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Management Practices against Cotton Mealybug, *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae)

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ABSTRACT

The influence of different management practices (insecticide, plant extract, homeo chemical & biological control) on the mealybug (*Phenacoccus solenopsis*) infestation was studied to evaluate their potential as a management strategy. Five treatments *viz.* chemical control (Profenofos 50 EC), plant product (Neemosal 0.5% EC), homeo-chemical (Fierce), biological control agent (*Chrysoperla carnea*) and a control plot were tested in three replicates. Profenofos showed the best control against cotton mealybug population. Neemosal and Fierce did not notably lower the mealy bug population while *C. carnea* failed to produce any result. It is suggested that neem based insecticide (Neemosal) and homeo chemical (Fierce) can be applied during initial or low mealybug infestation, however chemical control (profenofos) should remain as the last option during heavy infestations. © 2010 Friends Science Publishers

Key World: Profenofos; Neemosal; Homeo chemicals; *Chrysoperla carnea*; *Phenacoccus solenopsis*

INTRODUCTION

Cotton crop has experienced a new and emerging threat from mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) that has attained the status of a serious pest (Arif *et al.*, 2009). This pest has been reported from 35 localities of various ecological zones of the globe (Ben-Dov *et al.*, 2009) with initial reports from Texas, USA (Fuchs *et al*., 1991). From Pakistan, it has been recorded as a serious pest since 2005 on cultivated cotton *Gosspium hirsutum* in Punjab and Sindh (Abbas *et al.,* 2007; Muhammad, 2007; Hodgson *et al*., 2008). It has also been reported as a serious pest in India (Nagrare *et al*., 2009) and as a potential threat in China (Wang *et al*., 2009). Cotton mealybug is a soft-bodied insect that sucks the cell sap and plays havoc with the crop (Aijun *et al*., 2004). The attacked cotton plants remain stunted and produce fewer bolls of a smaller size; leaves become distorted, yellow and eventually drop off (Dhawan *et al*., 1980; Mark & Gullan, 2005). The insect also produces honey dew resulting in sooty mold growth, which hinders photosynthesis process (Saeed *et al.,* 2007).

Winged males and wingless females of mealybug (*P. solenopsis*) have two and three nymphal instars, respectively (Hodgson *et al*., 2008). Eggs are normally laid in an ovi-sac (McKenzie, 1967; Hodgson *et al.,* 2008). This pest is also suspected as a vector of plant diseases (Culik & Gullan, 2005) and has a wide range of variation in morphological characters, biological adaptations and ecological adjustability (Hodgson *et al*., 2008). It has been recorded from 154 plant species including field crops, vegetables, ornamentals, weeds, bushes and trees (Arif *et al*., 2009; Saini *et al.*, 2009). Most of these belong to the family Malvaceae, Solanaceae, Asteraceae, Euphorbiaceae, Amaranthaceae and Cucurbitaceae, however, the economical damage has been observed on cotton, brinjal, okra, tomato, sesame, sunflower and China rose (Arif *et al*., 2009).

Integrated pest management of mealybug could be the safest and cheapest method of pest control (Ahmad *et al*., 2003). However, the use of insecticides is inevitable to check the mealybug outbreaks as compared to predators and parasitoids (McKenzie, 1967; Joshi *et al*., 2010). Several insecticides belonging to different groups have been documented as effective against cotton mealybug. For example, Suresh *et al*. (2010) recommended a need based application of insecticides like profenofos 50 EC 2 mL/L, chlorpyriphos 20 EC 2 mL/L, dimethaote 2 mL/L, imidacloprid 0.6 mL/L and thiamthoxam 0.6 g/L. Other insecticidal solutions like Buprofezin against nymphal and adult population of bunch infestation (Muthukrishnan *et al.*, 2005) besides insect growth regulators and nicotine based insecticides in some vineyards (Danne *et al*., 2006). Some other non-insecticidal chemical control measures include use of petroleum spray, oils and soap sprays (JainHua, 2003).

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In developed countries, biological control has proved very effective but in developing countries like Pakistan, very little attention has been given on such environment friendly techniques of IPM. Little is known about the biological control of *P. solenopsis* under field conditions. *C. carnea* has been reported as an important predator of long tailed mealybug in green houses and interior plant scapes (Geetha & Swamiappan, 1998).

Keeping in view the hazardous nature of insecticides and incomplete knowledge of biological control against *P. solenopsis*, the current study was planned to evaluate some non-insecticidal options (homeo chemicals, plant extract & biological control) along with well studied profenofos aiming to develop the best package of management practices for mealybug control.

MATERIALS AND METHODS

Study area: The research was conducted at a farmer field in a village (264-GB), Toba Tek Singh, District Faisalabad. The climate of the area is semi-arid with hot summer and cold winter. The mean monthly temperature of the area varies between 20°C and 25°C, with maximum of 35 and 40°C and minimum of 10 and 15°C. The highest maximum temperature of the region, recorded in the past sixty years is 48°C in May and June, while the lowest minimum temperature is -5°C, recorded in January. The mean number of rainy days is 15 to 25 per year, with an average wind speed of zero to three knots (Khan *et al*., 2010). Agro-ecologically it is a mix-zone, where six major crops i.e., rice, wheat, cotton, sugarcane, maize and potato are grown along the year (Hassan *et al.*, 2004).

Experimental material and layout: The cotton var. CIM-496. The seeds were drilled in flat bed at 16th May, 2009 on an area of 1 acre. The experiment was laid out under Randomized Complete Block Design (RCBD) with three replicates. Five treatments were applied in each replication and each treatment was of 2904 square feet. The five treatments included: Control (un-treated), Biological control, Neemosal product, Homeo chemical and chemical control (Profenofos).

On the whole, two major methods were applied for the control of mealybug i.e., biological control and chemical control. *Chrysoperla carnea* was used as biological control agent and three types of chemicals were tested *viz*., homeo chemical (Fierce @ 1 L/100 of water), plant product (Neemosal 0.5% EC @ 1 L/acre) and organophosphate insecticide (Profenofos 50 EC @ 1 L/acre). The chemicals were sprayed with the help of knapsack sprayer. Five applications of chemicals and biological control agent were made throughout the study.

Rearing and release of *Chrysoperla carnea*: Rearing of *C. carnea* was done in biological control laboratory of Agriculture Extension Department at Toba Tek Singh on artificial diet. Augmentation of *C. carnea* was done at egg stage. Grey eggs of *C. carnea* stalked on black paper were stapled with the plant leaves fortnightly in the form of paper strips at the rate of 5-10 eggs/strip (400 eggs per treatment/fortnight).

Data collection and analysis: The chemicals (Profenofos, Nemosal, Homeo chemicals) and biological control agent (*C. carnea*) were applied at 12 days intervals from 2nd week of July to 1st week of October (Fig. 1). Data on mealybug population (per plant) was recorded at weekly intervals. In this way there were two consecutive censuses between two chemical and biological control applications (Fig. 1). Five plants were observed randomly in each treatment for mealybug population. Mealybugs on top five inches of plant terminal portion were counted including stems and leaves irrespective of their life stage. Mean population of cotton mealybug in biological and chemicals control plots, was compared with that of control plot to know their effectiveness. Percent population change (increase or decrease) among treatments in relation to control was calculated by using modified Abbot's formula (Flemings & Ratnakaran 1985) as below:

$$\%\ \text{Population change} = \left\{ 1 - \frac{\text{Post treatment population in treatment}}{\text{Pre treatment population in treatment}} \times \frac{\text{Pre treatment population in control}}{\text{Post treatment population in control}} \right\} \times 100$$

Data on mealybug populations was subjected to statistical analysis using one way Analysis of Variance (ANOVA) and the means were compared by LSD test at P=0.05.

RESULTS

There was significant difference in mealybug population (df = 4.0, f = 4.60, p = 0.027) before the application of chemical and biological controls during 2nd week of July (1st observation) (Fig. 1). First application of chemicals (Profenofos, Neemosal & Homeo chemical) and biological control agent (*C. carnea*) were applied followed at the end of 2nd week of July with data recording on mealybugs after 3 days (mid of 3rd week of July). At this stage, there was a non-significant difference (df = 4.0, F = 1.37, P = 0.316) among the four treatments and control plots. However, the maximum population decrease was observed in chemical control (Table I).

The 3rd observation during 4th week of July revealed significant differences (df = 4.0, F = 4.431, P = 0.030) in mealybug population among treatments. The 2nd application of chemicals and biological control agent was done at the end of 4th week of July (Fig. 1) and the data was recorded during 1st week of August (4th observation). At this stage, there was a significant difference (df = 4.0, F = 8.572, P = 0.004) among the four treatments and control plots however, chemical control showed maximum population decrease followed by biological control. Homeo chemical and Nemosal could not effectively reduce the mealybug population.

Table I: Mean population (per plant) and percent population increase or decrease (%) of cotton mealybug before and after treatment applications

Treatments	1st spray		2nd spray		3rd spray		4th spray		5th spray	
	Before	After*	Before	After*	Before	After*	Before	After*	Before	After*
Biological control	74.50	79.4 a (43.61)	102.70	92.6 ab (14.58)	95.00	108.7 a (-2.85)	108.00	89.6 b (20.07)	106.00	92.9 b (-4.110)
Neemosal	72.93	67.4 a (49.81)	83.93	77.46 bc (11.28)	87.26	82 b (9.94)	95.40	82.06 bc (18.29)	97.53	78.6 c (1.31)
Homeo chemical	98.26	90.8 a (51.50)	93.33	86.93 b (8.25)	102.60	107 a (-0.21)	110.33	91.8 b (21.01)	103.80	89.66 bc (-5.327)
Chemical control	70.20	56.73 a (55.95)	69.26	57.73 c (19.76)	81.73	73.8 b (13.86)	76.40	67.06 c (14.62)	80.86	51.13 d (22.57)
Control	39.60	71.4 a (0.00)	104.66	110.06 a (0.00)	115.26	121.06 a (0.00)	129.93	136.73 a (0.00)	146.66	120.2 a (0.00)

*Figures in parentheses refer to the percent increase or decrease of mealybugs in treatments over control

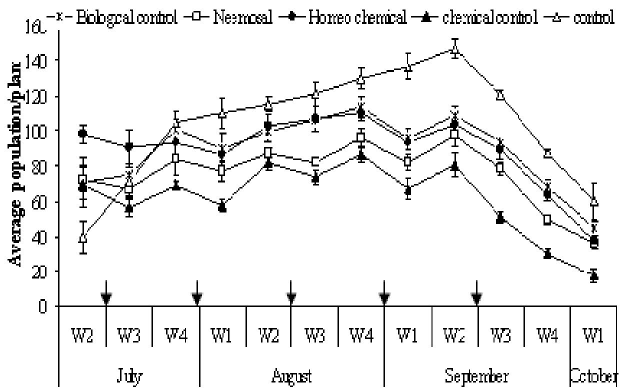
The 5th observation during 2nd week of August revealed significant differences (P<0.01) in mealybug population among the five treatments. The 3rd application of chemicals and biological control agent was done at 2nd week of August (Fig. 1) and the data was recorded during 3rd week of August (6th observation). The 6th observation revealed significant (P<0.01) differences in mealybug population among the five treatments. At this stage, mealybug population decreased only in the plots, where Profenofos and Neemosal were applied. However, in biological control and Homeo chemicals treatments mealybugs increased slightly.

The 7th observation done during 4th week of August showed that there were significant (P < 0.01) differences among mealybug populations of five treatments. The 4th application of chemicals and biological control agent was done at the end of 4th week of August (Fig. 1) followed by 8th observation during 1st week of September. At this stage, there were significant (P<0.01) differences among the four treatments and control plots. Contrary to the previous observations, the biological control and homeo chemical plots proved to be the best towards lowering the mealybug population.

The 9th observation taken during 2nd week of September revealed a significant (P<0.01) difference in mealybug population among the five treatments. The last (5th) application of chemicals and biological control agent was done at the end of 2nd week of September and the 10th observation done during 3rd week of September showed significant (P<0.01) differences for mealybug population among the five treatments. At this stage, the population decrease was observed only in chemical control plots, while other three treatments proved ineffective.

The seasonal dynamic pattern of control plot revealed a sharp increase in mealybug population between 2nd and 4th week of July, where population increase was from 39.60±9.59 to 104.67±6.87 individuals/plant. Afterwards a slow but continuous increase in population was evident until the 2nd week of September; the time when the maximum population (146.67 ± 5.48 individuals/plant) was observed. Beyond this stage, a sharp decline in mealybug population

Fig. 1: Comparison of mealybug populations in different treatments during crop season (Mean±SE). The arrows indicate the timings of application of chemicals and biological control agent and "W" represents week



was observed with a population of 60.33±10 individuals/plant during 1st week of October.

The percent population change obtained through modified Abbot's formula revealed that population change in Neemosal and chemical control plots was always positive (decreasing) whereas a couple of negative trends (increasing) were observed in Homeo chemical and biological control plots after 3rd and 5th sprays. Comparison of seasonal average population of mealybugs among the five treatments indicated best control offered by Profenofos followed by Neemosal and homeo chemical. *C. carnea* did not prove to be efficient towards lowering the mealybug population (Fig. 2).

The average temperature fluctuated between 23°C to 35°C and relative humidity varied between 39% and 65% throughout the study period (Fig. 3). Mealybug population was negatively related with the temperature through different observation weeks (Y = 134.11 -1.02X, R^2=0.014, P=0.711) (Fig. 4) and there was a positive relationship with relative humidity (Y = 58.00 + 0.91X, R^2=0.051, P=0.478) (Fig. 5). However, influence of both the weather factors was statistically insignificant.

Fig. 2: Average temperature °C and relative humidity % across different observation dates at District Toba Tek Singh during 2009

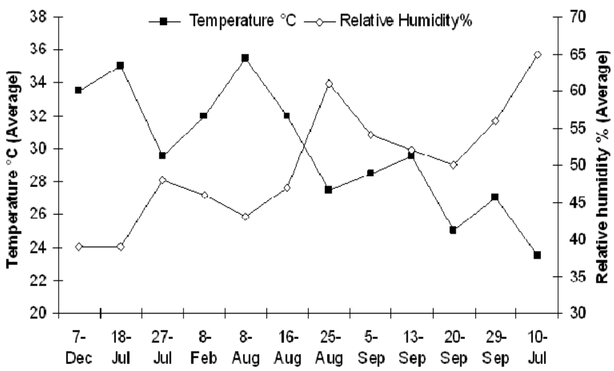


Fig. 3: Comparison of seasonal means of mealybug populations in different treatments (2nd week of July to 1st week of Oct.) (Mean±SE)

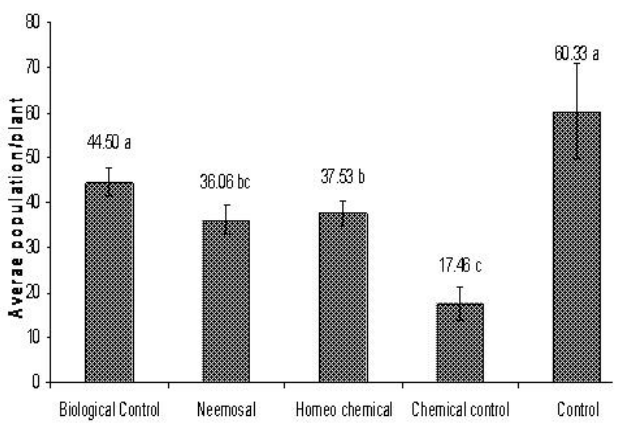
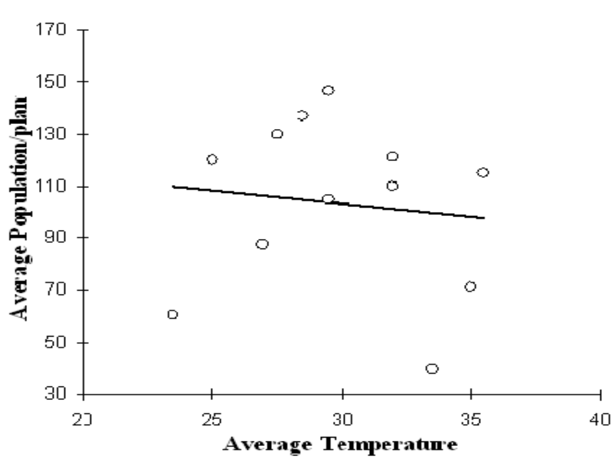


Fig. 4: Relationship between average temperature and average population of cotton mealybug at Toba Tek Singh during July to October, 2009 in control plots. The regression equation is "Average Population = 134.11 -1.02*Average Temperature", R^2=0.014, P=0.711



DISCUSSION

The population of mealybug was not similar statistically before the application of insecticides and biological control agent during 2nd week of July. This is a usual problem faced in such kind of studies, where crop is grown under natural field conditions and natural infestation of insects is accounted for (Hanchinal *et al*., 2009). To overcome this problem in this study, a transformed Abbot formula (Flemings & Ratnakaran, 1985) was used in which percent mortality was predicted out of the average populations amongst pre and post treated and control plots.

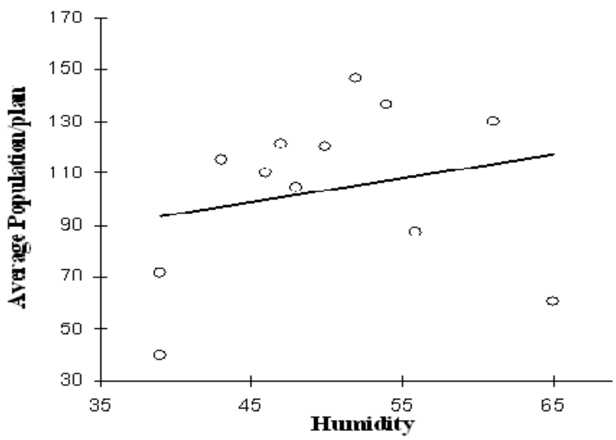
The results showed that Profenofos (50 EC) effectively controlled cotton mealybug (*P. solenopsis*) and had lowest population over other treatments during all the observation dates throughout the crop season. Organophosphates have already been reported to be the best for mealybug control e.g., methomyl, chlorpyrifos, methidathion and profenofos (Saeed *et al*., 2007; Aheer *et al*., 2009; Suresh *et al*., 2010) along with some other insecticides belonging to synthetic Pyrethroid group e.g., Mustang 380 EC (ethion + zeta Cypermethrin) and bifenthrin.

Organophosphate insecticides have also been documented as effective control measures against other mealybug species i.e., citrus root mealybug *Rhizoecus falcifer* (Huang *et al*., 1983). Furness (1977) reported aminocarb and methomyl as toxic and effective towards dense infestation of the *Pseudococcus longispinus* (Targioni-Tozzetti) (Hemiptera: Coccidae) on citrus. Likewise, the root mealybug (*Paraputo* spp.) and spherical (*Nipaecoccus viridis*) mealybug were effectively controlled by chlorpyrifos (Bekele, 2001; Gross *et al*., 2001).

The results revealed that the plant based insecticide (Neemosal 0.5% EC; 0.5% azadirachtin) was the next best control strategy after insecticidal control. Azadirachtin (neem oil) is structurally similar to insect hormones called "ecdysones", which controls the process of metamorphosis as the insects pass from larva to pupa and then adult (Johnson, 2009). The Neem based insecticides are considered as safest for human beings and beneficial insects due to its lesser residual toxicity (Caboni *et al*., 2006). Neem derived insecticides have been found to be striking and economical in controlling major cotton pests (Hasan *et al.*, 1996; Gahukar, 2000). Neem products act both as systemic and as contact poisons and their effects are antifeedant, toxicological, repellent, sterility inducing or insect growth inhibiting. Furthermore, it appears to be environmentally safe and have the potential to be adopted on commercial scale, together with other control measures in order to devise a low cost management strategy (Gahukar, 2000).

Besides Neem, some other common plant species have also been tested controlling insect pests of different crops significantly. For example, extracts of some locally available plant materials (*Aegle marmelos, Calotropis*

Fig. 5: Relationship between average humidity and average population of cotton mealybug at Toba Tek Singh during July to October, 2009 in control plots. The regression equation is "Average Population = 58.00 + 0.91*Humidity", R^2=0.051, P=0.478



gigantea & *Tagetes erecta*) helped in decreasing the mealybug population (Dinesh *et al*., 2003). Some combinations of plant extracts with other organic substances have also been tested for their efficacy against mealybugs. Sunitha *et al*. (2009) characterized azadirachtin and garlic chilli extracts as the most effective in reducing the mealybug infestation. Currently the trend in botanical pesticides is shifting towards propriety botanical formulations e.g., 'Universal biopesticide' formulation containing *Aloe vera*, *Lantana camara*, *Calotropis gigantea*, *Azadirachta indica* and *Vitex negundo* and garlic are effective against the mealybug (Dinesh *et al*., 2003).

The results showed that the biological control agent (*C. carnea*) did not significantly control cotton mealybug. The efficiency of the biological control agents is determined by several biotic and abiotic factors (Mohyuddin *et al.*, 1997). The poor control of mealybug by *C. carnea* in this study might also be due to their insufficient releases i.e., over all 3000 eggs were introduced per biological control treatment in this study. Pawar (1991) recommended release of *Chrysoperla* sp. at the rate of one lakh per hectare thrice at fortnight intervals for controlling sucking pests of cotton, which is 63% higher than the present study. The augmentative stage of natural enemies also matters in its efficacy. We introduced the *C. carnea* eggs, while several other studies have used larval and adult releases (Iqbal *et al*., 2008). The efficiency of releases at different life stages of *C. carnea* needs to be critically judged particularly in cotton agro-ecosystem however, Hoddle and Robinson (2004) could not see any significant difference between egg and larval releases of *C. carnea* in California avocado orchards.

In conclusion, it is suggested that neem based insecticide (Neemosal) and homeo chemical (Fierce) can be applied during initial or lower mealybug infestations, while heavy infestations require the use of chemical control (profenofos). The validity of this experimentally derived recommendation needs further profundity of the management approaches by integrating insecticides, plant extracts and biological control for evolving effective and efficient strategies of cotton mealybug suppression.

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