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YIELD DECLINING TREND OF COTTON IN PAKISTAN: DIFFERENT AGRONOMIC AND BIOLOGICAL APPROACHES FOR CONTROL OF COTTON MEALY BUG (*Phenacoccus solenopsis*)

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During the last few years, the production of cotton crop declined sharply due to unfavorable environmental conditions and attack of several insects such as cotton mealy bug (*Phenacoccus solenopsis*). It is a very troublesome insect and causes severe damage to the cotton crop. Its outbreak habit and great variance in biology makes it more noxious. Entomologists are striving hard to develop an effective method for its control. However, several agronomic approaches can be employed to overcome this problem like clean cultivation (to destroy alternate host weeds), use of acid delinted seed, site recommended varieties, growing of alternate host crops (*Cajanus cajan*, *Pennisetum glaucum* and *Zea mays*) and regular pest scouting. Entomologists have also developed some botanical and biological methods to control its population. Neem (*Azadirachta indica* L.) seed extract @ 50ml/L and its seed oil @ 5ml/L are effectively used to control the population of cotton mealy bug. This is an eco-friendly method and does not have any consequence for the environment. Moreover, fish oil along with neem extract (10ml/L) can also be sprayed for controlling its population. Some organism like *Cryptolaemus montrouzeiri*, *Aenasius bambawalei* and *Cryptolaemus montrouzeiri* are also being used as biological control agents. Some bio-insecticides such as *Verticillium lecanii* and *Beauveria bassiana* (@10gm/mL) are effectively sprayed during the month of August-October at the rate of 10gm/mL for the control of its population.

Keywords: Cash Crop, Cotton yield, Cotton mealy bug, Biological control.

INTRODUCTION

Cotton *(Gossypium hirsutum* L.) is an important high value cash crop of Pakistan and plays a major role in the national economy by contributing 21% in total GDP (gross domestic product). Cotton crop is a multipurpose crop and provides raw material for many industries such as textile and oil industry. Pakistan earns a major part of foreign exchange by the export of cotton and 80% of total country's oil requirements are fulfilled by cotton oil (Agha, 1994). In Pakistan, approximately 5000 oil removal units, 1221 ginning plants, 458 revolving mills are working and providing 35% of total industrial labor (Economic Survey of Pakistan, 2004-05). Cotton crop is cultivated on 2699 thousands of ha area (Economic Survey of Pakistan, 2017-18). Pakistan stands 4th in the production of cotton, but unfortunately per acre yield is very low due to the many factors among which the insect attack remains a major reason. In Pakistan, cotton is facing a major decline in production during the last few decades due to increased prevalence of sucking pests and subsequently the huge costs spent on their control using pesticides (Dutt, 2007; Khatry, 2008; Khan, 2009) and Abro *et al.* (2004) recorded 30-35% reduction in yield due to severe attack of insects (Fig. 1). *Bemisia tabaci* Genn. (White fly), *Thrips tabaci Lind* (thrips) and *Amrasca biguttula* Ishida (Jassid) are the most important insects of cotton crop and held responsible for 40-50% yield in its reduction (Naqvi, 1976). Cotton mealy bug created havoc in Pakistan and caused losses to the tune of 0.2 million bales during 2007 and caused 30-60% reduction in yield of cotton during 2005-2009 in India and Pakistan (Dhawan *et al.*, 2007; Muhammad, 2007; Jhala *et al.*, 2008; Nagrare *et al.*, 2009).

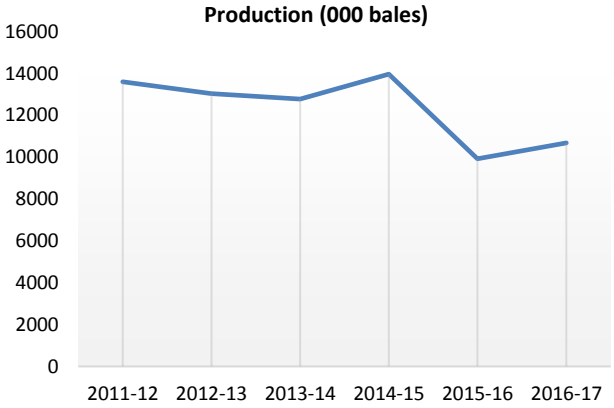

Figure 1. Cotton production in Pakistan (Pakistan Bureau of Statistics, 2016-17).

The mode of damage caused by cotton mealy bug is well understood. It also releases the poisonous material and causes

coiling and drying of leaves. Mealy bugs also attacks on lower plant parts, particularly at collar region of the cotton plant. Mealy bug has a widespread geographical dispersion with its basis in Central America (Fuchus *et al.,* 1991; Williams and Granara de Willink, 1992), Caribbean (Ben-Dov, 1994), Chile (Larrain, 2002), and Brazil (Mark and Gullan, 2005). Its attack was also recorded on the ornamental plants, weeds and other vegetable crops in the Eastern Sri Lanka (Prishanthini and Laxmi, 2009) and on the cotton crop in China (Wang *et al.,* 2009; Wu and Zhang, 2009).

In Indo-Pak region, the population of *Phenacoccus* spp. is on rise and has lead to serious injury to the cotton crop (Dhawan *et al.,* 2007; Dharajyoti *et al.,* 2008; Mahmood, 2011). Mainly mealy bug attacks on buds, branches, flower, bolls, foliage part and the main stem, and result in complete wilting of the plant. Initial symptoms of its attack include a whitish cottony appearance on the upper portion of central stem or the main branches associated with reduced growth, and activity of ants increased due to the honey condensation secreted by the mealy bug (Saini and Ram, 2008). This pest is also reported to infest many other host plants such as *Bombax ceiba*, *Withania somnifera* and *Cestrum nocturnum* (Arif *et al.,* 2009).

An integrated approach should be adopted to control the population of mealy bug. This may include the removal and the subsequent destruction of the diseased plants, eradication of its alternate hosts, efficient water and fertilizer application. Different pesticides can also be used for the control mealy bug, and Larrain (2002) discussed that chlorpyrifos and carbofuran effectively controlled the mealy bug. Different insecticide are also be used for the control of cotton mealy bug and results illustrated that recommended doses of different insecticides such as Profenofos, Methomyl and Chlorpyrifos provided best results at the field conditions (Shafqat *et al.,* 2007). As biological control nymphal endoparasitiod and *Aenasius bambawalei* effectively used for Cotton mealy bug (Ram *et al.,* 2009). Three type of wasps such as *Chalcaspis arizonensis, Cheiloneurus spp.,* and *Aprostocetus minutes* were also used to reduce the population of mealy bug on cotton (Fuchus *et al.,* 1991). In biological control some endoparasite species such as *Aenasius spp. and P. solenopsis* also helpful for mealy bug control (Sharma, 2007; Tanwar *et al.,* 2008). Hayat (2009) concluded from his study that new parasitoid species (*Aenasius bambawalei*) are the very help for control the mealy bug by biologically. The studies on biological control of cotton mealy bug was not on precised manner so, present study was conducted to determine the different biological method for control of cotton mealy bug.

***Epidemiology (Description*)**: *Phenacoccus* spp. as bisexual, produce multiple peers in a year and is famous for its morphology of its adult female. Adult female is covered with waxy powdery secretions, with six pairs of crosswise dusky bands present on the thorax. A sequence of the waxy filament prolonged from throughout the border of the body with the couple of the final filament protracted. The ovisac of cotton mealy bug is drawn up from fluffy, fine-textured wax strings (Mckenzie, 1967; Kosztarab, 1996). Length and width of adult female cotton mealy bug is 2-5 mm and 2-4 mm respectively and produce up to 600 eggs (Lu *et al.,* 2008).

Female of this bisexual species has ability to produce a large number of pale yellow eggs (150-600) in white waxy ovisac. The first instar crawlers disperse and settle on the leaves primarily. After that infestation these crawler can also settle down on the stems, petioles of the leaf, brackets of the fruiting cotton plants (Ben-Dov, 2010). Development of the cotton mealy bug mainly depends upon the temperature. It can take 25-30 days to develop an adult from the crawler (Sharma, 2007).

***Favorable condition for pest development*:** High temperature and long sunshine hours have a positive impact on the growth of *P. solenopsis*, while high RH (relative humidity) and rainfall poses negative impact of mealy bug population (Suresh *et al.,* 2008). According to Ali *et al.* (2012) an experiment was conducted to evaluate the pest biology at different temperatures and RH. Results of this study revealed that the incubation period was significantly reduced from 32 to 0 hour with the increase the temperature from 20 to 40°C. Significant impact of the temperature was recorded on the fertility of the female at the adult stage. The adult life of both male and female is prolonged at the lower temperature, and the high temperature shortened the adult stage. Optimum temperature and RH for the growth and development of the mealy bug pest is 32°C and 55+5%, respectively (Ali *et al.,* 2012). Cotton mealy bug can survive with temperature ranging from 0-45°C throughout the year (Sharma, 2007) and males mostly produced at 30-36°C (Prasad *et al.,* 2012). Mealy bug is a poikilothermic organism, and temperature is considered as the most dominant abiotic factor, which influences the distribution, survival, behavior, development and reproduction of mealybug (Bale *et al.,* 2002). The data about the ability of cotton mealybug (*P. solenopsis*) to reproduce and develop at 20-35°C and 60±5 to 75±5% RH may help in predicting abundance and distribution of mealybug in different ecological regions of Pakistan (Hameed *et al.,* 2012). According to the data, obtained from Pakistan Meteorological Department (PMD), these temperature ranges are recorded in the month of October (Fig. 2), so this month (October) is very suitable for insecticide applications and release of natural enemies to achieve effective pest control.

***Host range*:** *Phenacoccus solenopsis* has a wide range of alternate host plants ranging from herb weeds, woody trees and many crop species. The infestation of *P. solenopsis* has been recorded on 154 different plants and tress species, on 20 different agronomic field crops, 64 herb weeds, 45 horticultural ornamental plants, and 25 shrubs and tree species (Arif*et al.,* 2009). Furthermore, Ben-Dov (2009) recorded his infestation on 55 different families. Majority of host plants

belongs to the family Cucurbitaceae, Amaranthaceae, Euphorbiaceae, Asteraceae, Solanaceae and Malvaceae (Arif *et al.*, 2009). Economic loss is observed on the Cotton (*Gossypium* Spp.), Brinjal (*Solanum melongena*), Okra (*Abelmoschus esculentus*), Tomato (*Solanum lycopersicum*), Sesame (*Sesamum indicum*), Sunflower (*Helianthus* Spp.) and on China rose (Sharma *et al.*, 2007; Arif *et al.*, 2009; Jagadish *et al.*, 2009).

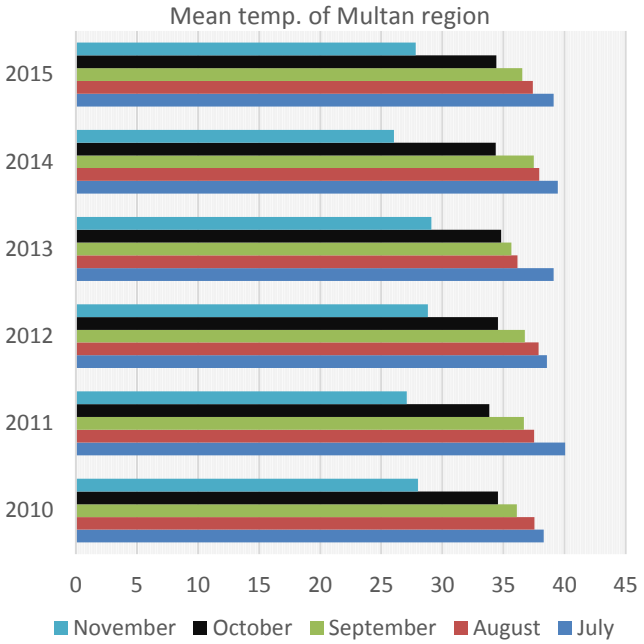

Figure 2. Mean monthly temperature of Multan region (2010-2015) during the growing month of cotton (July to November). Data taken from *Pakistan* Meteorological department, Islamabad.

***Mode of attack, nutrition and impact on yield*:** *Phenacoccus solenopsis* is a polyphagous sucking insect with incomplete transformation and have a wide range of hosts. It has a waxy defensive covering on the abaxial side which pawns the potential death factors. Mealy bug damage the plant by sucking of leaves and twigs, sooty mould appears on leaves and twisted twigs, young plants die and elder plants become weakened (Hameed *et al.*, 2012). It has high reproductive rate and have capability of overwintering, which assist the insect pest to fetching a serious pest for the important crops. It attacks the host plant by lapping cell sap in plant phloem tissues (Zhang *et al.*, 2004). It conceals the honeydew which produce grimy mold on the outward of the plant leaves, reduce the photosynthesis process, and resulting in the death of the cotton plant tissues (Dhawan *et al.*, 1980). Damage potential of cotton mealy bug insect pest stated by various researchers which is shown in the Table 1.

Table 1. Cotton mealy bug (*Phenacoccus solenopsis*) effects on cotton yield.

Authors	Study traits	Effects
Kakakhel (2007); Sahito *et al.* (2011)	Mealy bug insect and cotton yield in Punjab, Pakistan	Mealy bug reduced the cotton yield by 14%, 12% and 40% in 2005, 2006 and 2007, respectively.
Naqvi and Nausheen (2008)	Mealybug and cotton production in Pakistan.	*P. solenopsis* reduce the cotton yield by 20% during 2007-2008.

***Symptoms*:** Mealy bug extract the cell sap from the leaves and leaves turn yellow, become folded and deformed, which leads to reduction in the cotton plant vigor, drop of the leaves and fruits from stem and ultimately demise the potential of the plants. Phloem suckling affects the budding part of plant (Dhawan *et al.*, 2009; Jagadish *et al.*, 2009) and reduces the size of flower and final yield. Infested fields of cotton mealy bug shows different type of symptoms, leaves of the cotton plants turns to yellow, necrosis of leaves, wilting and anomalous leaf fall at lateral stages. Irregular patterns, discoloration and grimy mold are formed on the fruits as a result premature fruit drops. Root, stem and buds of the cotton crop become impaired and root system reduces its size under mealy bug infestation. Nagrare *et al.* (2009) discus that *P. solenopsis* is mainly found colonizing young growth including leaves, twigs and fruiting bodies. Severely infested plant stunted their growth, covered with sooty mould and result in partial opening (Fig. 3).

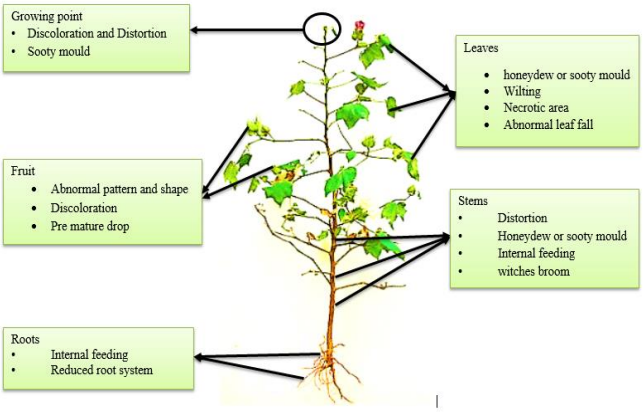

Figure 3. Symptoms of mealy bug attack.

***Control strategies*:** The supervision of the *Phenacoccus solenopsis* pest is very important to override the insect pest population of cotton mealy bug below the threshold level. Applying the measurement strategies on larval stage is best option to control the mealy bug population (Kumar *et al.*, 2013). Commonly, chemical and biological approaches are used to control the population of mealy bug under field conditions. The operational flexibility and sequence of the growth stages allow the mealy bug to pawn single type or any other type of control strategies effectively. So IPM is the main strategy in contradiction of the mealy bug.

***Allelopathic control*:** Different types of Plant extracts such as *Azadirachta indica* seed extract are used as insecticide, to control the many type of harmful insects (Nagrare *et al.*, 2011). Some other plants extract such as tobacco (*Nicotiana tabacum*), dhatoora (*Datura stramonium*) and *Malia azadirachta* are also effectively used for control various kind of insect (Narwal *et al.*, 1997). Plant based insecticides are environmentally compatible and harmless for human, animal health and provide favorable conditions for soil microbes (Nabil and Wakeil, 2013). Plant extracts are decomposable and less poisonous to a wide range of life. All these leaves extract have certain degree of repellent effects against *P. solenopsis* under laboratory conditions, however further research are needed before their application on field conditions or large scale (Table 2).

Table 2. Different types of plant extract against mealy bug pest (*Phenacoccus solenopsis*).

Plant extracts	References
Azadiracta indica oil and seed extract, *Nicotiana tabacum* and *Allium sativum* extract	Arain (2009); Lanjar *et al.* (2015)
Azadiracta indica oil extract @300ppm (0.5ml/l), and	Gowda *et al.* (2013)
Calotropis sp., Datura stramonium, Eucalyptus camaldulensis and *Azadiracta indica*	Lanjar *et al.* (2015)
Ficushispida, Lantana sp., Swietia chratam, Azadiracta indica Aegle marmelos, Holde-hurhuri Cleomp viscosa and *Targetes erecta* and seeds *Swietenia mahagoni*	Azad *et al.* (2012)
Azadirachta indica; Ocimum sanctu; Parthenium hysterophorus	Naik and Naik, (2012; 2015).
Neem (*Azadirachta indica*) oil extract	Suresh *et al.* (2010); Mamoon-ur-Rashid et al. (2011)
Rosales: Rosaceae; Myrtales: Myrtaceae, Magnoliids: Annonaceae, Asterales: Asteraceae Asterales: Asteraceae.	Roonjho, *et al.* (2015)
Azadirachta indica, Pongamia pinnata, Madhuca longifolia and only leaf extracts of *Lantana camara, Adathoda vasica*.	Thinnaluri *et al.* (2014)

***Biological control*:** Various natural enemies of *P. solenopsis* has been stated from numerous researchers from different part of the world (Table 3). A majority of the researcher has defined the destructive potential of various hunters and parasitoids. It is stated that the biological control procedures are harmless to host crops. The thoughtful eruptions of *P. solenopsis* results in the absence of their natural enemies and classical biological control has been considered as the most suitable method for the supervision of many striking mealy bug species in various parts of the world (Dhaliwal *et al.*, 2010; Shah *et al.*, 2015).

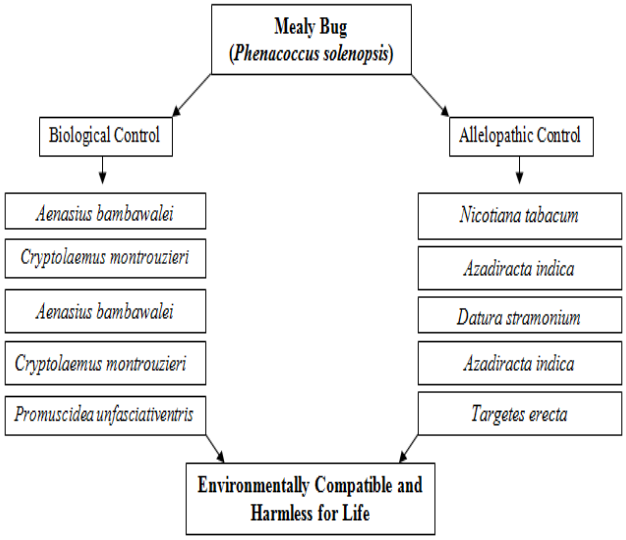

Figure 4. Biological and allelopathic control of Mealy bug.

***Conclusions and recommendations*:** Under field conditions, once the crop is infested by the cotton mealy bug, than turn out to be difficult task to overcome pest. So pre-attack adoptive techniques are very necessary for save the crop from its attack. Furthermore, different allelopathic strategies and other chemicals are effectively used for control the mealy bug population under field conditions. For enhancing the effectiveness of extracted and insecticides, some footstep should be taken. Unnecessary plants should be removed from field because they provide the shelter as alternate host. Severely damaged plants should be buried under the soil, to save the regeneration. Cotton mealy bug insect pest have renaissance thus, should avoid the unnecessary use of the chemical pesticides to conserve our ecosystem. Although the chemical control is so far best solution to control it but the researchers should adopt biological technologies like to promote biological control at field level to overcome the problem of cotton mealy bug in Pakistan. Biological control is the best option for control the mealy bug population without any environmental hazards but large concentration required by researcher to promote the biological techniques under field conditions (Figure 4).Due to predicted climate change, in tropics and subtropics *P. solenopsis* is likely to invade many other countries phenology and special based model delineate the risk for *P. solenopsis* invasions and multiplication in various geographical region (Fand *et al.*, 2014). This information may be used to implement strategic management and region-specific risk assessments to restrict the entry in new areas.

Table 3. Different types of organism, used for control the cotton mealy bug.

Authors	Study traits	Effects
Sahito *et al*. (2013)	*Aenasius bambawalei* against cotton mealy bug	*Aenasius bambawalei* sp. provided a natural control for mealy bug on cotton crop.
Solangi *et al*. (2012)	*Cryptolaemus montrouzierimulsant*, and cotton mealy bug under different climatic conditions.	*Cryptolaemus montrouzierimulsant* very efficient against mealy bug but less sensitive under light temperature conditions.
Solangi and Mahmood, (2011)	*Aenasius bambawalei* and mealy bug population especially in Tandojam, Sindh Areas.	*Aenasius bambawalei* show finest biological control against cotton mealy bug in Sindh province.
Tanwar *et al*. (2011)	*Aenasius bambawalei* and *Promuscideaun fasciativentris Girault sp. a*gainst cotton mealy bug	*Aenasius bambawalei* and *Promuscideaun fasciativentris Girault*sp. May effectively used against cotton mealy bug as biological control.
Kaur and Virk, (2011)	*Cryptolaemus montrouzieri* and cotton mealy bug infestation	*Cryptolaemus montrouzieri* provide an effective use against mealy bug, without any harmful effects.
Rashid *et al*. (2012)	*Cryptolaemus montrouzieri* and *Crysoperla carnea* on cotton Mealy bug.	*Cryptolaemus montrouzieri* and *Crysoperla carnea* provide a best biological control for mealy bug without any hazards.
Khuhro *et al*. (2013)	Effects of *Brumus suturalis* on mealy bug under controlled and open field conditions.	*Brumu ssuturalis* as a good prey may use for reduce the population of mealy bug.
Gosalwad *et al*. (2009)	*Cryptolaemus montrouzieri* and mealy bug.	*Cryptolaemus montrouzieri* sp. effectively used for control the mealy bug population.
Solangi *et al*. (2012)	Australian lady bird beetle (*C. montrouzeiri*) against *P. solenopsis*	Australian lady bird beetle effectively used for cotton mealy bug in Pakistan

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