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SURVEY OF MEALYBUG, *PHENACOCCUS SOLENOPSIS* (TINSLEY) AND EFFECT OF BIO-ECOLOGICAL FACTORS ON ITS POPULATION IN DIFFERENT ECOLOGICAL ZONES OF SINDH

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ABSTRACT

The study on the effects of bioloigical factors on the population of mealybug was conducted in different locations of Khairpur (Mir's), Naushahro Feroze, Sanghar, Matiari, Hyderabad, Mirpurkhas, and Tando Allahyar districts throughout season at fortnightly intervals. Results indicated a new mealybug specie *Phenacoccus solenopsis* Tinsely was identified from the British Natural History Museum through help of CABI (South Asia) which appeared on cotton two months after sowing and remained till harvest of the crop in all Farms. The pest infestation was more severe during 2007 compared with 2008 which may be due to increased parasitization of pest by a hymenopteran parasitoid, *Aenasius bambawalei* Hapat first time recorded in Pakistan during August, 2008 and population development and activity of predators. There was a significant reduction in overall pest population during 2008 compared with 2007 which may be due to a significant overall increase in predator activity in cotton fields throughout study area in 2008. The highest and the lowest pest population 106.21±15.29 and 55.21±18.71 of mealybugs per twig per plant was recorded during 2007 at Mirpurkhas and Tando Allahyar, respectively. However, during 2008, the highest and the lowest population 58.30±12.42 and 18.34±5.32 of mealybugs per twig per plant was recorded from Naushehro Feroze and Tando Allahyar, respectively. The predators population recorded during 2007 was highest at Mirpurkhas 1.73±0.37 per plant and the lowest 0.19±0.08 predators per plant observed from Tando Allahyar. The higher predators activity was recorded during 2008 compared to 2007. The highest predators population was 11.96±2.83 per plant observed at Nashahro Feroze and the lowest 2.29±0.79 per plant found at Tando Allahyar. The predators such as *Coccinella spp., Chrysoperla sp.*, *Geocoris* sp., *Orius sp.* Spiders were found active feeding on mealybug population at all different varieties and farms during both seasons.

Keywords: *Aenasius bambewalei*, cotton, *Phenacoccus solenopsis,* pest infestation, predators

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INTRODUCTION

Cotton, *Gossypium hirsutum* L. is the most important fiber crop of Pakistan and in the world. It is used in textile as well as in oil industries and earns foreign exchange through export in shape of raw cotton, cotton yarn, cloth, garments and other cotton made products. It provides about 80% of national edible oil (Agha, 1994). The cotton provides raw material to 550 textile mills, 1150 ginning factories and 5000 oil mills (Ghani, 1998).

In Pakistan, the eruption of mealybug on cotton and other plants was first recorded at Vehari Agriculture Farm, during 2005. It has now spread throughout the cotton growing areas and is continuously affecting the crop yield. In 2006, it was seen in epidemic form at Multan, Bahawalpur, Vehari and Khanewal. Cotton yield suffered a severe setback due to the attack of this insect (The daily Dawn, 2006). In Sindh, southern winds blow from May to September and the intercropping are very common which might have favoured this pest to infest cotton. Situation in Sindh was even worse than Punjab. Severe infestation of mealybug was recorded first time on an area of about 3000 acres in Kot Ghulam Mohammad, Tando Allahyar, Tandojam, Mirpurkhas and Sanghar district in 2005 and 2006.

The mealybug species are widespread throughout the world. Mealybugs are found outdoors in the warmer climatic zones of India, Pakistan, America, Europe, Africa, and Hawaii. They produce a large amount of honeydew which is responsible for the development of a black fungus commonly known as sooty mold (Gullan and Kosztarab, 1997). Mealybug species have been found on a relatively wide variety of host plants including species of economically important families such as Cucurbitaceae, Fabaceae, Solanaceae and Malvaceae. The *Phenacoccus solenopsis* was first recorded in Brazil, infesting tomato plants was found on common weeds in Manguinhos indicating that mealybug originating from nearby weeds might had infested those crops. The feeding of mealybug may cause leaf yellowing, defoliation, reduced plant growth and in some cases death of plants (Culik and Gullan, 2005).

A similar out break of mealybug on cotton was also recorded at Gujrat, India (Muralidharan and Badaya, 2000). Wale, (2000) described that the level of damage caused by mealybugs on potato is steadily increasing in Adet area. As storage time increases mealybugs increase in large numbers, feeding on the tuber contents by sucking with their stylets and causing the tuber to shrink. The nymphs and adults form colonies mostly at the bases of the sprouts and on the eyes of the tuber. The insect produces a cotton-like mass that covers the tuber and eventually the tuber rots. The level of mealy bug infestation varied greatly with the cultivar in storage, with some showing no sign of damage and others being completely damaged. Different integrated pest management strategies are being tried in affected areas, for control at this pest which includes biological control, physical control, use of resistance varieties as cultural control that offers ecological and economic sustainability of farming systems by reducing both the risk of crop losses and the risk to human health from insecticide use. These

approaches are not only friendly to human health and the environment, but also self-perpetuating. The benefit-cost ratios are correspondingly high (Zeddies *et al*., 2001). Keeping in view the out break of mealybug on cotton crop and use of different controlling strategies as IPM tool "Survey of mealybug, *Phenacoccus solenopsis* (Tinsley) and effect of bio-ecological factors on its population in different ecological zones of Sindh" was conducted so that destruction of cotton crop may be saved in cotton growing areas of Sindh.

MATERIALS AND METHODS

The survey for infestation of *P. solenopsis* on cotton crop was conducted at different locations of Sindh (Figure 1). The studies on survey of cotton mealybug and effect of bio-ecological factors on the population of mealybug in different ecological zones of Sindh, were conducted in seven districts from cultivation till harvest of crop 2007-08. The places selected for the survey are shown in Table 1. Survey was conducted from sowing till harvesting of crop at fortnight intervals. One progressive farmer was selected from each district and study was conducted on his farm. Out of his cotton crop, one acre was selected at random and put under study. Thus, observations on infestation of *P. solenopsis* started one month after sowing of cotton crop. Most infested plants and patches were observed and highlighted with the red cloth ribbon for checking the spreading of mealybug on cotton.

Sampling method of *P. solenopsis* its predators and parasitoid

For taking observation, 25 plants were observed randomly from 5 different locations i.e. five plants from each corner and one from centre, if infested patches were found, those were highlighted for recording mealybug along with predators and parasitoids. As mealybug developed population to out break level and started affecting crop adversely, farmers used pesticides to control the pest population from completely devastating the crop. Therefore, the data were taken from one acre kept free from pesticides to check the population growth of pest and predators, and to encourage parasitoids to establish their population and exert their full potential in population regulation of pest. The plants were thoroughly examined, only adult mealybugs with visible crawlers and predators population were counted. During survey, the infestations at different phenalogical stages were recorded. In the field the distribution of mealybug population was also recorded to observe, whether mealybug is uniformly distributed or in patches and if there was influence of wind, water or weeds, (alternative hosts) etc. so that, the most preferred alternate host plants of mealybug could be exploited for mealybug control in cotton field. The agro-ecosystem/ cropping pattern surrounding cotton and within cotton was also evaluated. The data on effect of climatic factors on the population growth of mealybug in different ecological zones were taken from the nearest Government Meteorological centers working at Tandojam, Mirpurkhas and Sukkur. The different zones have their own Temperature, Relative humidity, wind velocity and rain fall conditions.

When mealybug parasitized mummies were first observed in the second fortnight of August, 2008 from different districts of Sindh, the 25 twigs were cut from the plant along with mealybug and brought into laboratory in petridishes or in transparent plastic bags individually and kept for emergence of parasitoids. When the adult parasitoids emerged, they were counted and percent parasitiztion was worked out. The data on parsitization was collected till harvest of the crop from every farm under study.

Table 1. Details of survey of mealybug, *P. solenopsis* conducted at different locations of Sindh.

Farms	Location / Districts	Date of sowing, 2007	Date of sowing, 2008	Area under cotton cultivation
Sharif farm	Khairpur Mir's	3rd week of May	2nd week of May	3 acres
Zeeshan farm	Naushahro feroze	3rd week of May	4th week of May	10 acres
Hashmi farm	Sanghar	2nd week of May	4th week of April	80 acres
Mansoor Allam Laghari farm	Matiari	4th week of April	1st week of May	5 acres
Agriculture Research Institute, Tandojam	Hyderabad	2nd week of May	4th week of April	1 acre
Bhugio farm	Mirpur Khas	1st week of May	2nd week of May	14 acres
Sahito farm	Tando Allahyar	2nd week of May	last week of April	12 acres

RESULTS AND DISCUSSION

Sharif farm

The mealybug, *P. solenopsis* population remained negligible 0.32±0.16 / twig per plant in the first week of July after that it increased and severely damaged the crop (Table 2). The predators population was low 0.08±0.06 per plant observed in the initial period of crop infestation which remained low with an over all seasonal mean of 0.73±0.19 per plant (Table 3). Regression analysis gave a significant (F= 23.98; P= 0.004; DF= 1, 6; R^2 = 0.828) relationship between pest and predator population. There was no significant effect of temperature (F= 4.15;

P= 0.097; DF= 1, 6; R^2 = 0.454) and relative humidity (F= 0.43; P= 0.541; DF= 1, 6; R^2 = 0.071) on population growth of pest.

Figure 1. Map of Sindh showing locations of study areas

The mealybug started infestation in the last week of May as plant attainted 2-3 leaf stage during 2008. Pest population increased continuously and severely damaged the crop (Table 4). The predators appeared in the crop in the second

fortnight of June and their population was found increasing in the subsequent dates of observations (Table 5). The mealybug parasitoid mummies were observed in the last week of September. There was significant (F= 7.25; P= 0.020; DF =1, 12; R^2 = 0.398) relationship between pest and predators population. There was significant effect of temperature (F= 6.42; P= 0.027; DF= 1, 12; R^2 = 0.369) and insignificant effect of relative humidity (F= 1.90; P= 0.195; DF= 1, 12; R^2 = 0.148) on population growth of pest. There was no significant difference in (T= 1.60; DF= 6; P= 0.161) population development of mealybug during 2007 and 2008. Significantly (T= 2.45; DF= 6; P=0.0495) higher predator population was recorded in cotton crop of 2008 compared with 2007.

Zeeshan farm

As the mealybug appeared in the crop, data were taken in first week of July, latter pest population increased and it severely damaged the crop. The mean mealybug population recorded was 73.91±11.17 / twig per plant). The predator population was negligible with mean of 1.11±0.24 per plant. Regression analysis gave a significant (F= 55.16; P= 0.001; DF= 1, 6; R^2 = 0.917) relationship between pest and predator population. There was no significant effect of temperature (F= 3.35; P= 0.126; DF= 1, 6; R^2 = 0.402) and relative humidity (F= 0.37; P= 0.568; DF= 1, 6; R^2 = 0.061) on population growth of pest. The mealybug established their colonies from the third week of June, 2008 in cotton crop. The mean mealybug population observed was 58.30±12.42 per twig. Where as, the first peak population of predators 17.52±3.30 per plant was observed on last week of July. The seasonal mean population of predators was 11.96±2.83 per plant. The mummified mealybugs were also recorded at this farm in the month of September. There was significant (F= 15.56; P= 0.023; DF= 1, 12; R^2 = 0.586) relationship between pest and predators population. There was no significant effect of temperature (F= 0.00; P= 0.962; DF= 1, 12; R^2 = 0.001) but significant effect of relative humidity (F= 6.42; P= 0.027; DF= 1, 12; R^2= 0.369) on population was growth of pest. Population development of pest was not significantly (T= 1.695; DF= 6; P= 0.142) different during both years of study, where as, predator population was significantly different (T= 2.98; DF= 6; P= 0.025) and more predators population was recorded in 2008.

Hashmi farm

Because of the severe attack of mealybug the grower tried to root out the affected plants to save the others. Where, mealybug population remained higher through out the first season. The pest population continuously kept growing till harvest of the crop. The average seasonal population of pest at this farm was 102.37±20.14 mealybugs per twig. The predator populations could not control the pest population and was found low in numbers with mean of 1.12±0.23 per plant through out the season. Only the *Coccinellid* beetles were higher in population. Regression analysis gave a significant (F= 22.36; P= 0.005; DF= 1, 6; R^2= 0.818) relationship between pest and predator population. There was no significant

effect of temperature (F= 2.08; P= 0.208; DF= 1, 6; R^2 = 0.294) and relative humidity (F= 0.33; P= 0.590; DF= 1, 6; R^2 = 0.062) on population growth of pest.

As plants attainted 3-4 leaf stage during 2008, the mealybug appeared in cotton crop. The first pest population peak 15.36±3.52 per twig was recorded in the last week of June, the second peak 42.32±10.33 in last week of August and the third peak 127.40±20.58 in the last week of October. The predator population was low and started to appear in the last week of May of as 0.16±0.11 per plant that increased to 3.48±0.55 in the last week of August with mean population of 4.75±1.23 per plant. At this farm the mummies were found in the last week of August that reduced the pest populations. There was significant (F=19.30; P= 0.001; DF= 1, 12; R^2 = 0.637) relationship between pest and predators population. There was no significant effect of temperature (F= 0.77; P= 0.399; DF= 1, 12; R^2 = 0.066) but significant effect of relative humidity (F= 4.98; P= 0.047; DF= 1, 12; R^2 = 0.312) on population growth of pest. Significantly (T= 2.72; DF= 6; P= 0.0349) less *P. solenopsis* population was recorded during 2008 compared with 2007, which may be due to increased population and activity of natural enemies.

Mansoor Alam Laghari farm

The mealybug population was recorded when the mealybug appeared in patches in cotton field with 1.88±0.21 mealybugs per twig / plant in the first week of July. Regression analysis gave a significant (F= 24.02; P= 0.004; DF= 1, 6; R^2 = 0.828) relationship between pest and predator population. There was significant effect of temperature (F= 18.75; P= 0.007; DF= 1, 6; R^2 = 0.781) on population growth but insignificant effect of relative humidity (F= 3.69; P= 0.112; DF= 1, 6; R^2 = 0.425) on population growth of mealybug.

During 2008, the mealybug started its appearance with sever infestation of cotton crop. There were 5.52±1.07 mealybugs per twig in third week of May. The seasonal mean mealybug population was 40.00±5.70 per twig. The predators were found appearing in crop in the first fortnight of May and continued their presence throughout the season. There was significant (F= 80.10; P= 0.001; DF= 1, 12; R^2 = 0.871) relationship between pest and predators population. There was no significant effect of temperature (F= 9.29; P= 0.111; DF= 1, 12; R^2 = 0.458) and relative humidity (F= 0.05; P= 0.820; DF= 1, 12; R^2 = 0.005) on population growth of *P. solenopsis*. More natural enemies population and less pest population were recorded in 2008 compared with 2007, however, the differences were insignificant.

Agriculture research institute Tandojam

The pest started its appearance in the first week of July when 1.48±0.21 mealybugs were recorded per twig and the maximum pest population was recorded as 238.40±36.13 per twig in the first fortnight of October. The predator population was negligible from beginning and never provided any significant reduction in pest population. The mean population of predators was 0.69±1.48

per plant. Regression analysis gave a significant (F= 19.60; P= 0.006; DF= 1, 6; R^2 = 0.797) relationship between pest and predator population. There was significant effect of temperature (F= 15.01; P= 0.117; DF= 1, 6; R^2 = 0.751) and relative humidity (F= 3.10; P= 0.138; DF= 1, 6; R^2 = 0.383) on population growth of mealybug.

As mealybug started their colonies in first fortnight of May when 3.44±0.49 mealybugs were observed / twig per plant in 2008. In this year, higher predator population was observed from starting on the cotton crop that was 1.04±0.45 per plant. First peak population 5.64±1.59 was observed on third week of July. For the first time mealybug parasitized mummies were observed in the second week of August. This parasitoid reduced the mealybug population in the first fortnight of November. There was significant (F= 120.20; P= 0.001; DF= 1, 12; R^2 = 0.917) relationship between pest and predators population. There was significant effect of temperature (F= 12.17; P= 0.005; DF= 1, 12; R^2 = 0.526) on pest population but insignificant effect of relative humidity (F= 0.34; P= 0.568; DF= 1, 12; R^2 = 0.031) on population growth of pest. The predators population development during 2008 was significantly (T= 3.48; DF= 6; P= 0.014) more and pest population significantly (T= 2.47; DF= 6; P= 0.049) less compared with 2007.

Bhugio farm

Mealybug population at this farm remained high throughout the cropping season. The mealybug peak population was observed 634.40±113.05 in third week of September and seasonal mean of 106.21±15.29 / twig per plant. The predator population was found low with mean of 1.73±0.34 pre plant. The natural enemies population increased in September with 5.92±1.17 pre plant. Among natural enemies, only *Coccinellid* beetles were in abundance. Regression analysis gave a non significant (F= 3.96; P= 0.103; DF= 1, 6; R^2 = 0.449) relationship between pest and predator population. There was significant effect of temperature (F= 7.50; P= 0.040; DF= 1, 6; R^2 = 0.600) and insignificant effect of relative humidity (F= 6.13; P= 0.056; DF= 1, 6; R^2 = 0.551) on population growth of *P. solenopsis*.

The mealybug population appeared in the third week of June, 2008 in cotton crop. The highest mealybug population was observed 52.72±8.90 per twig in the last week of October. The seasonal average population of pest at this farm was recorded as 20.82±4.13 per twig (Table 4.10). The predators population increased steadily in the cotton crop and peaked in the first fortnight of November 13.72±2.31 per plant. In the last two months the mummified mealybugs were also observed. There was significant (F= 46.30; P= 0.001; DF= 1, 12; R^2 = 0.808) relationship between pest and predators population. There was no significant effect of temperature (F= 1.53; P= 0.242; DF= 1, 12; R^2 = 0.122) and relative humidity (F= 1.19; P= 0.298; DF= 1, 12; R^2 = 0.098) on population growth of pest. Significantly less (T= 3.17; DF= 6; P= 0.019) pest population development took place during 2008 compared with 2007 which may be due to increased natural enemies population in cotton crop.

Sahito farm

The infestation of mealybug was found in low numbers in patches at experimental plot in the last week of June, 2007. The average population counted in the first week of July was 1.80±0.35 / twig per plant. The mealybug population increased and reached at peak 81.40±36.44 / twig per plant in the second week of September. It decreased in the first week of October. The seasonal mean population was 55.21±18.71 / twig per plant. The predator population was found negligible at this farm with mean of 0.19±0.08 per plant. Among natural enemies *Coccinellid* beetles were major group of predators (Table 4.9). Regression analysis gave a significant (F= 11.03; P= 0.021; DF= 1, 6; R^2 = 0.688) relationship between pest and predator population. There was no significant effect of temperature (F= 3.30; P= 0.128; DF= 1, 6; R^2 = 0.397) and relative humidity (F= 0.04; P= 0.848; DF= 1, 6; R^2 = 0.008) on population growth of pest.

During cropping year 2008, when plants attainted 2-3 leaf stage, mealybug was found infesting the crop. The pest continued its population growth and peak population was recorded in the second week of October. The mean mealybug population this year was 18.34±5.32 / twig per plant. There was no significant (F= 0.64; P= 0.44; DF= 1, 12; R^2 = 0.055) relationship between pest and predators population. However, since August 2008, parasitoid, *Aenasius bambewalei* was a major mortality factor against *P. solenopsis* causing 18.79 % parasitization of mealybug at Tando Allahyar, Similarly there was no significant effect of environmental conditions (temperature F= 1.17; P= 0.303; DF= 1, 12; R^2 = 0.096 and R. H %, F= 4.02; P= 0.070; DF= 1, 12; R^2 = 0.268) on population growth of mealybug. Compared with last year increased natural enemies population was recorded this year with a mean population of 2.29±0.79 per plant. The increased natural enemies activity in 2008 had impact on mealylbug population, and less *P. solenopsis* was recorded during 2008, however, the difference in population development was insignificant. Analysis of variance also showed the insignificant difference (F= 0.90; DF= 6, 12; P = 0.412) in the population of *P. solenopsis.* Where as, the predators population observed was significantly (F= 7.30; DF= 6, 12; P= 0.001) different during both years, 2007-2008.

The results of studies show that mealybug infested at all districts of Sindh. However; this was a new kind of mealybug specie that attacks all cotton cultivated varieties in different districts of Sindh. At the time of invasions, the mealybug excretes honeydew on the plant of cotton crop that promote the sooty mould disease that suppress plant growth. The results are in agreement with those of (Arif *et al.,* 2007) who described this kind of cotton mealybug species, *Phenacoccus gossypiphyllou nomen nudum* is a synonym of *Phenacoccus solenopsis*. (Hodgson *et al.,* 2008) who reported mealybug could damage the plant become crinkled and twisted leaves that can condense the flower, buds, bolls growth and finally plant exploited along with shaggy look that may affect the yield. Besides this, ants feed to the honeydew and transfer the mealybugs from plant to plant also reported from cotton growing country like India. Further, this study is agreed with that of (Fuchs *et al.,* 1991) who recorded mealybug infesting

cotton first time in the United States. This devastating polyphagous pest spread rapidly to all other cotton growing areas of the country and has become most damaging pest of cotton and many other economically important plants (Arif *et al*., 2009). No cotton crop field was observed resistant against this vigorous pest during the survey of cotton mealybug in Sindh. Further results agreed with (Sahito *et al*., 2009) who studied the different varieties of cotton crop against mealybug, *P. solenopsis*. Result further revealed that the peaks population started from July-August when temperature and humidity becomes high the biotic and abiotic factors correlate with the pest and predators. Jhala and Bharpoda (2008) and Wang *et al*. (2009) have reported about occurrence and epidemics of *P. solenopsis* on cotton from several countries. Muzammil, *et al*., (2007) and Chandrababu *et al*. (1999) revealed that *C. carnea* larvae and *Brumus saturalis* were found voracious feeders of mealybugs. Many of the predators always showed their co-existence with their hosts in various agro-ecosystems (Shah and Baloch, 1999; Singh *et al*., 2004; Genesoylu and Yalc, 2004).

At all farms predators like *Brumus* spp., *Menochilus* spp., *Orius* spp., *Geocoris* spp., *Chrysoperla* spp., were recorded. Biological control by the use of predator, *Chrysoperla carnea* has gained importance in pest management in Pakistan. The larvae of *C. carnea* have a ferocious appetite for sucking pests of cotton crop and other plant pests (Saminathan and Baskaran, 1999) thus; Nordlund and Correa (1995) studied the correlation between the predator and its prey. Rajeswaran *et al.* (2005) reported the spiders are carnivorous arthropods, consume a large number of preys and do not damage plants. The use of bio pesticides/ botanicals will enhance the spider population in different ecosystems. Whereas the fauna of spider present in cotton ecosystem is classified by (Dhulia and Yadav, 1991).

During the survey, the growers at different farms applied their own techniques to reduce the *P. solenopsis* but all methods went ineffective. Its population reduced when its proper biological control agent naturally occurred during August, 2008, which was a hymenopteran encyrtid parasitoid identified as *Aenasius bambawalei* Hayat. *Aenasius bambawale* was originally described by Hayat (2009). This parasitoid was found in each district of Sindh where *P. solenopsis* established its colony either in cotton crop or on other host-plants. The results agree with the report of (CCRI, 2007). This encyrtid parasitoid has been multiplied and released in cotton belt of the Punjab, Sindh and in Balochistan provinces of Pakistan to control cotton mealybug through different bio-control laboratories established at cotton fields as Natural Fields Enemies Reservoir (NEFR) with the collaboration of CABI, South Asia. It is concluded from the results that pesticides can are not effective in reducing population of mealybug. Parasitoid, *A. bambawalei* was effective in reducing pest population. The results agree with (Imran, *et al.,* 2010) who described the cotton mealybug, *Phenacoccus solenopsis* (Tinsley) parasitoid, *Aenasius bambawalei (*Hayat) recorded for the first time from mummified mealybugs collected in the fields on various weeds and cotton crop from different districts of Punjab, Pakistan.

Table 2. Mealybug, *P. solenopsis* population recorded on cotton at different locations of study area during 2007 (Mean ± SE per twig per plant).

Fort-night	Khairpur (Mir's)	Naushahro feroze	Sanghar	Matiari	Hyderabad	Mirpur Khas	Tando Allahyar
Jul.1	0.32±0.16	0.20±0.13	1.80±0.33	1.88±0.21	1.48±0.21	3.56±0.44	1.80±0.35
Jul.2	0.36±0.20	0.36±0.22	2.80±1.02	2.64±0.64	1.84±0.39	12.20±1.87	5.32±1.54
Aug.1	1.40±0.63	12.16±3.54	58.72±8.36	45.48±8.52	56.24±9.18	73.52±10.99	35.48±6.05
Aug.2	3.68±1.30	15.28±4.25	71.28±18.90	52.44±11.05	43.08±8.88	390.60±61.73	52.28±38.28
Sept.1	84.52±5.92	112.28±13.67	155.72±13.40	138.80±18.43	108.00±18.79	438.80±39.73	71.84±15.43
Sept.2	107.12±8.27	121.88±14.36	178.88±43.31	161.00±20.97	146.80±14.36	634.40±113.05	81.40±36.44
Oct.1	224.32±37.62	255.20±42.04	247.36±55.66	287.60±42.12	238.40±36.13	123.64±21.75	138.36±32.88
Mean	60.25±7.73 bc	73.91±11.17 abc	102.37±20.14 ab	98.55±14.56 abc	85.12±12.56 abc	106.21±15.29 a	55.21±18.71c

Table 3. Mealybug, *P. solenopsis* predator population recorded in cotton at different locations of study area during 2007 (Mean ± SE per plant).

Fort-night	Khairpur (Mir's)	Naushahro Feroze	Sanghar	Matiari	Hyderabad	Mirpur Khas	Tando Allahyar
Jul.1	0.08±0.06	0.16±0.11	0.00±0.00	0.08±0.08	0.00±0.00	0.00±0.00	0.04±0.04
Jul.2	0.12±0.09	0.08±0.06	0.00±0.00	0.00±0.00	0.08±0.06	0.04±0.04	0.00±0.00
Aug.1	0.08±0.08	0.24±0.14	0.20±0.12	0.08±0.08	0.36±0.16	0.16±0.12	0.20±0.14
Aug.2	0.16±0.09	0.20±0.14	0.32±0.21	0.12±0.09	0.36±0.17	0.60±0.20	0.00±0.00
Sept.1	0.96±0.22	1.40±0.36	0.48±0.14	2.20±0.46	0.36±0.16	4.28±0.61	0.40±0.15
Sept.2	1.44±0.35	2.20±0.40	1.72±0.41	2.48±0.74	0.36±0.17	5.92±1.17	0.20±0.10
Oct.1	2.28±0.43	3.52±0.49	5.12±0.73	3.24±0.58	3.28±0.62	1.08±0.26	0.48±0.15
Mean	0.73±0.19 ab	1.11±0.24 ab	1.12±0.23ab	1.17±0.29 ab	0.69±1.48 ab	1.73±0.34 a	0.19±0.08b

Table 4. Mealybug, *P. solenopsis* population recorded on cotton at different locations of study area during 2008 (Mean ± SE per twig per plant).

Fortnight	Khairpur (Mir's)	Naushahro Feroze	Sanghar	Matiari	Hyderabad	Mirpur Khas	Tando Allahyar
May. 1	0.00±0.00	0.00±0.00	1.84±0.42	5.52±1.07	3.44±0.49	0.00±0.00	3.08±0.75
May. 2	7.84±176	0.00±0.00	7.36±1.71	3.96±0.80	5.64±1.40	2.72±0.46	12.36±3.92
Jun.1	3.08±0.54	5.76±1.04	6.92±2.07	8.44±1.68	8.36±1.96	8.84±2.39	9.96±1.51
Jun.2	19.60±6.92	21.16±4.36	15.36±3.52	5.28±1.59	4.24±0.96	7.48±1.59	11.92±3.24
July.1	16.52±5.13	41.52±10.30	13.16±3.07	16.76±4.79	7.48±3.50	15.36±3.01	17.44±4.28
July. 2	29.68±7.61	85.56±15.17	3.24±1.22	11.60±4.54	3.36±0.88	9.16±2.21	29.08±6.59
Aug.1	47.08±10.33	97.32±10.62	17.68±4.54	9.64±3.67	9.08±3.13	17.76±4.32	13.84±4.40
Aug.2	41.72±10.20	87.68±13.28	42.32±10.33	18.36±5.29	15.40±4.78	15.48±4.29	23.64±7.79
Sept.1	76.96±15.55	93.24±16.71	28.08±4.54	53.24±8.51	29.44±10.18	34.64±5.51	21.36±8.50
Sept.2	51.84±9.82	107.12±19.85	54.08±11.86	69.72±9.66	46.24±8.22	23.36±5.56	27.92±8.41
Oct.1	67.48±11.45	81.36±13.05	62.40±11.76	105.84±10.39	64.12±11.24	35.84±6.24	32.60±10.35
Oct.2	65.36±11.31	75.64±13.42	127.40±20.58	127.40±14.27	92.80±9.25	52.72±8.90	19.76±5.49
Nov.1	114.52±9.51	61.48±18.85	84.24±18.45	84.24±7.84	77.72±8.70	47.40±9.22	15.40±3.98
Average	41.67±8.34 b	58.30±12.42 a	35.70±7.24 bc	40.00±5.70b	28.26±4.98bcd	20.83±4.13 cd	18.34±5.32d

Table 5. Mealybug, *P. solenopsis* predator population recorded in cotton at different locations of study area during 2008 (Mean ± SE per plant).

Fortnight	Khairpur (Mir's)	Naushahro Feroze	Sanghar	Matiari	Hyderabad	Mirpur Khas	Tando Allahyar
May.1	0.00±0.00	0.00±0.00	0.00±0.00	2.20±0.64	1.04±0.45	0.00±0.00	0.00±0.00
May.2	1.64±0.68	0.00±0.00	0.16±0.11	2.20±0.57	1.16±0.50	0.00±0.00	1.52±0.68
Jun.1	0.56±0.22	5.44±1.56	0.76±0.36	0.32±0.23	3.68±1.46	0.84±0.36	0.36±0.16
Jun.2	7.32±2.26	7.36±2.18	2.68±0.77	1.68±0.71	2.16±0.67	0.48±0.16	0.12±0.12
Jul.1	5.40±1.61	12.84±2.35	1.92±0.76	5.12±1.37	5.64±1.59	3.84±1.07	0.88±0.44
Jul.2	17.52±3.49	17.52±3.30	1.20±0.30	7.20±2.14	1.36±0.47	0.76±0.27	2.28±0.87
Aug.1	9.72±2.92	9.56±1.90	0.12±0.07	1.64±0.45	4.84±1.17	1.84±0.32	3.64±0.92
Aug.2	7.36±2.69	7.04±1.85	3.48±0.55	4.76±1.31	7.28±1.21	0.56±0.24	0.04±0.04
Sept.1	18.72±4.13	21.48±3.57	5.64±1.11	8.36±1.97	12.72±3.36	3.60±1.25	1.16±0.40
Sept.2	16.24±3.22	19.20±5.82	4.12±1.56	11.48±2.80	17.04±3.14	1.72±0.31	1.48±0.48
Oct.1	20.20±3.49	17.48±3.96	6.76±2.03	19.52±6.77	21.76±3.59	7.68±1.58	4.16±1.94
Oct.2	25.76±3.88	23.76±4.08	12.36±3.47	21.84±6.90	27.52±3.56	9.56±2.24	6.68±2.12
Nov.1	9.12±2.96	13.80±3.42	22.60±4.90	23.96±7.57	37.48±5.17	13.72±2.31	7.44±2.12
Average	11.63±2.47 a	11.96±2.83 a	4.75±1.23 b	8.48±2.57a	11.05±2.03 a	3.43±0.78 b	2.29±0.79 b

CONCLUSION

The results of studies show that mealybug infested at all districts of Sindh. However; this was a new kind of mealybug specie that attacks all cotton cultivated varieties in different districts of Sindh. At the time of invasions, the mealybug excretes honeydew on the plant of cotton crop that promote the sooty mould disease that suppress plant growth. At all farms predators like *Brumus* spp., *Menochilus* spp., *Orius* spp., *Geocoris* spp., *Chrysoperla* spp., were recorded. Biological control by the use of predator, *Chrysoperla carnea* has gained importance in pest management in Pakistan. During the survey, the growers at different farms applied their own techniques to reduce the *P. solenopsis* but all methods went ineffective. Its population reduced when its proper biological control agent naturally occurred which was a hymenopteran encyrtid parasitoid identified as *Aenasius bambawalei* Hayat.

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