BIOLOGICAL CONTROL OF APHIDS

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Abstract

The fungus, *Neozygites fresenii*, is a valuable natural enemy of the cotton aphid, *Aphis gossypii*. This fungus has caused epizootics each year since 1988 throughout cotton growing areas in the mid-South and Southeast. In many cases the fungus reduces high aphid populations to below economic thresholds. The fungus has a complex life cycle precisely coordinated with periods of high relative humidity. Aerial spores in cotton fields are important in the rapid transmission of the fungus throughout a field. Regular scouting of cotton fields and accurate diagnosis of the fungus can lead to less reliance on chemicals for aphid control.

Introduction

The most common aphid cotton growers will encounter is the cotton aphid, *Aphis gossypii* (O'Brien et al. 1993). This insect is a secondary pest that has increased in importance since the 1980's (Rummel & Kidd 1994). Several factors are responsible for the increasing importance of this pest, including: development of insecticide resistant aphids, pesticide alteration of leaf nitrogen and carbohydrate levels that stimulates aphid population growth (Slosser et al. 1989), and reduction in aphid predator numbers by insecticides (Rummel & Kidd 1994).

Cotton aphids are tiny, soft bodied insects that feed by sucking phloem sap from the plant. Phloem sap is rich in carbohydrates and water, but low in amino acids needed for aphid growth. Consequently cotton aphids "waste" much phloem sap, excreting it from the anus as honeydew. Honeydew is utilized as a food source by ants, bollworm moths, and other insects, and it makes plants in aphid infested fields shiny and sticky. Honeydew supports growth of sooty mold fungi that make leaves and cotton lint black and dirty. Sugar-rich honeydew is a major factor causing "sticky cotton".

Small cotton aphid populations probably do not damage cotton and, while they represent the source of potential aphid outbreaks, they also serve as a food source for beneficial insects. As such they may "hold" and support predatory insects in cotton fields making it possible for natural enemies to later attack bollworm eggs, larvae, or other pests. Therefore, small aphid populations may serve a useful purpose.

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Unfortunately, cotton aphid outbreaks develop extremely rapidly, sometimes as a result of insecticide applications. Insecticides kill beneficial insects as well as pests. If an aphid population possesses resistance to the chemical used, the aphids survive, but the destruction of predators and parasitoids sets the stage for an aphid outbreak. Aphids may become abundant in a cotton field within 8 to 10 days after insecticide treatment. This is evidence of the aphid's incredible reproductive powers and also the natural control exerted by predators and other natural enemies (Isely 1946).

Aphid Biology

Every aphid in a cotton field is a viviparous, parthenogenetic female. In other words, each aphid gives birth to live offspring, no time is wasted laying eggs and there is no need for males for fertilization. Under favorable conditions cotton aphids can develop from birth to maturity and start producing their own young in as little as 4 days (Isely 1946). One aphid female can produce up to 154 offspring in her lifetime and in one year there may be 57 generations (Paddock 1919). These characteristics permit aphid populations to increase rapidly.

The cotton aphid has several morphological forms. Depending on circumstances, cotton aphids vary in color from pale yellow to dark green or almost black. Aphids may be winged (alate) or wingless (apterous). The different colors and wing conditions of the cotton aphid are confusing and different morphs of *A. gossypii* may be mistaken for different aphid species. The pale yellow wingless form has been most abundant during aphid outbreaks in mid-South cotton during June and July. Wingless forms reproduce rapidly because they don't waste energy making wings.

Winged aphids are responsible for initiating aphid populations in cotton fields during early summer and are carried for long distances (hundreds of miles) by winds and storms, then deposited in mid-South cotton fields. There is no way to protect a field from this aerial onslaught of winged aphids. The major defense a grower has against early season aphids is maintaining abundant populations of beneficial insects such as ladybird beetles and lacewings. Unfortunately insecticide applications for thrips, bollweevil, tarnished plant bug, and other cotton pests, make it difficult to maintain beneficial insect populations in a field.

Plant Injury

High aphid densities cause direct and indirect plant damage. Direct damage is caused by hundreds or thousands of aphids feeding on each leaf and terminal. Aphid mouthparts (stylets) penetrate plant tissue and suck phloem sap (Leclant & Deguine 1994). Aphid infested leaves are deformed and appear crinkled or cupped. Often this damage is temporary and plants outgrow the injury. High aphid populations that persist for many weeks, particularly under drought conditions, may reduce yield.

Aphid feeding removes photosynthate from the leaves making it unavailable for boll production. Honeydew contains up to 10% sugars (Mittler 1958) and some aphid species produce 5-10 mg dry weight of honeydew during development to the adult stage (Heimbach 1985). If a plant has 10,000 aphids feeding on it, up to 100 grams of dry weight photosynthetic sugars could be lost from the plant, resulting in yield loss (Andrews & Kitten. 1989, Bagwell et al. 1991, Harris et al. 1992).

Indirect damage is caused by honeydew. Honeydew collects on lint causing sticky cotton, a serious problem at weaving mills. Honeydew also supports the growth of sooty molds that interfere with photosynthesis by hindering light absorption by chlorophyll, interfere with plant respiration, and stain cotton lint.

Chemical Control Problems

Cotton aphids are difficult to control for several reasons. First, aphids live on the underside of cotton leaves, making uniform insecticide coverage difficult. Second, many aphid populations are resistant to insecticides, making them difficult to kill. Third, even if a chemical kills 80% of the aphid population, the remaining 20% can rapidly build back to high populations in a short time. Especially because once the ladybird beetles, lacewings, and other predators and parasitoids have been killed by an insecticide, there is little to hinder the rapid increase of the aphid population. The loss of natural enemies after chemical application for aphids also may lead to future difficulties in controlling worms. Fourth, insecticides and application are expensive, in 1995 the average cost per acre for one treatment was $13.62 (Williams 1995).

Predators and Parasitoids

The main subject of this paper is the cotton aphid fungus, however, predators and parasitoids are extremely important in controlling early season, low density populations of aphids. The most important predators attacking aphids are lacewing larvae (Chrysopidae & Hemerobiidae), ladybird beetle larvae and adults (Coccinellidae), hoverfly larvae (Syrphidae), damsel bugs (Nabidae) and other predacious bugs (Anthocoridae). The most important parasitoid wasp attacking cotton aphids is *Lysiphlebus testaceipes*. Generally, once aphid populations are extremely high, predators and parasitoids by themselves can not keep up with the high reproductive rate of aphids and will not quickly control aphid populations.

Fungus Biology and Epizootics

Since 1989 epizootics (rapid declines in aphid populations due to the disease caused by the fungus) have been documented in the mid-South states (Steinkraus et al. 1995). The fungus has a short somewhat complicated life cycle. In 1991 the causal agent was identified as the fungus *Neozygites fresenii* (Steinkraus et al. 1991). This fungus attacks only aphids. It is so closely dependent on aphids that it cannot be cultured on microbiological media. This fungus is responsible for widespread declines in aphid populations and is a valuable ally of the grower. However, because no one has been successful in growing this fungus apart from a living aphid, commercial prospects for *N. fresenii* are limited.

Understanding the fungus life cycle is necessary to scout for the fungus in the field and identify it in the laboratory. The life cycle starts with a microscopic spore called a primary spore, 15 micrometers in diameter (1 micrometer = 0.001 of a millimeter). Approximately 3,000 primary spores per aphid are explosively shot off a dead infected aphid. About 75% of these spores enter the air and 25% hit the leaf (Steinkraus et al. 1993). The fungus has mechanisms to closely time spore discharge to night periods of high relative humidity. Within 2-4 hours after dusk the fungus kills the aphid and begins growing out of the host cadaver. By 1:00 a.m. millions of spores are broadcast into the air over a cotton field during an epizootic. We have found up to 60,000 primary conidia per cubic meter of air present over commercial cotton fields at 3:00 a.m. These aerial spores rapidly infect aphids throughout the field and are involved in infecting aphids in adjoining fields within a county.

Primary conidia germinate within 6-9 hours (around daybreak) to form secondary conidia (capilliconidia), the infective stage of the fungus. Secondary conidia are formed on the tips of thin stalks, are shaped like almonds, and have a sticky apex. Secondary spores are formed at the height of the aphids legs and are like cockleburs. When aphids walk across a leaf, the spores stick tightly to the aphid, germinate, and penetrate the aphid's exoskeleton. Once in an aphid's blood, the fungus reproduces vegetatively as yeast-like cells called protoplasts or hyphal bodies. Three days after the aphid host was first contacted by the fungus, the aphid dies and shoots off thousands of new spores. This short life cycle permits the fungus to destroy populations of hundreds of aphids per leaf over entire cotton fields within 7-9 days.

Cotton aphid populations begin to decline when the prevalence of fungus killed aphids in a field reaches approximately 15%. Declines are faster in fields with large aphid populations. Scouting for fungus-killed aphids is the most practical method for detection of fungus during early stages of epizootics. However, microscopic examination is more accurate. It is necessary to examine a subsample of only 100 aphids from 4-5 leaves collected from 4-5 areas of the field for 95% probability of fungus detection when average prevalences are less than or equal to 4%. Relatively few samples can provide growers with timely, accurate information regarding the presence of the fungus within their fields (Hollingsworth et al. 1995).

Scouting for Fungus

Scouting cotton fields for the fungus is essential but not foolproof. With experience it is possible to recognize

recently killed aphids. Freshly killed infected aphids are pale gray, somewhat crystalline in appearance, and stand on their heads attached to the plant by their mouthparts. After aphids have been dead several days, they are frequently overgrown by saprophytic fungi. Saprophyte covered aphids are very noticeable because they are brown, green, or gray and covered with "woolly" fungi. Saprophyte covered aphids are a good indicator of an epizootic.

It is possible to scout a field with the naked eye, counting the number of living and fungus-killed aphids in 4-5 areas, but this method is not totally accurate. A hand-lens of about 7x magnification or a dissecting microscope at 25-50x increases accuracy.

The most accurate method for determining aphid fungus in a field is to collect aphids from 4-5 areas of the field by rolling up infested leaves or cutting off leaf strips containing aphids and placing these in vials of 70% ethanol. The aphids can be analyzed in the laboratory by squashing a random subsample of 100 aphids in lactophenol-acid fuchsin stain. Individual aphids are diagnosed for8 signs of the fungus at 200x magnification using a phase microscope. If an aphid has secondary spores, protoplasts or hyphal bodies, resting spores, or conidiophores, present, there is no doubt that the aphid was infected. From this analysis the percentage of infected aphids (prevalence) can be determined.

Fungus Diagnostic Service

Between 1993-1995 we conducted a pilot study to determine prevalence rates of the fungus from cotton aphids collected from fields across Arkansas. Aphid collection kits and directions were distributed to cooperating agents and consultants. When aphids were considered a problem, they were collected by extension agents or consultants, mailed by express mail to the Cooperative Extension Laboratory in Lonoke where they were squashed and analyzed by a technician at the Plant Disease Diagnostic Laboratory. She reported the results to the sender within 24 hours when insecticide treatments were being considered. The presence or absence of the fungus in the field is an additional piece of information that can be used by the consultant when making management decisions. This service was considered useful by the majority of participants.

Funding for this experimental diagnostic program ended in 1995. If there is interest from the cotton community in the mid-south, and funding for such a service can be found, it could be continued and expanded to a multi-state program. At the moment the future of this program is unclear. Once set up such a program has the potential to save many costly unnecessary insecticide applications.

What Individuals Can Do

It is feasible for individuals to learn sampling and microscopy techniques used to diagnose aphids for the fungus. Once mastered, diagnostic techniques permit an individual to scout fields, take aphid samples, and immediately analyze them for fungal prevalence. This information is necessary to determine whether to apply insecticide or wait for the fungus wipe out the aphids.

Aphid fungus benefits growers by eliminating aphid populations naturally. It must be emphasized that the fungus is a natural resource, not under human control, and may not always be present, or appear early enough, to prevent plant damage. Therefore, the foundation for successful utilization of this resource must be careful scouting of the cotton field and accurate diagnosis of the levels of fungus present.

The critical moment for scouting for the fungus is when a grower is considering insecticide application for aphid control. If the aphid population is large, if the fungus is present in several areas of the field at a prevalence level of $\approx$15% or higher, then there is a high likelihood that a fungus epizootic will develop in the next 5-7 days and greatly reduce the aphid population. On the other hand, if permanent plant damage is being caused by an aphid population and scouting reveals no fungus or very low levels of fungus, the consultant must use his best judgment as to protecting the crop.

Summary

- Fungus won't solve all aphid problems, but when present may reduce aphid populations without insecticide application.
- Scouting each field is essential. This requires either a trained operator or a diagnostic service.
- If a fungus epizootic is imminent, an insecticide treatment is wasted. If the fungus is not present, failure to treat may result in yield loss.

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