato growing areas in the eastern United States. Frequent rain and high humidity can exacerbate the situation causing complete blighting and defoliation of plants in three to four weeks from the initial infection. These organisms can also infect and survive on tomato stems and fruits.

Figure 1. Septoria leaf spot infected tomato leaves fallen on the ground that can keep the organism alive until the next growing season. (Photo credit: MM Rahman)

Remove infected debris

The significance of harvest and removal of infected plant debris extends beyond the time frame of the current year's production cycle. If growers leave infected plant debris intact, next year's crop can be infected from the previous year's inoculum left on infected debris. For instance, Septoria leaf spot or early blight infected leaves fallen on the ground (Figure 1) will obviously act as an inoculum source for the next crop if tomato or potato is planted in the same area.

These organisms need a food source to remain alive during the period from one crop to another. If removal of plant debris is not practical, alternative approaches that will decay or degrade tissues and deprive organisms of their food source may be effective.

Fall tillage

One approach is to deep plow the debris at the end of the season. As crop residue goes underneath the soil, microbes will degrade the tissues exposing organisms in soil that will not support their survival.

Numerous studies have proven fall tillage that buries infected residue for six months can reduce disease in the following crop in many host-pathogen combinations. A study on the influence of tillage practices on anthracnose development and distribution in dry bean fields found a significant correlation *($r = 0.75$)* between the percentage of debris left on the surface and subsequent bean anthracnose disease incidence on pods in the field. They also found that anthracnose incidence or severity in the field was highly correlated with disease incidence on harvested pods (r values ranged between 0.87 and 0.98) from previous season (Ntahimpera et al.). If removal of stubble to a suitable distance or burying by deep plowing is not possible, burning may be an alternative option.

Pruning

In perennial crops where complete removal of plants is not possible, pruning of infected plant parts will achieve the same goal. Examples are removal of fire blight or other canker disease-infected twigs of pome fruits, removal of anthracnose-infected grape vines, removal of black knot or mummified fruits (Figure 2) from stone fruit trees, and pruning and destruction of infected limbs or foliage from landscape trees.

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This principle also applies to greenhouse or high tunnel crops.

Intercultural operations

Intercultural operations are needed for any crop production system. However, subtle adjustments or modifications can largely contribute to the management or lowering of disease severity in many crops. Sanitation and removal of plant debris more importantly breaks the disease cycle. Although crop production inside a greenhouse or in some heated high tunnels is possible year-round, it is always a pragmatic approach to take a month-long break from continuous cropping and sanitize the whole area for disease management.

Figure 2. Brown rot infected and mummified plums in a tree that can be a source of infection during the next season. (Photo credit: MM Rahman)

Modification of cultural practices that can have a profound effect on plant disease management include the following:

- Tillage practices – No till can pose disease threat where crop rotation is not possible. Deep plowing allows infected crop stubble to be buried and provides quick microbial degradation.
- Sowing and harvesting practices – Early sowing when soil temperature is not high enough or soil is too moist can cause seedling damping off in snow peas. Delay in sowing or planting seedlings instead of seed sowing can minimize damping off disease. Seedling diseases caused by *Fusarium* spp. and *Rhizoctonia* spp. are more serious if seeds are planted deeply. Similarly, potato seed pieces, celery and cauliflower seedlings are more readily attacked by *Rhizoctonia* if planted too deep. Any unharvested or over-ripened fruit can be infected by pathogens, acting as a source of inoculum for the next crop. Complete harvest and removal of fruit can reduce the potential of future disease.
- Mulching – It puts a barrier between susceptible plant parts and pathogens in the top soil layer, which prevents initial infection.
- Scouting and roguing – Quick removal of plant disease when it appears only on a few plants or in a small area of a field prevents the spread of the disease to the whole area. This is specifically important for viral disease.
- Timing of intercultural operations – Avoiding intercultural operations when plants are wet can reduce the spread and infections by many fungal pathogens. Fungal pathogen propagules need moisture to germinate and infect plant tissues. Work at suspected diseased areas at the end of any intercultural operation in order to prevent spread of disease to unaffected areas.

Integrated pest management – solution for resistance management

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crop production systems, although IPM is highly relevant and applicable in crops that have more intensive production systems.

While pesticides may continue to be an important tool in crop protection in the IPM toolbox, other methods must be incorporated to achieve sustained levels of pest control. The next few issues of *IPM Chronicle* will focus on the important topic of pesticide resistance and how IPM could be used more effectively to manage the same.

Common muskrat damage and control

The common muskrat *(Ondatra zibethicus)* is a relatively large, semi-aquatic rodent found in wetlands, streams and other aquatic areas across West Virginia. Its hair is usually rich brown but may vary from tan to red to almost black. Its back is usually darker than its sides due to the black-tipped guard hairs (Figure 3). Muskrats average 1.5 to 2 feet in length and weigh between 2 and 3 pounds, with some rare specimens weighing close to 4 pounds. Muskrats have larger back feet that are webbed for swimming and smaller, unwebbed front feet used for digging and feeding. The muskrat's tail is sparsely haired and laterally compressed with a ridge at top and bottom. Named for the musky odor produced in its scent glands, the muskrat uses this musk to mark territories during the breeding season.

Figure 3. The common muskrat.

Life cycle

Muskrats usually breed at one year of age and can have multiple litters per year. Litter size varies from four to seven kits per litter with gestation lasting around 30 days. Population sizes fluctuate, varying from location to location, depending on competition, food resources and water levels. Muskrat populations can grow rapidly; however, trapping, predation, competition and other mortality factors limit population eruptions. Other than humans, muskrat predators include mink, great-horned owls and marsh hawks. Minks are especially adept at feeding on muskrats.

Feeding habits

These herbivores feed on the roots, stalks and leaves of numerous aquatic plants. They may also travel into agricultural fields feeding on crops. Muskrats can close their lips behind their teeth to cut vegetation under water. They may also feed on fish and aquatic mussels; however, these usually make up only a small portion of their diet.

Habitats

Muskrats typically build dens of either underground burrows or vegetation domes in farm ponds, streams, ditches and lakes with stable water levels and abundant aquatic vegetation. Both underground burrows and vegetation domes will have underwater entrances.

Damage

Damage from muskrats includes chewing on trees, damage to agricultural crops, or washouts of levees and dams. Muskrats will burrow into levees or dams to build tunnels and dens. This burrowing activity can potentially compromise the integrity of these structures by erosion and cave-ins causing washouts. Populations that experience an occasional eruption can cause "eat outs" where they significantly reduce or completely remove vegetation in a wetland due to over foraging.

Control

Muskrats are considered a furbearer species in West Virginia and can be trapped during the annual trapping season between November 3, 2018 and February 28, 2019. There is no bag limit during the season. If muskrats are causing damage outside of the regulated trapping season, contact your local West Virginia Division of Natural Resources to determine if a damage permit can be obtained for trapping or shooting.

Harvest data and biological reports suggest a decline in the muskrat population in West Virginia and across the United States. Fur harvest reports have declined from 5,909 muskrats in 2012-2013 season to 1,900 during the 2016-2017 season. While these harvest trends do not show us the entire picture, these trends are similar to those in other states in our region and indicative of population declines. For more information on muskrats, contact West Virginia University Extension Service Wildlife Specialist Sheldon Owen (*Sheldon.Owen@mail.wvu.edu*; 304-293-2990).

Adding beneficials to an IPM program

If you have not considered using biological control agents in your high tunnel or greenhouse, you should. Their use has proven very effective at managing a number of pests. It does require a paradigm shift on how you deal with control of pests. However, it is something that not only West Virginia State University has done but so have several of the farmers around our state.

Figure 4. Biological control agents deployed on tomato vines in West Virginia State University greenhouse. (Photo credit: Barbara E. Liedl)

Monitor

Your first shift is going to require you to monitor the pests. If you have been scouting for pests, then you already know the pests you are likely to encounter with different crops. This helps you anticipate when and where various pests are likely to become a problem. You can plan ahead and release natural enemies with sufficient time to deal with potential problems.

It is important to review your pesticide use in the greenhouse or high tunnel, because many insecticide residues can adversely affect biological control agents for as many as three to four months after their application. Do not forget that this includes not only the plants, but also the containers, benches and greenhouse plastic. Check with your supplier or other resources for pesticide compatibility with the natural enemies.

Develop a plan

Developing a plan for control will require some research, as well as contacting suppliers that specialize in biological control agents. Instead of finding the pests and spraying them with a pesticide labelled for that purpose, you will need to have a plan before the season begins to know what pests you might encounter, followed with what and when you need to release the biological control agents.

Start with one structure or area to learn how to use these natural enemies. It is also a good idea to work with a crop that makes most sense for your operation. For example, one grower lost their entire high tunnel strawberry crop to spider mites, so they decided to start with that crop and pest problem. After switching to biological control agents appropriate to the pest and temperatures in their high tunnel, they had zero loss that year.

Thinking ahead to the next crop is also necessary when using biological control agents. The same strawberry grower was going to follow up that crop by growing green beans – another spider mite-loving crop. It was recommended to the grower to change their rotation plan of this crop to another less attractive to spider mites to reduce the pest pressure.

Finally, use of biological control agents does not mean you will never use chemical sprays again. Keep a few pesticides on hand in case there is no other option but to spray to save a crop – and, in some cases, there may not be a biological control for a particular pest.

Figure 5. Tomato plants grown using only biological control agents at West Virginia State University greenhouse. (Photo credit: Barbara E. Liedl)

Bitter pit – it's not what you think it is

Bitter pit is a physiological disorder that occurs in apples and is induced by a mineral deficiency; in this case, a lack of calcium.

Figure 6. Severe case of bitter pit in Honeycrisp apples. (Photo credit: M. Danilovich)

Symptoms

Calcium plays a major role in cell wall structure. In its absence, the cell walls under the skin collapse, creating spongy, corky, brown spots of dead tissue that appear as indentations or "pits" on the surface of the fruit (Figure 6). Those spots are not only unsightly, but taste bitter and render the fruit unmarketable.

This disorder has caused significant economic losses to apple growers since the symptoms are not often visible at harvest time, but develop while in storage.

Preventing bitter pit

In order to prevent bitter pit from developing, it is important to manage calcium levels by looking into factors that influence calcium uptake. Some of the most vital factors governing nutrient availability are soil pH and the choice of rootstock. Soil pH influences chemical pathways of nutrient availability thus keeping the pH at the optimum range; a slightly acid to neutral range is recommended. Many rootstock trials have shown that rootstocks influence mineral absorption and affect the overall quality of the fruit (size, mineral composition, etc.).

Sensitivity to bitter pit development is variety specific. Honeycrisp apples are one of the most sensitive varieties. This disorder is also quite common in Red delicious, Golden delicious, Idared, Jonathan, McIntosh, Gala, Cortland, Empire and others.

Over the years, it has been established that large fruit develops bitter pit. So, too much nitrogen can lead to this disorder. Some of the management practices that lead to excess nitrogen include heavy pruning, the amount and timing of nitrogen fertilizer applications, fruit thinning, and other practices that would result in increased amounts of nitrogen available to the fruit making it large and more susceptible to this disorder.

The ratio between calcium and nitrogen is important, but there is one more essential piece to the equation to consider – the antagonistic relationship between the elements. Research has shown that aggressive amounts of potassium and, to some extent, phosphorus and magnesium, lead to calcium deficiency.

Minimizing losses

In an attempt to minimize fruit losses due to bitter pit, growers have been spraying calcium throughout the season with various results. The timing of applications in respect to physiology and fruit development is important, as well as the source of calcium. Most calcium that will be absorbed by the fruit will occur if calcium is applied by mid-July or when the shoot growth, leaf development and expansion stop. Most of the calcium goes to leaves rather than the fruit, necessitating higher calcium applications during the first part of the season or during the period of active and rapid growth.

Leaf analysis and fruit analysis indicated that there were differences in calcium levels, as well as the antagonistic elements of potassium, phosphorus and magnesium in the leaves and fruit. Higher concentrations of calcium and lower concentrations of the antagonistic elements have been found in the leaves. There are significant differences of calcium concentration even within the fruit. At the bottom, or calyx end, of the fruit is where the bitter pit symptoms first appear. Researchers have found that calcium levels were low and potassium levels were higher in this region or part of the fruit. In the peel of the fruit (epidermal tissue), potassium, phosphorus and magnesium levels were high while calcium was low resulting in a more severe bitter pit.

Identification and control of Canada thistle

Thistles have been cited in both ancient and modern literature. They were referred to as "weeds whose cure is often worse than the disease itself" by Jethro Tull in 1751 in his book, "Horse Hoeing Husbandry," and that "weeders cut back thistles only to find out that they sprout up again like Hydra, with more heads than before!"

Despite advances in modern agriculture, thistles continue to enjoy notoriety as troublesome and difficult weeds to control. Thistles also are known to possess medicinal values and to serve as forage for certain beneficial insects (Figure 7).

Identification and growth habit

Thistles are characterized by spines on aboveground parts and bright purple or pink flowers that attract pollinators. They may be categorized as biennials or perennials based on their life cycle.

Canada thistle (*Cirsium arvense*), also referred to as creeping thistle, is a perennial. It initially invades fields through wind-borne seeds or root fragments. Over a period of three to five years, it can form a colony if not managed. Its persistent nature is due to its extensive root system capable of producing sporadic shoots along long roots that run parallel to the soil's surface (Figure 8). Tillage or cultivation can break these roots into smaller fragments, spreading them and aggravating the problem. Findings indicate that increasing levels of atmospheric carbon dioxide lead to higher root production compared to shoots, making it even more difficult to control.

Figure 7. Thistle blooms serve as forage for pollinators and other beneficial insects. (Photo credit: R. Chandran)

Figure 8. Taproots of biennial thistles (A) compared to creeping roots of Canada thistle (Cirsium arvense) (B) which makes the latter difficult to control. (Photo credit: R. Chandran)

Control

To control perennial thistles, monitor fields for new emergence and execute timely management efforts. Established colonies may require a carefully planned two- to five-year management strategy.

Stored reserves in the root system are lowest during early-bloom stage (late May to early June). Removal of top growth or application of a systemic herbicide inflicts the most damage during this stage. As cut or treated plants try to regrow, it depletes additional food reserves, making it the best time to apply management efforts. If mechanical control is used, repeated mowing at a frequency of two to three weeks is recommended.

Chemical control using herbicides containing the active ingredients, aminopyralid (Milestone) or clopyralid (Stinger), are somewhat effective for use in pasture or hayfields.

If the early-bloom stage is missed, fall is the second best window to apply a systemic herbicide. Sequential applications are recommended to manage established populations. Cut the thistles back two weeks after the initial application and allow them to regrow prior to second application.

Biennial thistles, such as bull thistle (*Cirsium vulgare*) and musk thistle (*Carduus nutans*), are most vulnerable to broadleaf herbicides during the rosette stage in early spring. Thistle weavils (*Rhinocyllus conicus*) have been documented as effective biocontrol agents.

Boxelder bugs – a nuisance pest

The boxelder bug, *Boisea trivittata*, is a common nuisance pest in and around homes. Twice a year, in the spring and in the fall, large groups of these insects gather in warm, sunny outdoor locations. Seeing a cluster of thousands on a tree trunk or the side of a house can be quite upsetting to some people. They can also become indoor pests in the fall when they invade structures to find a place to overwinter.

Description

Adult boxelder bugs are approximately ½ inch long and mostly black in color. The abdomen of the insect, three lines on the thorax (one down the center and on each margin) and the margins of the wings are reddish orange. Immature nymphs are bright red and smaller than the adults. As nymphs approach adulthood, they begin to develop black wing pads.

Boxelder bug adults and nymphs feed on seed-bearing (female) boxelder trees and other members of the maple family (Figure 9). They use their piercing sucking mouthparts to extract sap from the leaves, twigs and seeds of host trees. Their feeding does little damage to the trees.

Life cycle

Female boxelder bugs lay their eggs in the spring in the cracks and crevices of the tree's bark. The eggs hatch when new leaves begin to appear on host trees. Boxelder bugs complete two generations per year.

Normally, boxelder bugs overwinter as adults in mulch or leaf litter around trees or shrubs. When they emerge in the spring, they often congregate in large groups on surfaces warmed by the sun. In the fall, second generation adults will cluster in the same locations. As temperatures begin to cool in the fall, they begin looking for sheltered areas in which to overwinter. Consequently, boxelder bugs that have gathered on houses or other structures may find their way inside.

Figure 9. Adult boxelder bug and nymphs. (Source: William M. Ciesla, Forest Health Management International, Bugwood.org)

Damage and control

Indoors, boxelder bugs are mainly nuisance pests. They do not cause structural damage to homes or breed indoors. They do not injure people or pets, but they may spot furnishings and draperies with their excrement and omit an odor if crushed.

Boxelder bugs clustered on surfaces outdoors do not cause damage; therefore, insecticide use is rarely justified. Management should focus on keeping them out of homes. Caulking openings around windows and doors should keep the bugs from entering structures. Sanitation practices, such as vacuuming, can be used to remove any bugs that do make their way indoors.

Experts recommend removing seed-bearing boxelder trees to control boxelder bugs. Such a drastic control measure should be viewed as a last resort and may not solve the problem if there are other boxelder trees nearby.

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