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## IPM and insect resistance management

Integrated pest management can be thought of as best management practices for controlling pest organisms. IPM focuses on long-term prevention of pests by using a combination of cultural, mechanical, biological and chemical tools. Integrating multiple control strategies in a pest management program can help prolong the effectiveness of each individual tactic, because long-term and repeated use of a single control tactic can lead to reduced effectiveness over time if the pest population develops resistance.

### Pesticide resistance

Resistance is a genetically-based characteristic that allows certain individuals to survive a pest management tactic that would prove lethal to most individuals in a normal population. Pesticide resistance is the most well-known form of resistance for many pest organisms.

Pesticide resistance occurs when individuals in a pest population have the genetic predisposition to survive exposure to a particular pesticide. These surviving individuals subsequently reproduce and pass on the trait(s) for resistance to the next generation, while the susceptible individuals are eliminated by the pesticide treatment.

If the treatment continues, the percentage of surviving (i.e., resistant) individuals will increase over time, and the susceptibility of the population to the pesticide will decrease to a point that it no longer provides adequate levels of control. This process is evolution in action and is the same process that leads to antibiotic-resistant bacteria that pose health threats to humans.

Pesticide resistance is a major concern in agricultural systems. With every new pesticide introduction, cases of resistance development have occurred two to 20 years later. Today, approximately 500 insect and arthropod species, 200 plant pathogens and 273 species of weeds are resistant to one more of the major pesticide classes/groups. Once a pest population becomes resistant, that pesticide and all others with the same mode of action become forever ineffective for controlling that pest.

### Other forms of resistance

Although pesticide resistance is the most common form, resistance can occur with other pest management tactics. For instance, resistance to biological controls has been documented for the larch sawfly (*Pristiphora erichsonii*) and certain mosquito species. Populations of northern corn rootworm (*Diabrotica barberi*) and western corn rootworm (*D. virgifera virgifera*) have developed resistance to crop rotations, and resistance to certain transgenic Bt crops has been observed with several insect pests, such as corn earworm (*Helicoverpa zea*), fall armyworm (*Spodoptera frugiperda*) and western corn rootworm (*D. virgifera virgifera*).

### Resistance management

Resistance is a possibility for any tactic that is used on a widespread and/or intensive scale for pest suppression. The most effective strategy to combat resistance is to prevent it from occurring by considering resistance management as part of a larger IPM approach. In the next several issues, we will continue to explore the conditions that promote resistance and methods to manage or slow its development.

## Tree squirrel damage management

There are three tree squirrel species commonly found in West Virginia: the red squirrel (*Tamiasciurus hudsonicus*), eastern gray squirrel (*Sciurus carolinensis*) and eastern fox squirrel (*Sciurus niger*). Of these, the eastern gray squirrel and eastern fox squirrel are common small game species found throughout the state. The red squirrel is most commonly found within the more coniferous forests in the eastern portion of the state.

### Eastern gray squirrel

The eastern gray squirrel is gray on its head and back, and white on its belly. Its ears are relatively short and lack any tuft. It has flattened, bushy tail. The hairs on the tail are brown at the base, blackish near the middle and tipped with silvery gray



Figure 1. Eastern gray squirrel (Photo credit: flickr.com/photos/93649757@N07/11095711445).

(Figure 1). Eastern gray squirrels are found in deciduous and mixed woodlands throughout West Virginia. They are active during the day (diurnal) with activity peaks at dawn and late afternoon. They are active throughout the year, limiting feeding activity to the warmest parts of the day during extreme winter conditions. They are arboreal (found in trees), but spend much of their time foraging on the ground for hard mast, such as acorns, beechnuts and hickory nuts, seeds (such as pine nuts and samaras), buds, fruits and agricultural crops. Eastern gray squirrels will cache food by burying and stashing, then locate these by smell and memory during winter months.

Eastern gray squirrels will build nests in tree cavities but also will build nests of leaves and twigs in tree crowns or crooks of tree limbs. They can have one to two litters per year with an average litter size of two to three pups.

### Eastern fox squirrel

The eastern fox squirrel is larger than the eastern gray squirrel. It is rusty brown above and tan below with a bushy, rusty tail (Figure 2). The eastern fox squirrel can exhibit extreme color variation throughout its

range. In West Virginia, the most common color variation is rusty brown; however, individuals that are gray with a black face occur in Virginia and Maryland. More coastal populations in Virginia and the Carolinas can be gray with a black head and feet and a white belly.



Figure 2. Eastern fox squirrel (Photo credit: flickr.com/photos/stinkenroboter/32182220137).

Similar to the eastern gray squirrel, the eastern fox squirrel is diurnal but most active in the morning and late afternoon. Eastern fox squirrels also feed on hard mast, seeds, buds, fruits and agricultural crops.

Eastern fox squirrels also are active year-round, building nests in cavities or building leaf nests in the canopy. They, too, can have one to two litters per year with two to three pups per litter.

### Red squirrel

The red squirrel is smaller than the eastern gray squirrel and eastern fox squirrel. These squirrels are reddish above and whitish below in color (Figure 3). The red squirrel will have long tufts of hair on their ears during the winter months.



Figure 3. Red squirrel (Photo credit: flickr.com/photos/the\_webhamster/5645340560).

Red squirrels typically inhabit coniferous forests and mixed forests throughout the eastern portion of the state.

Similar to the eastern gray squirrel and eastern fox squirrel, the red squirrel is diurnal, active all year and builds nests in cavities or tree crowns. The red squirrel feeds on conifer seeds, fungi, acorns and

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## Is it safe to use Roundup®? Notes from a scientific perspective

There is a lot of public concern about the safety of using the herbicide glyphosate, more commonly known as Roundup® but also available under various trade names from different manufacturers (Figure 4).

In an attempt to provide readers with enough scientific information to make their own educated decision, here are some notes on what has been revealed by toxicologists, epidemiologists and other scientists related to glyphosate's safety.

### History of glyphosate

Glyphosate has been used extensively for more than 40 years to control weeds and is currently the most widely applied pesticide in the world. Its use increased exponentially when genetically modified crops, such as Roundup-Ready soybeans, came into the market. This combination of technology revolutionized pest management.

In the United States, glyphosate replaced a large proportion of older herbicides used in major row crops, such as corn, soybean, cotton and wheat. When compared to glyphosate, several of these older herbicides posed higher levels of risk to the environment and human health. Out of the 400 million pounds of older herbicides in the four major row crops in 1982, roughly 225 million pounds were replaced by glyphosate by 2012, with similar trends since then (United States Department of Agriculture – National Agricultural Statistics Service).

Glyphosate is also used commonly for weed control in and around homes and in non-crop areas, both terrestrial and aquatic. Such trends have resulted in exposures of human populations to glyphosate in the United States, albeit at levels well below those of concern.

### Is glyphosate carcinogenic?

A common public concern is whether glyphosate is carcinogenic (i.e., whether it causes cancer) or not. Globally, glyphosate has been under close scrutiny of toxicologists, epidemiologists and microbiologists

for a long time. Perhaps, no other pesticide has been subjected to such close scrutiny.

As of 2016, 23 epidemiological studies, 15 animal carcinogenicity studies and close to 100 genotoxicity studies had been carried out (T. Pastoor, Pastoor Science Communications). These studies include examining and interpreting its effect on large human populations, animal feeding studies to determine toxic effects and laboratory studies to examine its effect on the integrity of cellular components, such as DNA.

Many publicly funded agencies also have examined the safety of glyphosate, including the Environmental Protection Agency Office of Pesticide Programs; European Food Safety Authority (EFSA); a joint assessment by the Food and Agricultural Organization of the World Health Organization (FAO-WHO); and the International Agency for Research on Cancer (IARC), also an agency under WHO.

The EPA and all the member states of the EFSA, except one, concluded that glyphosate is not likely to be a carcinogen to humans. A similar conclusion was drawn by FAO-WHO.

Of those agencies, only IARC came to the conclusion that it is probably carcinogenic to humans. IARC's assessment chose to emphasize studies that exposed test animals to extremely high doses that are not realistic or relevant to possible human exposures. Furthermore, the tumors that formed in test animals were likely due to indirect effects through excessively high dosing where physiological pathways may be overwhelmed.

The IARC also concluded that there is a positive association in epidemiology studies of glyphosate exposures to humans with the incidence of non-Hodgkin lymphoma, a cancer associated with lymph nodes. No other regulatory agency has drawn this same conclusion. This cancer is triggered by a weak immune system, which also can be affected by other factors, such as exposure to medications, bacterial

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Figure 4. Glyphosate, commonly known as Roundup® (Photo credit: flickr.com/photos/jeepersmedia/26133879124).

## Community-based approach for managing needle cast diseases on evergreen landscape trees

Colorado blue spruce (*Picea pungens*), also known simply as blue spruce, is a popular tree used by homeowners in their residential landscapes throughout West Virginia. Blue spruce trees are among the most aesthetically pleasing and easily recognized trees in urban and rural landscapes of the state. Colorado blue spruce's stiff and sharp-pointed blue-green to silver leaves and wider branches that taper off toward the top forming a pyramid shape, make these trees an extremely attractive landscaping evergreen.

### Rhizosphaera needle cast

Unfortunately, the beauty of these trees can be short lived in many parts of the state due to a needle disease known as *Rhizosphaera* needle cast, which is caused by the fungal pathogen *Rhizosphaera kalkhoffii*. The disease causes the needles to turn purplish-brown and drop off, affecting the aesthetic value and health of the tree. A healthy spruce will usually hold its needles for five or more years; however, an infected tree will drop all but the current year's growth.

The disease starts on the needles at the base of the tree, with diseased trees showing barren branches progressing upward as affected needles drop (Figure 5). Spruces do not replace fallen needles; therefore, infected trees often have holes made up of bare branches in their canopies. Repeated needle loss can result in branch death after three to four years and eventually cause tree death. Replacing these trees is costly and requires a significant lapse in time before they can be grown to an attractive size and shape.



Figure 5. Blue spruce tree affected with *Rhizosphaera* needle cast. Dead needles have already fallen on the ground, and the disease is progressing upward (Photo credit: MM Rahman).

### Management

If homeowners and landowners are aware of this common disease problem, it can be managed using a combination of methods. Because of the microscopic nature of the pathogen that first infects the needles, regular scouting is needed to detect the disease at an early stage.

When a significant number of branches without needles are visible from a distance, it may be too late to initiate treatment. However, community-based prevention through careful observation of needle symptoms is simple and will likely produce the best results.

### Identification

The disease can be easily identified with the help of a 15x hand lens by incubating suspected needles in a moist chamber made with a zip-close plastic bag with three layers of moist paper towel inside (Figure 6). If needles are infected with the fungal pathogen, rows of white stomates will be filled with brown-colored pycnidia (asexual fruiting body of the fungus) (Figure 7). This diagnostic protocol helps determine treatment needs.

Without a community-wide approach, the problem will  
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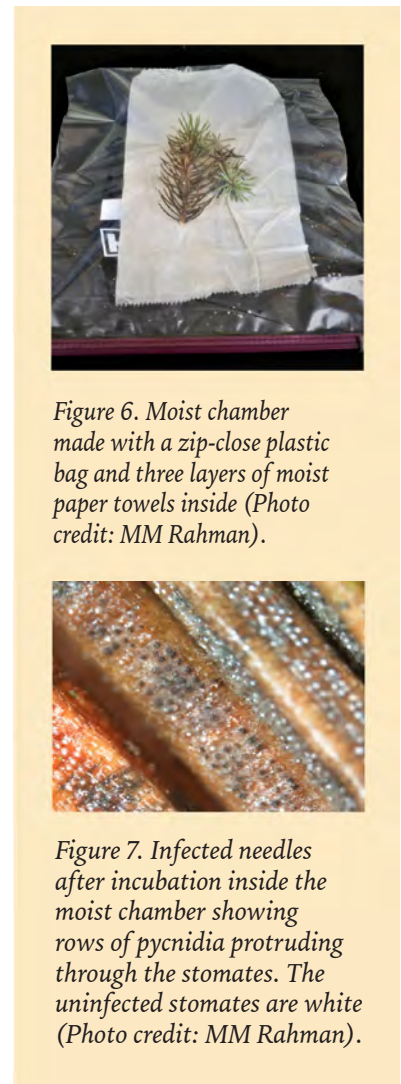


Figure 6. Moist chamber made with a zip-close plastic bag and three layers of moist paper towels inside (Photo credit: MM Rahman).

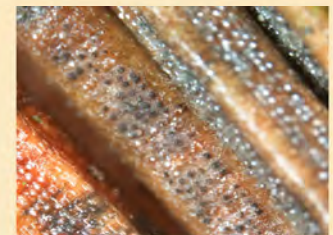


Figure 7. Infected needles after incubation inside the moist chamber showing rows of pycnidia protruding through the stomata. The uninfected stomata are white (Photo credit: MM Rahman).

## Community-based approach for managing needle cast diseases on evergreen landscape trees – continued from page 4 –

persist because infected fallen needles will be blown underneath healthy trees, starting a new infection and spreading the disease.

### Control

Community-based education and demonstration will boost the community members' confidence in controlling the disease if measures are taken early. This approach is more effective, because it eliminates the chance of the disease spreading from one site to another. In many communities where lawn care companies oversee maintenance of landscapes, trees can be included in an educational program to raise awareness about *Rhizosphaera* needle cast and discuss potential preventative measures.

Control measures include removing the infection source and applying chlorothalonil (Bravo/Daconil) or Bordeaux mix starting in the middle of the new growth. This should be done twice in the spring at a 21- to 28-day interval.

Although Bordeaux mix can be bought as a commercially prepared product, it can easily be prepared fresh for better efficacy and cost savings using the 8-8-100 (copper sulfate-slack lime-water) formula. To prepare a fresh mixture for multiple trees, 8 pounds of copper sulfate (blue vitriol) is dissolved in 50 gallons of water. An equal amount (8 pounds)

of slack lime (spray lime) is also dissolved in 50 gallons of water. The two solutions are then poured together under continuous agitation. Just before spraying, the mixture is strained to remove insoluble particles. For lower volume, the amount of each component can be reduced proportionately. Similar preventative measures can be adopted for *Dothistroma* needle blight (also known as red band disease)

that affects many different types of pines, with Austrian pine being the most affected (Figure 8).



Figure 8. Pine tree infected with *Dothistroma* needle blight. The lower needles are completely blighted with the disease progressing upward infecting needles on upper limbs (Photo credit: MM Rahman).

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## Tree squirrel damage management – continued from page 2 –

occasionally, bird eggs. It also can have one to two litters per year with two to four young per litter.

### Damage

Squirrel populations can fluctuate annually based on available food resources. Forested habitats provide tree squirrels with the food and cover they require. Nevertheless, tree squirrels have nested in attics or barns, and close contact with human development has resulted in property and crop damage.

Squirrels can cause damage to trees in urban areas, forests and orchards by chewing or gnawing bark on branches and trunks. They frequently chew through lines used in maple syrup production.

Squirrels may chew holes in domestic structures, such as attics and barns, and take up residence. However,

most squirrel complaints are the result of tree squirrels disturbing bird feeders.

### Damage management

The eastern gray and eastern fox squirrels are considered a game species and can be hunted during the regulated small game hunting season.

Squirrels can be easily trapped and euthanized, but a landowner must obtain a damage permit from West Virginia Division of Natural Resources to trap squirrels. Remember, it is illegal to relocate wildlife, so landowners cannot just catch squirrels and release them down the road.

Fix or cover any holes or access points that squirrels can use to enter a house or building, making sure

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## Don't let eastern tent caterpillars set up camp in your landscape

The eastern tent caterpillar, *Malacosoma americanum*, is a common defoliator of many ornamental and fruit trees during the early spring.

The insect overwinters as eggs, which are laid in mass on small twigs approximately a pencil width in diameter. Egg masses are about ½ inch long, black in color and encircle the twigs on which they are deposited (Figure 9). These masses can contain several hundred eggs.

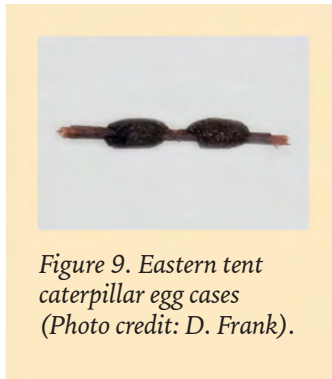


Figure 9. Eastern tent caterpillar egg cases (Photo credit: D. Frank).

### Life cycle

Eggs hatch in early spring as leaf buds begin to open. The young caterpillars gather in the forks of the limbs where they construct their dense, silken tents. These caterpillars do not feed within their tent but congregate there during the night and in inclement weather. They move out of tents to feed upon the newly opened leaves, and in the process, may completely defoliate branches within 3 feet of the tent.

As the caterpillars grow, their tents enlarge. Larvae become full grown in four to six weeks, at which time they are about 2 inches long. Larvae then wander away individually from the tent in search of protected areas to form a cocoon. Adult moths typically emerge from

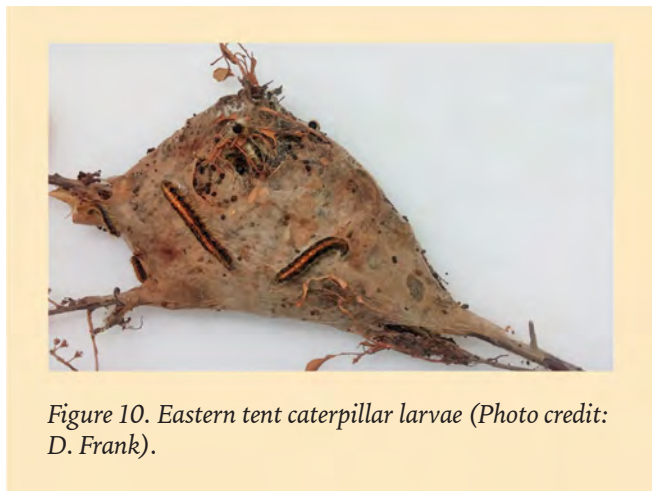


Figure 10. Eastern tent caterpillar larvae (Photo credit: D. Frank).

cocoons in June and July. There is only one generation per year.

### Description

Eastern tent caterpillar larvae are covered with long, soft hairs and are bluish-black in color with a white line running down the back (Figure 10). Moths are reddish-brown in color with two pale lines running across the forewings (Figure 11).

The webbing produced by eastern tent caterpillar can often be confused with those produced by fall webworm. Unlike the eastern tent caterpillar, fall webworm forms loose silken webs around foliage at the ends of branches. Additionally, fall webworm activity generally occurs later in the season.

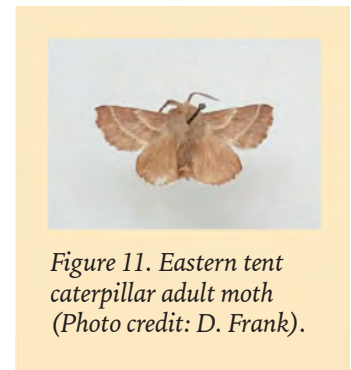


Figure 11. Eastern tent caterpillar adult moth (Photo credit: D. Frank).

### Damage

The preferred hosts of eastern tent caterpillar are black cherry, crabapple and apple trees. Damage can range from light to heavy defoliation, depending on the size of the tree attacked and the number of tents present. The webbing produced in trees can also be aesthetically displeasing.

### Control

For mature, well-established trees, controls are seldom necessary; however, if caterpillars attack young trees, or for aesthetic preservation, the tents and associated larvae can be removed and destroyed. Burning the tents out of trees is not recommended, because this can easily damage the tree or spark a wildfire.

The bacterial insecticide, Bt (*Bacillus thuringiensis*), as well as many synthetic insecticides are also effective against eastern tent caterpillar.

During the winter, egg masses can be pruned out and destroyed to prevent tents from developing the following spring.

## A control plan is critical for pest control success

Farmers should have a plan to control pests before going into production. This is important whether your operation is conventional or organic, or uses synthetic chemicals or biological control agents, because when a problem surfaces, you will have an action plan for how to proceed.

### Developing a control plan

The first step in developing a control plan is to know what pest you're dealing with. You'll need to learn how to tell common gardening insect pests apart. But, often you need to know the particular species of a pest, too, to best control the problem – especially if using biological control agents.

In the greenhouses at West Virginia State University, the primary pest problems have been caused by aphids and whiteflies. In the case of aphids, four main species have been found in the greenhouses: foxglove aphid (*Aulacorthum solani*), green peach aphid (*Myzus persicae*), melon or cotton aphid (*Aphis gossypii*) and potato aphid (*Mascrosiphum euphorbiae*).

In the past, the pest was identified, and then a chemical spray was selected to control the pest; however, that approach changed when staff began using biological control agents. So, in addition to identifying the pest, the species also needs to be identified.

In the last year, the greenhouses had two aphid infestations. For both, samples were collected and internet resources were used to identify foxglove aphids as the culprit in the major infestation and melon aphids in the minor infestation.

Using the camera on a smartphone with a clip-on lens (Figure 12) may allow you to get photos of your pests, but you may need to ask for help from your local extension service agent or an IPM specialist.

### Foxglove aphid infestation

Of the aphid species, the foxglove aphid is the hardest to control using biological control agents. For the major infestation, the beneficial parasite, *Aphidius colemani*, could not be used, because they only attack green peach and melon aphids. Sources differ on whether *Aphidius ervi* would feed on foxglove aphids, which didn't make it a good choice either. The predatory midge *Aphidoletes aphidimyza* also was considered, but it goes into diapause (dormancy) during the short days of winter, which was a problem since the infestation was in November.

West Virginia State University's research scientist worked with the biological control supplier to release



Figure 12. Using a smartphone with a clip-on lens to take photos of insects (Photo credit: B. Liedl).

lady beetles, a generalist predator, along with the predatory midge. To combat the short-day issue with the midge, a string of holiday lights was hung above the plants to interrupt the short-day issue.

In a week, the aphids were gone and didn't return the rest of the growing season.

### Melon aphid infestation

There was already a control plan in place when the melon aphids were identified during a minor infestation. It was early in the growing season, and while some beneficial parasites had been released to control aphids, including the melon aphid, it was decided to be proactive and prevent another major infestation and release lady beetles, too.

Fortunately, before the lady beetles arrived aphid mummies (Figure 13) were found, which indicated the aphid parasite, *Aphidius colemani*, was doing its job.

Within a week of releasing the lady beetles, the greenhouses were once again were aphid free.



Figure 13. Melon aphid and aphid mummy on a pepper leaf (Photo credit: B. Liedl).

## Tree squirrel damage management – continued from page 5 –

the squirrels are absent so as not to trap them inside. Trim back any limbs or trees to 6 to 8 feet away from any buildings to prevent squirrels from jumping onto roofs.

Place bird feeders away from any trees or wires that may give squirrels access to feeders. Construct squirrel barriers on any feeders to prevent access from the ground.

Squirrel damage in yards, forests or orchards is often difficult to manage. Consider trimming back trees near orchards or gardens to prevent easy

access to property. During population explosions, new squirrels quickly replace those that are removed making management a continual process. Metal flashing can be wrapped around tree trunks to prevent squirrels from climbing up into trees, but remember to trim back limbs from adjacent tree to prevent squirrels from jumping from neighboring trees.

For more information about tree squirrel management, please contact WVU Extension Service Wildlife Specialist Sheldon Owen (304-293-2990).

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## Is it safe to use Roundup®? – continued from page 3 –

and viral infections, age and health of the subject. The National Cancer Institute has an ongoing study that has evaluated more than 57,000 licensed pesticide applicators and has determined there was no association between glyphosate and cancer (updated in 2005 and 2017).

Another concern is the carcinogenicity of the proprietary chemicals added to a given formulation, intended to enhance the herbicide's uptake by plants, and not necessarily that of the active ingredient glyphosate itself. Research indicates that while agencies do not carry out extensive epidemiology or toxicology studies with such chemicals, manufacturers are only allowed to choose additives from a finite list that has been deemed to be safe.

Overall, these studies show that there is some risk involved, albeit very small, from glyphosate use. Such a risk is considered to be lower than that associated with other common carcinogens, such as tobacco, ultraviolet rays, alcohol, radon, crispy-brown foods, engine exhausts, etc. (<https://www.webmd.com/cancer/known-common-carcinogens#1>).

## Stewardship

Glyphosate is undoubtedly a useful pesticide in modern crop protection systems and needs to be stewarded so it continues to be available for farmers.

Stewardship includes proper and judicious use. Proper use includes wearing appropriate personal protective equipment while applying glyphosate. Always wear the minimal personal protective equipment stated on the label. It typically includes long-sleeved shirts, long pants, shoes and socks. Additional precautions, such as wearing protective eyewear, rubber gloves, a dust mask and washing hands and/or showering after application, may be a good idea. Never spray a pesticide while hungry or thirsty, or when the immune system is compromised.

## Conclusion

The effects of glyphosate applications on vast expanses of land, the ramifications on floral biodiversity and the development of resistant weeds are more of a concern than the human health risk.

