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Population dynamics of cotton mealybug, *Phenacoccus solepnosis* Tinsely in three talukas of district Sanghar (Sindh)

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Abstract
The cotton mealybug (CMB), *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) is an invasive pest species that has appeared on a large scale few years back. Considering lack of studies in population dynamic of CMB, this study was designed in three taluka of district Sanghar. In field survey, the highest CMB mean population of 99.8±7.8 per plant twig was observed from Shadadpur. Throughout the cotton growing season, highest CMB mean population of 222.3±22.8 was observed in second fortnight visit of September. The results regarding the population dynamics of *P. solepnosis* showed comparatively similar trend in all taluka. The significant effect of environmental factors on CMB population was observed through correlation however, there was no effect of relative humidity on the CMB population in all talukas. The maximum damage percentage of cotton crop was observed at first fortnight visit of October and such results were remain constant until second fortnight visit in all taluka.

Keywords: Cotton mealy bug, population dynamics, damage percentage, district Sanghar.

1. Introduction
The mealybugs are mostly polyphagous insects, affecting huge number of economically importance in field and horticultural crops including ornamentals [29]. They reproduce sexually as well as parthenogenesis. More than 160 mealybug species have been identified as pests worldwide and most of them are invasive species [18] and have short period of 30 days life cycle in tropical areas [6]. They are sucking insect pests and often observed in high numbers with aggressive population trend. Mealybugs do not only destroy the host plant by depleting the plant sap but they are also responsible for transmitting viral diseases [4]. Furthermore, their excreted honeydew on plant surfaces provides medium for growth of black sooty mold [6] which also disturb the photosynthesis process of plant [33]
They have ability to build populations within shoots and apexes and become difficult to control with foliar application of pesticide because of having waxy secretions on their body surface. Mostly mealybugs are not causing serious problems in their countries of origin because endemic parasitoids and predators suppress the population naturally. The serious outbreaks often occur when mealybugs get introduced in to new locations in the absence of their natural enemies [8, 18]. Therefore, classical biological control has been identified as the best option to manage many exotic mealybug species in different parts of the world [5, 17, 20, 23, 24, 28].

Few years back, an apparently un-described species of Genus *Phenacoccus* (Sternorrhyncha: Coccoidea: Pseudococcidae) was found to be a serious pest of cotton in Punjab and Sindh provinces of Pakistan [1]. The damage infestation of CMB was higher in Sindh as compare to Punjab [25] which caused high economic impact of this pest as a major problem in the country. Cotton crop has been reported to attack by number insect pests, about150 insect species have been associated with cotton crop but there were no any potential previous occurrence of *P. solenopsis* on cotton [27, 35]. However, during recent years, overuse of pesticides has increased the population of mealybug on cotton crop in entire Pakistan especially in Sindh province. After the spreading of CMB in 2005, about 154 host plants were reported as potential hosts and cotton crop was one of its most favoured host plants [2].
The district Sanghar is one of the major cotton growing areas in Sindh with area of 0.12 million hectares and production of 0.65 million tonnes bales per year [9]. Further, it is also a great hub of cotton ginning factories in Sindh province because out of 180 ginning factories, 55 ginning factories are located in district Sanghar [21]. Despite the hefty losses caused by *P.*

solenopsis over the vast cotton cultivation area of district Sanghar, information regarding factors responsible for their rapid spread along with accurate population distribution is still lacking. Therefore, this study was undertaken to determine the damage percentage and population distribution of CMB in three taluka of district Sanghar. The information obtained from this study will be useful in proper mapping of the distribution of pest population in various taluka to devise adequate management strategies not only for their control but also to restrict their further spread.

2. Materials and Methods

2.1 Surveying of cotton crop for collection of mealy bug population

The cotton crop was surveyed from June to October, 2006-07 to observe the infestation of *P. solenopsis* in three different taluka of district Sanghar (Sindh) Pakistan. The selected locations for surveying are shown in Fig.1 and from each location one progressive cotton grower's farm was selected. Each cotton field was visited at fortnightly interval from sowing till harvesting. The sampling area of 0.5 acre was selected which further divided into five sites including four corners and centre as mentioned in Fig. 2

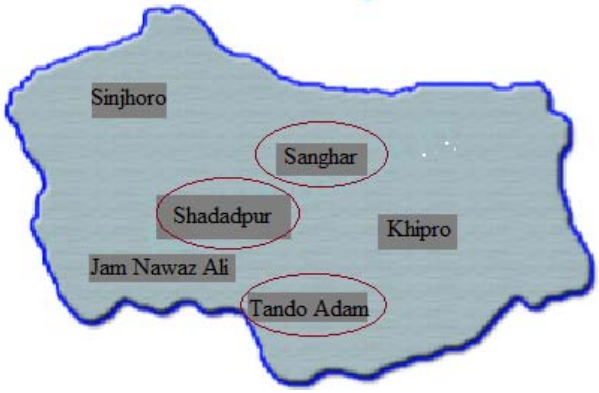

Fig. 1 Map of district Sanghar, showing location for sampling from three different taluka.

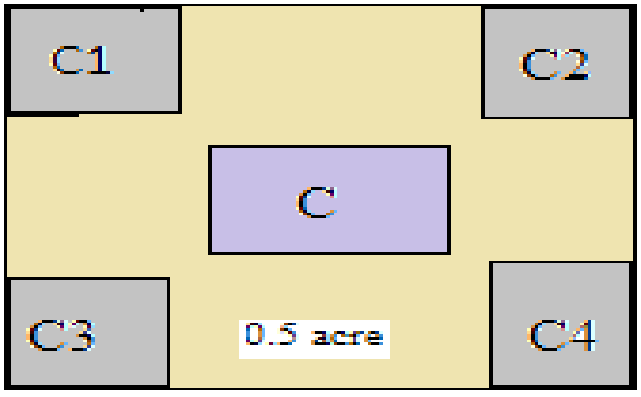

Fig. 2 Layout of selected field for insect sampling (C = Centre of selected area and C1 to C4 are Corner1 to Corner-4).

From each site, three infested plants were thoroughly observed resulting in 15 plants per location and samples were taken from one twig of each infested plant on random basis. Similarly, total 15 twigs having 6-7 cotton leaves were selected from cotton field area to take the samples of cotton mealybugs. The observed plants were tagged with red ribbon cloth as repetition of same plant could avoid on next visit. The entire twig was brought to Entomological Laboratory, Department of Zoology, Faculty of Science, University of Sindh, Jamshoro and numbers of adult mealybugs were counted from entire twig as in Figure 3.

Fig. 3 Damaged plants of cotton crop a. moderate damage in field observation b. cotton twig having CMB population brought in lab for counting.

The experiment design was based on Completely Randomized Design (CRD) and the collected data were analysed using one-way Analysis of Variance (ANOVA) whereas Least Significant Difference (LSD) at 0.05 probabilities was used to separate means with significant differences. All the analysis were done using Statistical Analysis Software version 9.3 [26]. Mean population of cotton mealybugs from selected taluka was also correlated with environmental factors such as temperature (^{0}C) and relative humidity (%). The meteorological record of selected taluka of district Sanghar was obtained from Department of Agriculture Extension (DAE), Sanghar

2.2 Population dispersion of cotton mealybug

For population dispersion, further different indices of dispersion were used to estimate the levels of dispersed population of CMB. Three indices were used in this study such as mentioned below;

Variance to mean ratio (VMR) = S^2/m (1)
Where'S^2 'is the variance and 'm' representing mean number of mealy bugs per cotton twig
If,
VMR=1, indicates 'Random Dispersion'
VMR>1, indicates 'Aggregate Dispersion'
VMR<1, indicates 'Regular/Uniform Dispersion'
Green coefficient (Cx) = $(S^2/m)-1/\Sigma x-1$ (2)
Where'S^2 'is the variance and 'm' representing mean number of mealy bugs per cotton twig
Σx is the total number of mealy bugs counted on cotton twigs.
If,
Cx=1, indicates 'Random Dispersion'
Cx>1, indicates 'Aggregate Dispersion'
Cx<1, indicates 'Regular/Uniform Dispersion'
Lloyd's index of patchiness (m^*) = $x + [(S^2/x)]-1$ (3)
Where 'S^2 'is the variance and 'm' representing mean number of mealy bugs per cotton twig
If,
m^*=1, then Lloyd's index of patchiness 'Random Dispersion'
m^*>1, then Lloyd's index of patchiness 'Aggregate Dispersion'
m^*<1, then Lloyd's index of patchiness 'Regular/Uniform Dispersion'

2.3 Damage percentage of Cotton crop

In selected cotton fields for this study, there were 50 rows in 0.5 acre with 250 plants per row (12500 plants), respectively. The five rows were observed randomly at every visit to record damage infestation of cotton mealybugs (Fig. 3) from every taluka and observed plants were tagged to avoid any repetition in counting on next visit. In case of fewer numbers of CMB on cotton crop those plants were not considered for data until significant development of population observe. The percentage of damage infestation was calculated by using following formula.

(Damage percentage=No. of damage plants X 100 /Total number of plants in each row) (4)

3. Results and Discussion

The results regarding the population distribution of cotton mealybug (CMB), *Phenacoccus solepnosis* illustrated the significant difference ($F_{0.05}$=393.34, P<0.05) of insect population per plant twig in three talukas of district Sanghar (Table 1). On fortnightly visit, the pest population started to build from the end of June in Shadadpur and Sanghar, however in Tandoadam, population of CMB was observed in first visit of July. No CMB population was recorded during the first visit of June, 2006 in all talukas of district Sanghar.

The overall highest mean population of 99.8±7.8 CMB per cotton twig was observed in Shadadpur followed by Sanghar in which mean number of 92.7±7.7 CMB per cotton twig was observed. However, the significantly lowest mean population of 77.8±6.8 CMB per cotton twig was observed in Tandoadam ($F_{0.05}$=6.16, P<0.05) as compared to other talukas of district Sanghar, respectively. The highest mean population of 222.3±22.8 with significant difference ($F_{0.05}$=20.66, P<0.05) of CMB in all taluka's was observed in the month of September during second fortnightly visit. The population of *P. solenopsis* was started to decline in the second fortnightly visit of October. The results regarding the effect of environmental factors on the population of cotton mealybugs showed influence of temperature in all selected taluka of district Sanghar (Table 2). The correlation matrix displayed negative correlation between CMB population and temperature in all taluka (Shadadpur=P<0.05, r= -0.96; Sanghar=P<0.05, r= -0.97 and Tandoadam= P<0.05, r= -0.74). Meanwhile, there was no effect of RH recorded on the CMB population at all selected of district Sanghar (P>0.05).

Table 1: Fortnightly population of mealy bug per cotton twig in three Taluka of district Sanghar.

Months	Fortnights	Tandoadam	Shadadpur	Sanghar	Total
		Mean ± S.E	Mean ± S.E	Mean ± S.E	Mean ± S.E
June	Visit-I	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0 e
	Visit-II	0.0±0.0	0.2±0.1	0.3±0.1	0.20±0.1 e
July	Visit-I	2.1±0.5	6.2±0.6	4.6±0.5	4.3±1.2 e
	Visit-II	6.6±0.4	15.1±1.3	13.1±1.3	11.6±2.6 e
August	Visit-I	26.4±1.8	69.6±4.1	44.6±4.3	46.8±12.5 d
	Visit-II	69.2±5.0	115.6±5.2	89.9±6.9	91.3±13.2 c
September	Visit-I	109.1±6.0	190.2±12.8	178.4±15.4	159.2±25.3 b
	Visit-II	178.0±8.8	254.0±18.3	234.9±18.1	222.3±22.8 a
October	Visit-I	221.8±10.7	206.2±9.3	212.9±11.7	213.6±4.5 a
	Visit-II	164.8±8.6	142.4±6.2	148.8±8.6	152.0±6.6 b
Total		77.8±6.8 c	99.8±7.8 a	92.7±7.7 b	

Means followed by different letters in the same column are significantly different at P>0.05.
Means followed by different letters in row are significantly different at P>0.05.
$LSD_{0.05}$=6.91

Table 2: Correlation matrix (r) between cotton mealybug population and environmental factors in three taluka of district Sanghar.

Taluka	Temperature	p-value	Relative humidity	p-value
Shadadpur	-0.95	<0.05	0.12	>0.05
Tandoadam	-0.96	<0.05	0.59	>0.05
Sanghar	-0.73	<0.05	0.54	>0.05

The population distribution of cotton mealybug from seven districts of Sindh with highest mean population of 102.37±20.14 was previously also recorded in district Sanghar [25]. Similarly, the trend of population was highest (216.41 to 204.49) during the months of September to October. Our results are also in accordance with [16] who reported that the population trend started to increase in August and were maximum (4800 CMB per five cotton twigs) during September at Tando Jam (Sindh) and declined (300-500 CMB per 5 cotton twigs) afterwards during the month of November at crop maturity.

Several control measures were applied to reduce the pest population by cotton growers in different cotton growing areas of Sindh including Sanghar but all went ineffective [25] because of heavy population densities. The other main reason of heavy infestation of cotton mealybug during that period was absence of natural enemies on this invasive pest [16]. But after introduction of new biological agent, *Aenasius bambawalei* [12] in 2008, significant reduction in the pest population was observed [16, 25].

The results regarding the population dispersion of *P. solepnosis* showed comparatively similar trend in selected taluka of district Sanghar (Table 3). The variance to mean ration indicate that mostly aggregate dispersion of CMB was found with values ranging between 2.02 to 7.80 at Tandoadam, 1.93 to 20.97 at Sanghar and 1.02 to 19.81 at Shadadpur except at first and second fortnightly visits of June in all taluka. Similarly, the results were aggregate in Lloyd's index of patchiness with values ranging between 3.33 to 228.6 at Tandoadm, 4.64 to 22.58 at Sanghar and 6.22 to 272.81 at Shadadpur, respectively. Meanwhile, the population dispersion of cotton mealy bug in green coefficient indices were observed regular or uniform in all selected taluka of district Sanghar at every fortnightly visit in cotton growing season.

Table 3: Population dispersion indices of cotton mealy bug in three taluka of district Sanghar in cotton growing season.

Tandoadam							
Months	**Fortnights**	**Total**	**Mean**	**Variance**	**VMR ratio**	**G.C**	**Lloyds**
June	Visit-I	0	0.00	0.00	0.00	0.00	0.00
	Visit-II	0	0.00	0.00	0.00	0.00	0.00
July	Visit-I	32	2.13	4.70	2.20	0.04	3.33
	Visit-II	99	6.60	5.11	2.47	0.00	6.07
August	Visit-I	396	26.40	53.40	2.02	0.00	27.42
	Visit-II	1038	69.20	379.03	5.48	0.00	73.68
September	Visit-I	1637	109.13	546.41	5.01	0.00	113.14
	Visit-II	2671	178.07	1175.78	6.60	0.00	183.67
October	Visit-I	3328	221.87	1729.84	7.80	0.00	228.66
	Visit-II	2472	164.80	1121.60	6.81	0.00	170.61
Sanghar							
Months	Fortnights	Total	Mean	Variance	VMR ratio	G.C	Lloyds
June	Visit-I	0	0.00	0.00	0.00	0.00	0.00
	Visit-II	5	0.33	0.24	0.71	0.00	0.05
July	Visit-I	70	4.67	4.52	0.97	0.00	4.64
	Visit-II	197	13.13	25.41	1.93	0.00	14.07
August	Visit-I	670	44.67	278.38	6.23	0.01	49.90
	Visit-II	1349	89.93	719.35	8.00	0.01	96.93
September	Visit-I	2676	178.40	3558.40	19.95	0.01	197.35
	Visit-II	3524	234.93	4927.64	20.97	0.01	254.91
October	Visit-I	3194	212.93	2054.92	9.65	0.00	221.58
	Visit-II	2233	148.87	1121.70	7.53	0.00	155.40
Shadadpur							
Months	Fortnights	Total	Mean	Variance	VMR ratio	G.C	Lloyds
June	Visit-I	0	0.00	0.00	0.00	0.00	0.00
	Visit-II	4	0.27	0.21	0.79	0.00	0.05
July	Visit-I	93	6.20	6.31	1.02	0.00	6.22
	Visit-II	227	15.13	25.55	1.69	0.00	15.82
August	Visit-I	1044	69.60	253.83	3.65	0.00	72.25
	Visit-II	1734	115.60	413.97	3.58	0.00	118.18
September	Visit-I	2853	190.20	2479.74	13.04	0.00	202.24
	Visit-II	3810	254.00	5031.43	19.81	0.00	272.81
October	Visit-I	3094	206.27	1320.64	6.40	0.00	211.67
	Visit-II	2137	142.47	588.12	4.13	0.00	145.59

VMR=Variance to mean ratio (S^2/m), G.C=Green coefficient (cx) {$(S^2/m)-1/\Sigma x-1$}, Lloyds=Lloyd's index of patchiness (m^*) {$x+[(S^2/x)]-1$} and S^2=Variance.

Furthermore, the results regarding damage infestation done by CMB were observed highest (100%) in first fortnight visit of October and similarly damage was observed constant until second fortnight visit in all taluka of district Sanghar (Fig. 4). Meanwhile, damage percentage recorded to begin in second fortnight visit of June except Shadadpur. Overall, damage was negligible in initial visits of June but with vegetative growth of cotton crop, CMB populating increased with significant damage occurred from August to October in all selected talukas of district Sanghar.

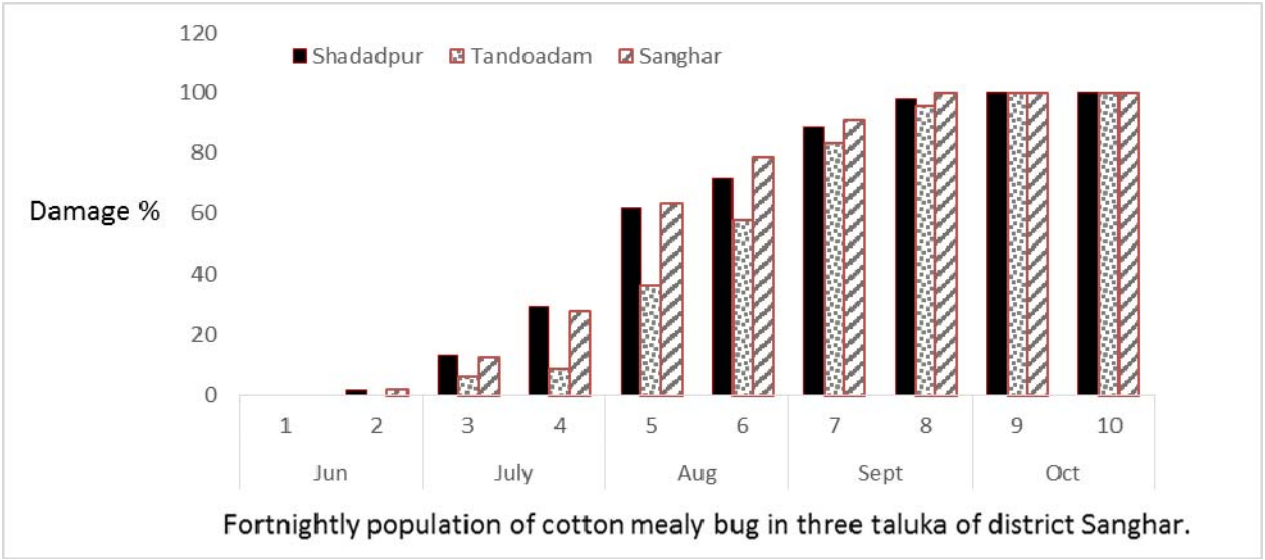

Fig. 4 Damage percentage of CMB, *Phenacoccu solenopsis* on cotton crop at fortnightly in three taluka of district Sanghar.

Although, population of CMB species have not been reported recently on cotton crop in Pakistan and India but its dispersal in Asia and beyond is a threat to the world's production of cotton and other crops [31]. Because its presence has been recently detected in South America [32], including Chile [15], Argentina [10], and Brazil [7], Hawaii [14], the Caribbean Islands and Central America [13], Nigeria [3], Thailand and Taiwan [13], Sri Lanka [22] and China [31, 34].

The majority of the mealybug species show a clumped distribution, and the natural rate of movement between host plants is poorly understood. One study showed that the dispersal of the grape mealybug can be aided by wind, although there was a marked decline in numbers with increasing distance from the source plant [11]. Furthermore, poor control of mealybugs may be partly due to a lack of knowledge about their feeding sites [30], so that the early stages of infestations go undetected and management decisions are initiated only after considerable damage has been done to the plants. Therefore, it is quite important to carry out proper monitoring of this invasive species throughout Pakistan on field as well as ornamental crops for its threat of resurgence.

4. Conclusion

We observed highest population of cotton mealy bug in all selected talukas of district Sanghar particularly in Shadadpur. Further, through indices we have come to estimate that population was mostly aggregate dispersed. In cultivation period, the damage percentage was high when crop was near to harvesting period i.e. months of September to October. Although, CMB is not more recently reported form cotton in Sindh province but such information will be useful. Further, insect pests have significant history of resurgence. Therefore, care must be taken to avoid unnecessary use of pesticides that may disturb the natural agro-ecosystem.

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6. References

1. Abbas G, Arif MJ, Saeed S. Systematic status of a new species of the genus *Phenacoccus* Cockerell (Pseudococcidae), a serious pest of cotton, *Gossypium hirsutum* L. in Pakistan. Pakistan Entomologist 2005; 27:83-84.
2. Arif MI, Rafiq M, Ghaffar A. Host plants of cotton mealybug (*Phennacoccus solenopsis*): A new menace to cotton agro-ecosystem of Punjab. International Journal of Agriculture Biology. 2009; 11(2):163-167.
3. Akintola AJ, Ande AT. First record of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on *Hibiscus rosa-sinensis* in Nigeria. Agricultural Journal. 2008; 3(1):1-3.
4. Bertin S, Cavalieri V, Graziano C, Bosco D. Survey of mealybug (Hemiptera: Pseudococcidae) vectors of *Ampelovirus* and *Vitivirus* in vineyards of north western Italy. Phytoparasitica 2010; 38(4):401-409.
5. Bokonon-Ganta AH, Groote H, Neuenschwander P. Socio-economic impact of biological control of mango mealybug in Benin. Agriculture Ecosystem and Environment 2002; 93(1):367-378.
6. Buss E, Turner J. Scale insects and mealybugs on ornamental plants. EENY-323. Featured Creatures. Entomology and Nematology Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Society. University Florida, Gainesville, FL, 2006, 1-6.
7. Culik MP, Gullan PJ. A new pest of tomato and other records of mealybugs (Hemiptera: Pseudococcidae) from Espirito Santo Brazil. Zootaxa 2005; 964:1-8.
8. Dhaliwal GS, Jindal V, Dhawan AK. Insect pest problems and crop losses: changing trends. Indian Journal of Ecology. 2010; 37(1):1-7.
9. DSS. Development Statistics of Sindh, Karachi. Bureau of Statistics, 2011.
10. Granara deWillink, Maria C. New records and host plants of *Phenacoccus* for Argentina (Hemiptera: Pseudococcidae). Revista de la Socieddad Entomolic Agentina 2003; 623(4):80-82.
11. Grasswitz TR, James DG. Movement of grape mealybug, *Pseudococcus maritimus* on and between host plants. Entomologia Expermentalis et Applicata 2008; 129(3):268-275.
12. Hayat M. Description of a new species of *Aenasius* Walker (Hymenoptera: Encyrtidae), parasitoid of the mealybug, *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae) in India. Biosystematica 2009; 3:21-26.
13. Hodgson C, Abbas G, Arif MJ, Saeed S, Karar H. *Phenacoccus solenopsis* Tinsley (Sternorrhyncha: Coccoidea: Pseudococcidae), an invasive mealybug damaging cotton in Pakistan and India, with a discussion on seasonal morphological variation. Zootaxa 2008; 1913:1-35.
14. Kumashiro BR, Heu RA, Nishida GM, Beardsley JW. New state records of immigrant insects in the Hawaiian Islands for the year 1999. Proceeding of Hawaiian Entomological Society 2001; 35:170-184.
15. Larrain SP. Insect and mite pest incidence on sweet pepinos, *Solanum muricatum* (Ait.) cultivated in the IV Region, Chile. Agricultura Técnica 2002; 62:15-26.
16. Mahmood R, Aslam MN, Solangi GS, Samad A. Historical perspective and achievements in biological management of cotton mealybug, *Phenacoccus solenopsis* Tinsley in Pakistan. In Proceedings of 5th Meeting of ICAC's Asian Cotton Research and Development Network, 2011, 23-25.
17. Meyerdirk DE, Muniappan R, Warkentin R, Bamba J, Reddy GVP. Biological control of the papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae) in Guam. Plant Protection 2004; 19:110-114.
18. Miller DR, Miller GL. Redescription of *Paracoccus marginatus* Williams and Granara de Willink (Hemiptera: Coccoidea: Pseudococcidae) including descriptions of the immature stages and adult male. Proceedings Entomological Society Of Washington 2002, 1-159
19. Mohyudddin AI. A review of biological control in Pakistan. Proceedings 2nd Pakistan Congress of Zoology 1980, 31-79.
20. Muniappan R, Meyerdirk DE, Sengebau FM, Berringer DD, Reddy GVP. Classical biological control of the papaya mealybug, *Paracoccus marginatus* (Hemiptera: Pseudococcidae) in the republic of Palau. Florida Entomologist 2006; 89:212-217.
21. PCGA. Pakistan Cotton Ginner Association, Multan. 2013. pcga@pcga.org

22. Prishanthini M, Laxmi V. The *Phenococcus solenopsis*. Sri Lanka: Department of Zoology, Eastern University. Available on-line at http://www.dailynews.lk/ 2009/07/01/fea30.asp.
23. Roltsch WJ, Meyerdirk DE, Warkentin R, Andress ER, Carrera K. Classical biological control of the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), in Southern California. Biological Control 2006; 37(2):155-166.
24. Sagarra L, Vincent C, Stewart R. Body size as an indicator of parasitoid quality in male and female *Anagyrus kamali* (Hymenoptera: Encyrtidae). Bulletin of Entomological Research 2001; 91(5):363-368.
25. Sahito HA, Abro GH, Mahmood R, Malik AQ. Survey of mealybug, *Phenacoccus solenopsis* (Tinsley) and effect of bio-ecological factors on its population in different ecological zones of Sindh. Pakistan Journal of Agriculture Agricultural Engineering and Veterinary Sciences 2011; 27:51-65.
26. SAS Institute. PROC user's manual (ver. 9.2 ed). Cary, NC, USA: SAS Institute, 2009
27. Shabir SG. Cotton pests, their distribution and seasonal prevalence. Seminar on Insect pests of cotton. PCCC; April, 1973, 49-61.
28. Shylesha AN, Joshi S, Rabindra RJ, Bhumannavar BS. Classical biological control of the papaya mealybug. National Bureau of Agriculturaly Important Insects, Banglore, India, 2010, 1-4.
29. Sinacori A. Bio-ethological observations on *Phenacoccus madeirensis* Green (Coccoidae: Pseudococcidae) in Sicily. Israel Journal of Entomology. 1995; 29:179-182.
30. Stewart L. Understanding the biology and improved management of long tailed mealybug in Western Australia. Final report to Grape and Wine Research & Development Corporation, Wine Industry Association, Western Australia, 2005.
31. Wang Y, Watson GW, Zhang R. The potential distribution of an invasive mealybug, *Phenacoccus solenopsis* and its threat to cotton in Asia. Agricultural and Forest Entomology 2010; 12:403.
32. Watson GW, Chandler LR. Identification of mealybugs important in the Caribbean region. 2nd ed. (revised). Egham, Surrey, UK: CABI. Bioscience, 2001.
33. Williams DJ, Granara de Willink MC. Mealybug soft Central and South America. CAB International, London, England, 1992.
34. Wu SA, Zhang RZ. A new invasive pest, *Phenacoccus solenopsis* threatening seriously to cotton production. (In Chinese with English summary). Chines Bulletin of Entomology 2009; 46:159-162.