K·STATE
Research and Extension

Aphid Management in Greenhouse Production Systems

Aphids are major insect pests of horticultural crops grown in greenhouse production systems. Species commonly found in greenhouses include green peach aphid, *Myzus persicae*; cotton or melon aphid, *Aphis gossypii*; potato aphid, *Macrosiphum euphorbiae*; foxglove aphid, *Aulacorthum solani*; and chrysanthemum aphid, *Macrosiphoniella sanborni*. This publication addresses aphid biology, damage, and management and includes in-depth information on aphid-plant interactions and insecticide resistance for those interested in these topics.

Biology

Aphids are soft-bodied insects with cornicles (tailpipes) protruding from the abdomen (Figure 1). They are 1.0 to 2.5 mm (0.04 to 0.10 inches) in length and green to black or yellow to pink in color depending on the host plant. For this reason, aphids should not be identified based on color. All aphids in the greenhouse are females, and there is no egg stage. Each female can produce up to 100 live female nymphs, which produce offspring that develop another generation of females. The high reproductive potential and rapid development enables aphid populations to grow and spread quickly among horticultural crops in greenhouses. Aphids and winged individuals in particular, disperse rapidly in greenhouse systems where plants are spaced close together. Some vegetable and ornamental crops are more susceptible to aphids than others.

Figure 1. Aphids on leaf underside. Note the cornicles (tailpipes) protruding from the end of the abdomen.

Damage

Aphids feed primarily on new growth (Figure 2) and the undersides of leaves (Figure 3) using their piercing-sucking mouthparts to withdraw plant fluids from the food-conducting (phloem) tissues. Feeding can result in leaf yellowing, distorted leaves (Figure 4) that curl up or down (Figure 5), and plant stunting.

Aphids excrete honeydew, a clear, sticky liquid (Figure 6) that serves as a growing medium for black sooty mold. The mold on leaves (Figure 7) inhibits the plant's ability to produce food via photosynthesis. Honeydew also attracts ants, which offer protection from natural enemies (e.g., parasitoids and predators). In addition, ants move

Figure 2. Aphids on new terminal growth.

Figure 3. Aphids feeding on leaf underside.

Figure 4. Leaf distortion caused by aphid feeding.

Figure 5. Leaf curling caused by aphid feeding.

Figure 6. Honeydew on plant leaf.

Figure 7. Black sooty mold on leaves.

non-winged aphids to other plants (Figure 8). An extensive aphid population can be detected by the presence of white cast or molting skins (Figure 9) that may compromise the aesthetic quality of plants. The white cast skins can be mistaken for whiteflies. Many plant viruses are vectored by aphids. For example, the green peach aphid can transmit more than 60 plant viruses to many horticultural vegetable and ornamental crops.

Management

Aphid management strategies include scouting, cultural and physical controls, insecticide applications, and the release of biological control agents, which are discussed in the following section.

Scouting

Scouting for aphids within horticultural cropping systems entails intensive plant inspections. The discovery of winged aphids on yellow sticky cards indicates the presence of an extensive population. This warrants implementation of an aggressive, weekly scouting program from spring through late fall with close attention to plants highly susceptible to aphids (e.g., chrysanthemum and many annual bedding plants). Scouting should focus on new growth and the undersides of leaves where aphids reside.

Cultural and Physical Controls

One way to maintain aphid numbers at low levels and avoid potential outbreaks is by not overfertilizing plants, especially with water-soluble, nitrogen-based fertilizers. Overfertilization encourages the growth of soft, succulent tissues that are easy for aphids to penetrate with their needle-like mouthparts. Young plants contain an abundance of essential amino acids, components of proteins, necessary for reproduction and population growth. Excess consumption increases reproduction rates, speeds development, and shortens generation times associated with aphid populations. Weeds located within the greenhouse and around the greenhouse perimeter should be removed, as many species serve as habitats for aphids and are an inoculum source for aphid-transmitted viruses. Plants harboring extensive aphid populations should be disposed of immediately by placing them in tightly sealed containers or in garbage receptacles outside the greenhouse.

Figure 8. Ant tending an aphid. Ants protect aphids from natural enemies.

Figure 9. Aphid cast or molting skins on leaf.

Insecticides

Contact insecticides can be applied early in the production cycle to keep aphid populations from building to damaging levels. All plant parts must be thoroughly covered with spray applications and repeat applications will be required. Ample spacing between plants enables thorough coverage with insecticide spray applications. Systemic insecticides are effective when applied preventively or early in the crop production cycle before excessive aphid populations can establish. Systemic insecticides can be applied to the growing medium as a drench or granule, or sprayed on plant leaves. Insecticides labeled for use against aphids in greenhouse production systems are listed in Table 1. Read the product label to determine whether the insecticide works by contact, systemically, or both.

Biological Control

A number of biological control agents are available for aphids. These include parasitoids (*Aphidius colemani*, *Aphidius ervi*, *Aphelinus abdominalis*, and *Aphidius matricariae*) and predators (*Aphidoletes aphidimyza*, *Chrysoperla carnea*, *Hippodamia convergens*, and *Adalia bipunctata*). When applied or released preventively, parasitoids or predators are effective in regulating aphid populations.

Table 1. Insecticides labeled for use against aphids in greenhouse production systems and designated mode of action.

Common Name (Trade Name)	Mode of Action
Acetamiprid (TriStar)	Nicotinic acetylcholine receptor modulator
Azadirachtin (Azatin O/Molt-X/Ornazin)	Ecdysone antagonist: inhibits action of molting hormone
Beauveria bassiana Strain GHA (BotaniGard)	Unknown
Cyantraniliprole (Mainspring)	Selective activation of ryanodine receptors
Dinotefuran (Safari)	Nicotinic acetylcholine receptor modulator
Flonicamid (Aria)	Selective feeding blocker/chordotonal organ modulator
Flupyradifurone (Altus)	Nicotinic acetylcholine receptor modulator
Imidacloprid (Marathon)	Nicotinic acetylcholine receptor modulator
Mineral oil (Ultra-Pure Oil/SuffOil-X)	Suffocation or membrane disruptor
Potassium salts of fatty acids (M-Pede)	Desiccation or membrane disruptor
Pymetrozine (Endeavor)	Selective feeding blocker/chordotonal organ TRPV channel modulator
Pyrifluquinazon (Rycar)	Selective feeding blocker/chordotonal organ TRPV channel modulator
Spirotetramat (Kontos)	Lipid biosynthesis inhibitor
Thiamethoxam (Flagship)	Nicotinic acetylcholine receptor modulator
Tolfenpyrad (Hachi-Hachi)	Mitochondria electron transport inhibitor

Parasitoids

Aphidius colemani parasitizes small aphid species such as green peach and cotton/melon aphid. Adults are 2.0 to 3.0 mm (0.08 to 0.12 inches) in length, and black with long antennae. Adults are adept at locating low aphid populations or patches of aphids colonizing plants. Females insert eggs into aphids using an egg-laying device known as an ovipositor. A larva hatches from an egg inside the aphid and begins feeding from within. Feeding leads to the formation of parasitized or mummified aphids (Figure 10). The mummified aphids associated with *A. colemani* are leathery and golden-brown. In approximately two weeks, adults emerge from mummified aphids by chewing holes through the hardened skin (cuticle). The optimum temperature for parasitism and development is around 86°F (30°C).

Aphidius ervi parasitizes large aphid species such as potato and foxglove aphid. Adults are 4.0 to 5.0 mm (0.16 to 0.20 inches) in length, and black with long antennae. Development time is contingent on temperature. For instance, the life cycle from egg to adult takes 14 days at 70°F (21°C) and 20 days at 59°F (15°C). A female uses her antennae to determine the aphid's size and whether it has been parasitized. Then, curling her abdomen under her body, she pokes the aphid with her ovipositor and inserts an egg. After hatching, the larva proceeds to consume the aphid's insides until it is mummified. *Aphidius ervi* can parasitize many aphids in a day. Parasitized or mummified aphids are golden-yellow to brown.

Aphelinus abdominalis parasitizes potato and foxglove aphids among other species and is more effective than other parasitoids at higher temperatures. Adults are 3.0 mm (0.12 inches) in length, and black and yellow with short antennae. *Aphelinus abdominalis* is more compact than *A. colemani* or *A. ervi*. Approaching an aphid, the female inserts an egg. Parasitized or mummified aphids of *A. abdomalis* are black, forming approximately seven days after an egg is inserted. The adult emerges in 14 days.

Aphidius matricariae parasitizes green peach and cotton/melon aphid. *Aphidius matricariae* looks similar to *A. colemani*. Adult females live 15 to 17 days, parasitizing more than 200 aphids. The optimum temperature for

Figure 10. Parasitized or mummified aphids on leaf underside.

development is 77°F (25°C). Compared to other parasitoids, *A. matricariae* is less tolerant of higher greenhouse temperatures (86°F or 30°C) that may occur during the summer.

Predators

Aphidoletes aphidimyza is a predatory midge that can be released near localized aphid populations in conjunction with certain parasitoids. The larval stage feeds on aphids, but the adults do not. *Chrysoperla carnea,* or green lacewing larva, feeds on as many as 200 aphids during its two- to three-week development period. Adults do not feed on aphids. Green lacewing larvae should be released among localized aphid infestations as plants with trichomes (hairs) may interfere with the larvae's ability to locate aphids.

Ladybird beetles, *Hippodamia convergens* and *Adalia bipunctata,* are limited in their effectiveness because they require high aphid populations for survival. If unable to find aphid colonies, adults may leave the greenhouse. For a list of commercially available biological control agents (parasitoids and predators) for use against aphids in greenhouse production systems, see Table 2.

Banker Plants

Banker plants support parasitoids in regulating aphid populations within the greenhouse. They provide sites for aphids to develop, allowing for continuous reproduction and dispersal to sustain aphid parasitoid populations. Banker plants host aphids such as the corn leaf aphid, *Rhopalosiphum maidis,* and bird cherry-oat aphid, *Rhopalosiphum padi,* that feed on plants not typically grown in the greenhouse. These include winter barely, *Hordeum vulgare*; winter wheat, *Triticum* spp.; or common rye, *Secale cereale*. Parasitiods use these aphids for reproduction throughout the growing season.

Banker plants should be placed along walkways and at the ends of walkways or benches (Figure 11). *Aphidius colemani* tends to disperse 3.2 to 6.5 feet (0.97 to 1.9 meters) from the point of release, with higher parasitism rates within a short distance. Banker plants should be placed evenly throughout the greenhouse.

Table 2. Biological control agents (parasitoids and predators) available commercially for use against aphids in greenhouse production systems.

Parasitoids	*Aphidius colemani* *Aphidius ervi* *Aphelinus abdominalis* *Aphidius matricariae*
Predators	*Aphidoletes aphidimyza* *Chrysoperla carnea* *Hippodamia convergens* *Adalia bipunctata*

Aphids and Interactions with Plants

Effect of Plant Nutrition on Susceptibility

Aphids prefer certain plants, choosing to feed on specific cultivars. For example, chrysanthemum (*Dendranthema* x *grandiflorum*) cultivars vary in susceptibility to aphids, mainly due to their nutritional quality, and specifically the amino acid concentration in plant tissues. Aphids require amino acids for growth, development, and reproduction. As they feed within the food-conducting (phloem) tissues, they select the developing leaves of cultivars containing high concentrations of amino acids.

A relationship exists between the number of aphids colonizing plants and the cultivar's nutritional quality. Aphids also select cultivars that are more favorable for reproduction, particularly those that promote faster development. Aphid life span and reproductive efficiency may differ in populations feeding on different chrysanthemum cultivars. Aphids feed on the undersides of leaves of some cultivars and the upper sides of leaves of others.

Any increase in reproductive efficiency influences the effectiveness of insecticides and biological controls. The number of aphids produced in a given time period increases the chance that the aphid population will develop insecticide resistance, and thus require more frequent insecticide applications. Biological control agents may not be as effective in regulating aphid populations on susceptible crops or those more favorable for reproduction. It can be difficult for biological control agents to keep up when large numbers of aphids are produced within a relatively short period of time.

Distribution on Plants

For the most part, aphids aggregate and feed on new growth, redistributing themselves as plants grow. For example, on certain chrysanthemum cultivars, green peach aphid populations migrate to where buds form at the top of plants. During flower development, amino acid concentrations within leaves may change, making them more attractive to aphids. Flowering plants support a greater number of individuals than non-flowering plants. When plants flower, the upper leaves become more suitable. This causes to aphids redistribute themselves vertically and aggregate on the upper leaves and flowers. This upward movement during flowering accounts for the sudden appearance of aphids on flowers.

Figure 11. Banker plant for aphid parasitoids located on the end of a bench.

Aphid preference for upper leaves increases their exposure to contact insecticides and biological controls, which improves suppression or regulation. Aphids that colonize new growth are easier to control than those feeding on mature leaves or leaf undersides because it is difficult to kill them with insecticides. In addition, open flowers may protect aphids from contact insecticides and biological control agents. When plants become crowded, winged individuals form and aphids redistribute themselves among surrounding plants. Aphid mobility influences insecticide efficacy and the ability of biological control agents to effectively regulate aphid populations.

Although aphids prefer to gather on new plant growth, some species distribute themselves differently. For example, melon aphid populations are typically located throughout the plant canopy and the undersides of lower leaves, whereas green peach aphid populations are found on the upper leaves. Nearly all aphids migrate upward as plants grow, but the green peach aphid disperses more rapidly than other species. Aphid movement is linked with transport of essential amino acids through the food-conducting (phloem) tissues of the plant. Young, developing leaves contain higher levels of amino acids than older or aging leaves, and some aphid species do not colonize older or aging leaves that are lower in nutritional quality or nutrient content. Therefore, aging leaves support fewer aphids, which are more difficult to detect when scouting.

The type of plant also affects the ability of aphids to colonize older leaves. For example, green peach aphids feeding on potato, *Solanum tuberosum*, prefer the older, lower leaves. Growth and reproduction rates are higher on lower leaves compared to upper leaves. In this case, the phloem sap of older leaves changes from mostly carbohydrates to predominantly amino acids. The relationship between reproduction and amino acid concentration may explain why green peach aphids prefer to feed on the lower rather than on the upper leaves of potato plants. Aphids located on older growth further down in the plant canopy are more difficult to kill with insecticides. Consequently, these aphids may produce more aphids that will be redistributed in the upper plant canopy.

Winged aphids develop due to a decline in plant nutritional quality, variation in plant chemistry, or crowding. For instance, if crowding occurs, aphids migrate down the plant and produce winged individuals. These winged aphids return to the top of the plant and fly to a new host plant where they give birth to live offspring. By the time winged aphids are noticed, it may be too late to apply insecticides or release biological control agents. Because aphids prefer to feed on plant cultivars higher in nutritional quality, it is important to avoid overfertilizing plants with water-soluble, nitrogen-based fertilizers.

Plant height and foliage density influence control by inhibiting coverage of plant parts with contact insecticides. For example, aphids can migrate into the interior plant canopy, thereby avoiding insecticides. The way aphids distribute themselves vertically on plants also varies depending on the aphid species, plant type, and cultivar. This can affect suppression/regulation with contact insecticides by making it difficult to obtain thorough coverage and prevents biological control agents from finding aphids. An understanding of within-plant or vertical distribution of certain aphid species may help in scouting for aphid populations before they disperse among greenhouse crops and in detecting aphid populations early to prevent outbreaks.

Aphids and Insecticide Resistance

The green peach aphid feeds on more than 400 plant species in 40 different plant families and is one of the most common aphid species found in greenhouses. Because of its short generation time and high female reproductive capacity, populations can quickly reach damaging levels. As a result, insecticides are routinely applied to manage this species in the greenhouse. Frequent application of insecticides allows aphids to adapt by acquiring the ability to overcome the insecticide's toxic effects. In fact, continual reliance on a number of insecticides has resulted in the development of multiple resistance mechanisms. The green peach aphid has developed the ability to resist more than 70 different compounds in the organophosphate, carbamate, pyrethroid, and neonicotinoid chemical classes through six different resistance mechanisms described below.

Resistance Mechanisms

Mechanisms of resistance are associated with the chemical classes noted in parentheses: 1) overproduction of enzymes that detoxify or break down the active ingredient before it reaches the target site in the central nervous system (organophosphates, carbamates, and pyrethroids); 2) mutations of specific enzymes that decrease susceptibility to certain insecticides by modifying the target site (carbamates); 3) changes in the voltage-gated sodium channels (pyrethroids); 4) overproduction of detoxification enzymes (neonicotinoids); 5) reduced penetration through the cuticle or skin (neonicotinoids); and 6) alterations in target site receptors (neonicotinoids).

Most resistance mechanisms are associated with increased production of metabolic detoxification enzymes or modification of target site receptors in the central nervous system. In some cases, several resistance mechanisms may be present, leading to resistance to insecticides that affect the aphid's metabolic or physiological processes by different modes of action.

Green peach aphids feed on many different plants and are more prone to developing resistance. Some of these resistance mechanisms may have evolved in response to chemical defenses and toxins associated with plants that are then manifested after exposure to insecticides. Resistance is more likely to develop in the presence of a variety of mechanisms that confer resistance to plant chemical defenses or plant-derived toxins. Some insecticides have properties that are similar to plant-derived toxins. For instance, the pyrethroids are synthetic derivatives of pyrethrins, which are natural components of the chrysanthemum (*Tanacetum cinerariifolium*) flower. This similarity confers resistance to pyrethrins and pyrethroids.

Behavioral avoidance, indicated by a preference for untreated leaves and dispersal from leaves that have been treated with an insecticide, is associated with neonicotinoid resistance. For example, green peach aphids avoid leaves treated with the neonicotinoid systemic insecticide, imidacloprid. Behavioral avoidance may not be the sole cause of resistance as imidacloprid also acts as a repellent.

Insecticide Modes of Action

There are two types of insecticides, which are distinguished by their modes of action. *Narrow spectrum insecticides* target specific sites in the central nervous system or certain enzymes responsible for metabolism. *Broad spectrum insecticides* act on a variety of target sites by employing multiple modes of action. These insecticides are less prone to resistance compared to narrow spectrum insecticides with more specific modes of action. In order to reduce the potential for resistance, rotate insecticides with different modes of action throughout the growing season when aphid populations are present, especially the green peach aphid. Insecticides labeled for use against aphids and their designated modes of action are presented in Table 1 on page 3.

Raymond A. Cloyd

Extension Specialist

Horticultural Entomology and Plant Protection

K·STATE
Research and Extension

Publications from Kansas State University are available at *www.bookstore.ksre.ksu.edu*

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

K-State Research and Extension is an equal opportunity provider and employer. Issued in furtherance of Cooperative Extension Work, Acts of May 8 and June 30, 1914, as amended. Kansas State University, County Extension Councils, Extension Districts, and United States Department of Agriculture Cooperating, J. Ernest Minton, Interim Director.

MF3442 March 2019