

**COTTON APHID *APHIS GOSSYPHII* L. (HOMOPTERA; APHIDIDAE); A CHALLENGING PEST;  
BIOLOGY AND CONTROL STRATEGIES: A REVIEW**

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**ABSTRACT:** Cotton aphid (*Aphis gossypii*) is a key pest of cotton crop. The indiscriminate use of insecticides and pesticides during 1930's and latter to control insects pests, developed resistance in cotton aphid against these chemicals resulting in outbreak of this pest. Cotton aphid has a major impact on quality and yield of cotton which emphasizes the need to manage this notorious pest. The main goal of this review is to highlight various strategies viz., biological, chemical and cultural control for cotton aphid management. The selection of suitable control strategy is made on by viewing the severity of cotton aphid outbreak. Furthermore, the role of transgenic crops in lowering cotton aphid population is also described. However, the preservation of the cotton aphid's natural enemies could be an ecologically sustainable method of maintaining the aphid population below threshold level.

**Keywords:** Sustainability; Integrated pest management; Predator-prey population; Host feeding

**INTRODUCTION**

Cotton Aphid, *Aphis gossypii* Glover, is an important pest in agriculture, horticulture and greenhouse crops (Aheer *et al.*, 2006; Khattak *et al.*, 2007). Hence, it can successfully harbour a vast diversity of host plants (Fuller *et al.*, 1999). Over 320 plant species belonging to 46 families have been documented as suitable host for *Aphis gossypii* worldwide (Blackman & Eastop, 2000) of which cotton (*Gossypium hirsutum*) is one of the economically important cash crop and is highly susceptible to a large number of arthropod pests including cotton aphid (Ebert and Cartwright, 1997). Cotton aphids injure cotton plants by continually feeding on fluids in plant phloem tubes. This feeding can stimulate foliar alterations, delay of the plant growth, fewer fruit setting, lower fruit retention and reduced cotton lint weight (Raboudi *et al.*, 2002). In addition, virus transmission can lessen the cotton yield up to 30-40%. Cotton aphids reduced leaf area by 58% and shoot biomass by 45%. Cotton plants infested with cotton aphids were shorter and produced fewer vegetative branches than non-infested plants. However, cotton plants compensated for the physiological alterations and no cotton seed yield losses were observed. Cotton aphid population dynamics can be influenced by agronomic and pest management practices. High densities commonly occur as resurgent populations following applications of selected insecticides for other insect pests (Slosser *et al.*, 2001; Torrey *et al.*, 2000). The present review focuses on different management strategies involved in controlling cotton aphids.

**GENERAL MORPHOLOGY**

The cotton aphid (*Homoptera*: Aphididae) is polymorphic with considerable variations in both size and colour (Rosenheim *et al.*, 1995). It is pear shaped small, soft-bodied and slow moving yellow or dark green in colour. It ranges from 0.5-7 mm in length (Minks *et al.*, 1986). Whereas the adult cotton aphid varies in colour from light to dark green and has dark siphunculi (Slosser *et al.*, 2001) at low temperatures. At high temperatures and in crowded environments length of an adult cotton aphid is approximately two millimetres and is pale yellow in colour (Blackman and Eastop, 1985). The dark siphunculi the main diagnostic structures in aphids. Siphunculi are tube-like structures on the posterior part of the abdomen. When muscles of siphunculi contract, a waxy liquid is secreted which solidifies in air and inhibits the mouth parts of predators from functioning, thus reducing their ability to prey on them. Aphids can also excrete alarm pheromones from siphunculi to warn other aphids of natural enemies (Borror *et al.*, 1989).

Cotton aphids may be apterous (wingless) or alate (winged). Environmental conditions commencing production of pterous or alate forms are usually associated with decreasing photoperiod and decreasing temperature. Furthermore, alate (winged) aphids generally form due to an increasing population and the resulting overcrowding that can occur.

Pterous aphids emigrate from deteriorating winter host plants and infest new host plants in the spring (Carter and Godfrey, 1999). On the basis of reproduction and host preferences, aphid species can put in two separate groups viz., holocyclic and anholocyclic genotypes (Zhang and Zhong, 1990).

The aphids constitute the piercing-sucking mouthparts, which are used to suck sap from the plant. It despite of reducing crop yield and quality through feeding damage also excretes sticky substance called honeydew. Plant leaves may become twisted and wilted due to development of moulds on honeydew. Honeydew is not only harmful for insects but also reduce yield and the quality of cotton fibres. Honeydew that falls onto the exposed lint in open bolls causes serious problems at the textile mill (Leser *et al.*, 1992). In processing and during spinning, honeydew on contaminated lint accumulates on machinery and affects it badly. At the same time sand particles trapped by the honeydew abrade and cause premature wear to machine parts. Sticky lint was a serious problem in cotton industry in 1995. As a result of honeydew contamination, growers received reduced prices for their lint. The concern over sticky lint promotes researchers to investigate the use of sprinkler irrigation system to wash aphid honeydew sugars from lint under emergency conditions (Arnold *et al.*, 2002).

### LIFE CYCLE

Cotton aphid comprises complex life cycle, therefore, complete description is difficult and laborious job (Parajulee *et al.*, 2003). Parthenogenetic reproduction is observed in many species of aphid females in which adult females give birth to live nymphs. Furthermore, off springs of this type of reproduction are clones of the mother and do not involve gene recombination. Slosser *et al.* (1989) reported that in United States mostly female cotton aphids are seen as compared to male aphids. Some aphids reproduce sexually and exhibit a holocyclic stage. In most cases *A. gossypii* reproduces asexually with either alate or apterous females. However, alternation of sexual and parthenogenetic reproduction (cyclic parthenogenesis) commonly occurs in aphids (Dixon, 1987). Kidd (1995) stated that reproductive male cotton aphids have the important role. They might mate with oviparous females to produce eggs having winter survival potential.

### DAMAGE TO COTTON

Cotton aphids are the most serious pests of cotton all over the world (Rummel *et al.*, 1995). Usually, late in the season when leaves are at less favourable feeding sites or during early colonization stage, it attacks underside leaves for sucking liquid from phloem tissue and infest cotton terminals also (Santos, 2001). With the help of piercing-sucking mouthparts aphids suck the fluid from phloem tissue (Hafez *et al.*, 1996), in turn reduce the plant vigour causing wrinkled, deformed leaves and buds, slowing plant development, hindering plant growth and reducing lint yield (Silva, 1992). Black sooty mould is observed in cotton, because honeydew that is excreted by cotton aphid may provide the medium for fungus growth. This fungus inhibits photosynthesis and reduces plant growth by covering substantial portions of leaves. When bolls are open, a threshold of 11 aphids per leaf is documented by Slosser and Parajulee (2002). Similar results are also reported by Rosenheim *et al.* (1995). Host plant hormonal stimuli, nutritional contents and other characteristics that stimulate the insect to start feeding, also influence the success of the development and reproduction of phytophagous insects (Fernandes *et al.*, 2001).

### PEST STATUS OF COTTON APHID

In spite of large acreage, yield of seed cotton is very low because of severe pest complex. According to an estimate, bollworms and sucking pest complex cause about 20-40% yield losses in Pakistan. Important sucking insect pests are whitefly, *Bemisia tabaci* (Genn.) (Hemiptera: Aleyrodidae), cotton thrips, *Thrips tabaci* Lind. (Thysanoptera: Thripidae) and cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) (Aslam *et al.*, 2004).

Most common agricultural insect pest is the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae) and it reduces the yield and quality of cotton. According to economic importance, the cotton aphid was ranked sixth and seventh in the United States in 2002 and 2003 respectively (Williams, 2003). Akey and Butler (1989) reported that cotton aphid has the potential to be a serious pest of cotton in any season due to its severe outbreaks. In the Texas high plains, intermittent problem is the cotton aphid infestation and in most years it is a secondary pest. In some years aphid will be economically significant pest and widespread aphid outbreaks will be severe. The cotton aphid was considered as the number one cotton pest in 1991 in the south western United States (Head, 1992).

### AGRONOMIC PRACTICES AND COTTON APHID POPULATIONS

Agronomic practices used in cotton production influence aphid populations. For instance, tillage operations modify soil habitats, where some pests and beneficial insects occur during some part of their life cycle (Funderburk *et al.*, 1988).

Jones *et al.* (2001) documented higher densities of cotton aphid in no-tillage or reduced tillage systems as compared to conventional tillage systems in Louisiana. Furthermore, Ruberson *et al.* (1995) observed higher cotton aphid populations in cotton planted into no-till plots following crimson clover, *Trifolium incarnatum*, as a winter cover crop compared to conventional-tillage plots with no winter cover crop. Plantation date and plant density can also influence cotton aphid populations (Slosser *et al.*, 1992). Cotton aphid densities were higher on cotton planted in late June compared to cotton planted in late April or May. Plots with low plant densities supported higher aphid numbers on individual plants because of higher plant moisture concentrations. Slosser *et al.* (2001) found higher cotton aphid densities in plots irrigated in September (late season) compared to those in plots that were not irrigated. The smooth-leaf isolate of DES 119 offered substantial resistance to the cotton aphid compared to hairy-leaf varieties (Weathersbee *et al.*, 1995).

## BIOLOGICAL CONTROL

Biological control is considered to be a long term, sustainable source for pest management compared to chemical control (Bale *et al.*, 2008). Two types of natural enemies viz., native or exotic are commonly in practice to control aphid population (Fox *et al.*, 2004; Desneux *et al.*, 2006). However, aphids are controlled by natural enemies, when they are at low density. When aphid density increases to threshold level, to avoid economic loss, insecticide application might be required.

Biological control is the important component within integrated pest management (IPM) programs. It is a powerful pest control option in situations, when chemical control is insufficient, or undesired. Biological control of insect pests has also been applied to pest load of ornamental plants (van Lentreten, 2000).

Control management program depends upon several factors such as influence of host plants and temperatures on growth parameters and reproduction rate. Comparison of aphid and parasitoid wasps population growth parameters, reveal the efficiency in controlling the aphid damage (Kersting *et al.*, 1999). Stary (1988) stated that the role of aphid natural enemies is the most important factor responsible for reducing aphid population. Almost 400 species and 60 genera & subgenera of aphid parasitoids have been documented (Lawo *et al.*, 2009). Luo *et al.* (2013) documented almost 500 species of natural enemies in cotton agro ecosystem in China, but few species were examined closely. All these species have significant impact on aphid control and solitary endoparasitoids of aphids. The process of host finding starts with the selection of suitable habitat. The food plant, the host aphid plays an important role, because aphid infested plant release odour and parasitoids are attracted towards this odour. Many species of aphid parasitoids and tritrophic associations were studied throughout the world. Aphid serves as food for several parasitoid and predator species has an important role in food chains within agro ecosystems (Lawo *et al.*, 2009).

**Table-1: Parasitoids for biological control of *Aphis gossypii***

S. No.	Parasitoid Group	Species
1	Entomopathogenic fungi	<i>Neozygites fresenii</i>
2	Anthocorid bugs	<i>Anthocoris</i> spp.
3	Predatory midges	<i>Aphidoletes aphidimyza</i>
4	Aphelinid wasps	<i>Aphelinus gossypii</i>
5	Parasitoid aphidiid wasps	<i>Aphidius colemanior</i>

Keeping in view the above discussion, biological control of cotton aphid is only possible, when the aphid population is low per plant. But if it is more than the threshold level, chemical methods are used to control aphid densities to minimize economic losses.

## CHEMICAL CONTROL AND RESISTANCE TO INSECTICIDES

Cotton aphids problem emerged in the 1930's as a result of frequent insecticide application for controlling cotton pests. Its outbreak occurred following calcium arsenate application for boll weevil (*Anthonomus grandis grandis* Boheman). The cotton aphid emerged as an imperative cotton pest in the late 1980's when most recommended insecticides for its control failed to provide satisfactory results (Hardee *et al.*, 1992). Resistance is an evolutionary adaptation conferred by genes encoding modified receptor proteins or enzymes that detoxify insecticides. By this mechanism, cotton aphid has developed high tolerance against several insecticides viz., organophosphates including dicotophos, oxydemeton-methyl and chlorpyrifos (Rummel *et al.*, 1995). Therefore, indiscriminate application of organophosphates (dicotophos, oxydemeton-methyl and chlorpyrifos) and other insecticides, instead of controlling cotton aphid populations, increases their reproductive potential (Denholm and Devine, 2013).

Cotton aphid resistance to insecticides also has been reported for several other commercially used chemicals such as bifenthrin, pyrethroids, chloronicotiny and cypermethrin (Slosser *et al.*, 2001). For instance in California, repeated applications of pyrethroid to control the lygus bug, (*Lygus hesperus* Knight), caused cotton aphid densities to enhance compared to that in non-treated fields (Godfrey and Keillor, 1999). The rapid life cycle and high reproductive rate enables the cotton aphid to develop resistance to insecticides (Robertson, 2004). However, Intruder tank-mixed with Dyne-amie, Carbine, Centric at 0.031 lb/acre, and Trimax have shown to be highly effective in controlling aphids. William, (2004) stated that Mustang Max alone is ineffective. Insecticides are applied on average 12 to 20 times on each crop field in the Midwest region (Tomquelski *et al.*, 2007). Some frequently used insecticides include:

**Table-2: Major insecticides used in chemical control of *Aphis gossypii***

S. No.	Insecticide	Chemical Class
1	Chlorpyrifos	Organophosphate
2	Bifenthrin	Pyrethroid
3	Quinalphos	Organothiophosphate
4	Indoxacarb	Oxadiazine
5	Methomyl	Carbamate

At present several chemicals appeared as effective controlling agents for cotton aphid. For instance, Vertalec<sup>®</sup> based on *Lecanicillium longisporum* has potential for simultaneous management of cotton aphid (Kim *et al.*, 2010). In Pakistan, Ahmad and Arif (2008) documented impact of several insecticides on *Aphis gossypii*. Generally, cotton aphid has very low resistance to endosulfan, monocrotophos, profenofos, chlorpyrifos, quinalphos, pirimiphos-methyl, carbaryl, methomyl, and a low to moderate resistance to dimethoate, parathion-methyl and thiodicarb. Some of the populations showed very high resistance to parathion-methyl, ethion and thiodicarb. However, no resistance was observed to carbamate aphidicides, furathiocarb and carbosulfan.

Transgenic crops constitute resistance to insect pests, hence required less application of insecticides, in turn minimum loss of environmental health (Naranjo, 2005; Cattaneo *et al.*, 2006). During the first ten years of transgenic cotton cultivation (1996 to 2006), a significant reduction in insecticide application was documented (Brookes and Barfoot, 2008). It is possible that the *Bt* technology has an indirect, positive effect on the *A. gossypii*, because less insecticides are applied as chemical control (Liu *et al.*, 2005). Yet some researchers are not satisfied with transgenic crops, for instance, Sisterson *et al.* (2004) reported that no significant difference is observed in mortality among aphid fed transgenic cotton. Furthermore, Sujii *et al.* (2008) documented that aphid life cycle, survival, fecundity and colony formation is not affected by transgenic crops. Very interestingly, Deng *et al.* (2003) observed more population of aphid on *Bt* cotton compared to conventional cotton. Cotton aphid's resistance to commercially used insecticides has forced IPM managers to develop new chemical control strategies to get better results.

### CULTURAL CONTROL OF COTTON APHIDS

Cultural controls embody an array of potential pest-control tactics, ranging from initial cultivar selection to a sequence of agronomic practices starting before planting and ending after harvest. Many of these strategies are singularly effective against one or more cotton insect pests, and may become particularly potent when used in conjunction with other cultural practices in an organized community-wide pest-management effort (Summy and King, 1992).

Fertilization is the process of adding fertilizers to plants. It is most important procedure in crop management and play key role in increasing crop yield. To promote crop production some macro elements such as Nitrogen (N), Phosphorus (P) and Potassium (K) were extensively applied. More and more research revealed that a lot of nitrate fertilizers applied by farmers to increase nitrate and soluble acids content in plants (Mengel and Kirkby, 2001), also improved the nutritional quality and infestation of phytophagous insects (Bentz *et al.*, 1995). Many studies explained that the rate, type and timing of fertilizer application has potential role on the population density of cotton aphids in cotton agroecosystem. For instance, the concentration of potassium fertilizer significantly reduced cotton aphid population density when nitrogen fertilizer was not used. Aphid population dynamics and density at peak time were obviously affected by the combination of nitrogen and potassium fertilizers at different rates, whereas different population dynamics of aphid were showed among different treatments. Compared with potassium fertilizer used alone, the same or significantly reduced aphid densities were observed in combination treatments of 120 kg/ha potassium with 108 kg/ha and 144 kg/ha nitrogen levels in both years (Ai *et al.*, 2011).



There are many other factors affecting cotton aphid severity in cotton but high nitrogen and water availability levels have shown to enhance aphid growth and development (Slosser *et al.*, 2001). Cotton aphid management should have the effect of combination of nitrogen application rate and water use and should not be ignored in its management. Rummel *et al.* (1995) and Parajulee *et al.* (2003) stated that cotton aphid infestation is affected by plant stand density. It is very difficult to expect the potential density of aphid populations in the field because less knowledge is available about aphid population growth parameters. Parajulee *et al.* (2003) stated that no accurate method is available of predicting cotton aphid population

## CONCLUSION

Cotton aphid *Aphis gossypii* Glover has harmed cotton crop resulting in low yield and thus economic loss to agribusiness. Multiple control techniques viz; biological, chemical and cultural controls have proven as remedy against this notorious pest. However, development of resistance to insecticides as well as the potential threat tossed by these chemicals to human and animal health favours the biological control of *Aphis gossypii*. The sustenance of environment and human health requires discovery of effective biological control strategies and less use of potentially harmful chemical and cultural control.

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