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ASSESSMENT OF NATURAL INCIDENCE OF *PHENACOCCUS SOLENOPSIS* ON DIFFERENT HOST PLANTS UNDER CORE AND NON-CORE COTTON ZONE OF PUNJAB, PAKISTAN

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ABSTRACT

Phenacoccus solenopsis Tinsley also known as cotton mealybug (CMB) is an important sucking insect pest with polyphagous feeding nature. Incidence of *P. solenopsis* was documented among 25 plant species in Punjab, Pakistan. Five plants from each plant species were randomly selected to investigate the infestation percentage of *P. solenopsis.* Data was recorded by taking 6 cm twigs of each host plant. Least infestation and population was observed on *Digeria arvensis* and *Chenopodium album* followed by *Chenopodium morale, Coronopus didimus, Achyranthes aspera, Eclipta prostrate* and *Conyza bonariensis.* High infestation (51.5%) was observed on *Trianthema partulacastrum* that was at par with both *Portulaca oleraceae* and *Euphorbia prostrate* (45%). Clusters analysis depicted that cluster-1 comprised of a set of susceptible host plants of *P. solenopsis* including *H. annuus, H. rosa-sinensis, A. spinosus, W. somnifera, S. melongena, A. esculentus, T. terrestris, C. frutescens, E. prostrate, G. hirsutum, L. camara, P. oleracea* and *T. partulacastrum*. Cluster-2 represented intermediate but cluster-3 characterized resistant plant species including *D. arvensis, E. prostrate, C. arvensis, C. didimus, C. bonariensis, C. album, C. morale, L. nudicaulis* and *A. aspera* respectively. It was concluded that special consideration should be implemented on susceptible plants to avoid their shift on major economic crops whereas resistant plants should be investigated for plant traits imparting role to keep pest population under control.

Keywords: *P. solenopsis*, incidence, hosts plant, cluster analysis

INTRODUCTION

Mealybugs are geographically present throughout the world on numerous plant species (Prishanthini and Laxmi, 2009). *Phenacoccus solenopsis* (Hemiptera: Pseudococcidae) is also one of the mealybug species, its existence in Pakistan was noticed for the first time during 2005 (Abbas et al., 2005), however reported in USA for the first time during 1890's on *Boerhavia spicata* Choisy and *Kallstroemia brachystylis* Vail weeds (Tinsley, 1898). *P. solenopsis* has been described as a serious cum invasive pest of cotton in Pakistan and India () and on *Hibiscus rosa-sinensis* in Nigeria (Akintola and Ande, 2009). Latest report on the invasiveness of *P. solenopsis* has been from the Eastern region of Sri Lanka (Prishanthini and Laxmi, 2009) on ornamentals, vegetable crops and weeds, and in China on cotton. First report of severe infestation of mealybug in Pakistan date back to 2005 and 2006 when mealybug population infestation was observed on about 3000 acres in Kot Ghulam Mohammad, Tando Allahyar, Tandojam, Mirpurkhas and Sanghar districts (Abbas *et al.*, 2005). Incidence of *P. solenopsis* has been extended now in all cotton growing districts of Sindh and Punjab, Pakistan (Arif et al., 2009, Sahito et al., 2011); infesting a total of 154 plant species comprising of numerous crops, weeds, vegetables, ornamental plants and economic fruits (Arif et al., 2009;). The feeding of mealybug caused leaf yellowing, defoliation, reduced plant growth and in some cases death of plants (Culik and Gullan, 2005). *P. solenopsis* remain active throughout the year and its peak population in Pakistan was recorded during August and September when temperature and humidity ranged 28-33.5˚C and 59-78% respectively (Shahid et al., 2012) however, it could tolerate temperatures from 0-45°C

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(Sharma, 2007).

Population dynamics of *P. solenopsis* was more abundant during October on cotton (*Gossypium hirsutum* L.) and Okra (*Abelmaschus esculentus* L.) but in winter it was maximum on Tomato (*Lycopersicon esculentum* L.) and Potato (*Solanum tuberosum* L.) during the month of February (Singh and Kumar, 2013). Plant families such as Cucurbitaceae, Fabaceae, Solanaceae and Malvaceae are favored by mealybug. The present research was carried out to study the population intensity and dynamics of *P. solenopsis* in cotton monocropping and mixed cropping areas of Punjab, Pakistan by comparing population of *P. solenopsis* in five different districts, and on twenty-five different host plants.

MATERIALAND METHODS

Districts of southern Punjab comprising of Vehari (29.36°N,71.44°E), Lodhran (29.54°N,71.63°E), Multan (30.2°N, 71.45° E), Bahawalpur (29.50°N, 72.50°E), Faisalabad (31.47°N, 73.40°E) and Sahiwal (30.40°N, 73.06°E) were surveyed on fortnightly basis to record incidence of *P. solenopsis* for two cotton seasons on different plant species during 2007-08. In Multan, Vehari, Lodhran and Bahawalpur, there is typical cotton monocropping pattern, but in Sahiwal and Faisalabad agricultural regions, crop diversification is followed every year, normally cotton and maize are the main crops in these areas; other crops are planted as a mosaic pattern among cotton and maize farms in a non-regular arrangement. Numerous weeds, fruits, vegetables, economic crops and ornamentals are grown adjacent to water channels and in cultivated fields. Incidence of *P. solenopsis* was recorded on 25 host plant species, there details are given in (Table 1). Five plants from each plant species at least one meter apart were randomly selected to investigate the infestation and population of *P. solenopsis* from 6 cm twig (Suresh and Kavitha, 2007). The twigs of the plants infested with mealybug were tilted and shaken on a white paper with the help of camel hair brush and *P. solenopsis* densities were estimated by counting individuals on each plant species. To study the seasonal population dynamics and carryover of *P. solenopsis* on economic crops, vegetables and ornamentals, plants were examined throughout the year. The population of both adults and nymphs on plant species were recorded on 6cm twig and infestation percentage was calculated by using formula:

$$\text{Infestation?\%?} = \frac{\text{Infested plants}}{\text{Total plants observed}} * 100$$

Statistical analysis:

District wise infestation and population was calculated on selected plant species. Due to the similar behavior of plant species to the pest during both growing seasons of cotton data were subjected to uni- and multivariate analyses using (, 2005). Dendrogram and genetic similarity among the plant species were also generated using the Jaccard's Coefficient of similarity expressed as Euclidean genetic distances and cluster analysis to sort the plant species into their appropriate groups with minimum error (Adinsoft, 2010).

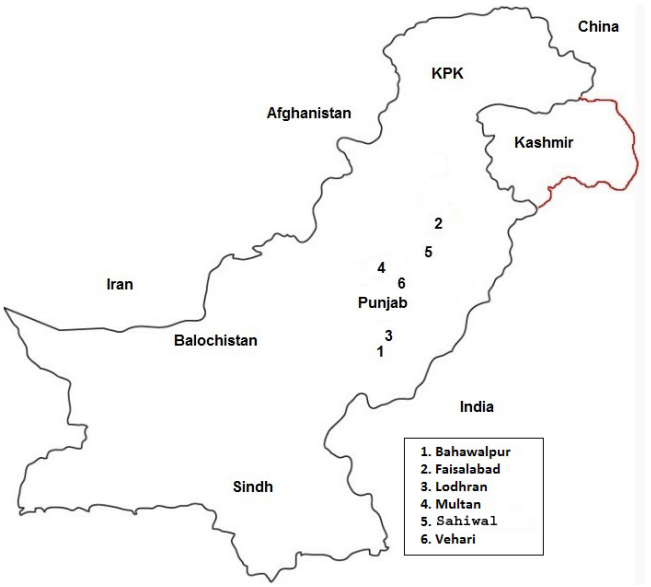


Figure 1: Geographic location of studied districts in the Map of Pakistan and Plate showing the studied area

RESULTS

The results of present study regarding infestation and population of cotton mealybug on different host plants in the tested localities viz. Bahawalpur, Lodhran, Multan, Vehari (cotton zone), Sahiwal and Faisalabad (mixed cropping zone) have been described under following sub-sections.

Infestation (%) of *P. solenopsis* on the selected host plants

Mean comparison regarding infestation of cotton mealybug among tested plant species by using Tukey Honesty Significant Difference test at P=0.05 revealed that infestation of mealybug among the tested plant species ranged from 5 to 51.5%. Least infestation was observed on *D. arvensis* and *C. album* that was at par with *C. morale* (6.0), *C. didimus* (8.0) followed by *A. aspera, Eclipta prostrate* and *C. bonariensis* (9.0% infestation). High infestation (51.5%) was observed on *T. partulacastrum* that was at par with both *P. oleraceae and Euphorbia prostrate* (45%) followed by *G. hirsutum* (39.0). Remaining plants had intermediate infestation between 11.0-29.0% (Figure- 2).

Population density of *P. solenopsis* on the selected host plants

Mean comparison regarding the effect of tested plant species on the population of cotton mealybug by using Tuckey Honesty Significant Difference test at P=0.05 revealed that population of cotton mealybug among the tested plant species varied from 11.0 to 146.6 numbers per 6 cm twig. Least population (<30 mealybug/6cm twig) was recorded on *D. arvensis, A. aspera* that was at par with mealybug population on *C. inerme* but high population (120-147/6cm twig) on *A. esculentus, L. camara, L. nadicaulis, T. terrestris, T. partulacastrum, A. spinosus, E. prostrate, C. arvensis, C. frutescence, C. inerme, H. rosa-sinensis* and *W. somnifera*. Remaining plants had intermediate mealybug population between the upper and lower population limit ranging from ≥30.0 to ≤120 (Figure- 3).

Infestation (%) of *P. solenopsis* on the tested host plants in selected districts

Mean comparison regarding percentage infestation of mealybug among the tested plant species by using Tukey Honesty Significant Difference test at *P*= 0.05 is given in (Figure- 4). Mealybug infestation among the tested plant species in different districts varied from 32.7 to 49.3%. Least infestation of mealybug on plant species existing in Faisalabad was recorded (32.7%) that was at par with (37.6%) in Sahiwal district, while infestation in cotton zones comprised of Multan (49.3), Vehari (48.8) followed by Bahawalpur (43.2%) and Lodhran (42.5) (Figure- 4).

Population of *P. solenopsis* on the tested host plants

Mean comparison regarding population of mealybug among the tested plant species by using Tukey Honesty Significant Difference test at *P*=0.05 is given in (Figure- 5). Mealybug population among the tested plant species in different districts varied from 37.6 to 110.8/6 cm twig. Least population (37.6 mealybugs/6cm twig) was recorded among tested plant species existing in Faisalabad that was at par with Sahiwal district. Higher population of mealybug (80.9-110.8 mealybug/6cm twig) was observed on plant species occurring in Multan, Bahawalpur, Lodhran and Vehari districts (Figure-5).

Cluster analysis among plant species on the basis of population and infestation of *P. solenopsis*

Twenty five plant species were categorized into three different clusters in dendrogram with the help of cluster analysis (Figure- 6). Clusters were made on the basis of infestation and population level of *P. solenopsis* among the selected plant species. Cluster-1 comprised of 13 plant species including *H. annuus, H. rosa-sinensis, A. spinosus, W. somnifera, S. melongena, A. esculentus, T. terrestris, C. frutescens, E. prostrate, G. hirsutum, L. camara, P. oleracea* and *T. partulacastrum* showed similarity with each other for mealybug infestation and population. Cluster-2 consisted of a group of three plant species including *C. arvense, C. inerme* and *P. hysterophorus* while cluster-3 possessed plant species including *D. arvensis, E. prostrate, C. arvensis, C. didimus, C. bonariensis, C. album, C. morale, L. nudicaulis* and *A. aspera* (Table- 2). The pair wise Mahalanobis distances (D^2=statistics) among three clusters of 25 plant species revealed that plant species of cluster-2 demonstrated maximum diversity (96.0%) against the members of cluster-1 for infestation and population of *P. solenopsis* (Table- 3).

DISCUSSION

Understanding of population dynamics of insect pests is very useful to devise sustainable management program. Various factors including cropping pattern and intensity of the cropping system affect the insect pest population. Based on survey results of present study, it was found that *P. solenopsis* population and infestation was higher in the fields of cotton growing districts including Multan, Bahawalpur, Vehari and Lodhran as compared with mixed cropping zones districts of Faisalabad and Sahiwal. *P. solenopsis* infestation (%) in Multan was 49.3 while in Faisalabad it was 32.7. Reason for increase in pest infestation was attributed to mono-cropping pattern, prolonged growing season of cotton and repeated cultivation of cotton year after year in the cotton growing districts. The studied alternate host plants available in cotton fields especially weeds in cotton field provide food for cotton mealybug and help in carryover the population to the next season crop without any bread leading to increase in incidence and severity of pest. Monocropping cotton cultivation promote mealybug and other insect pest pressure as compared with polyculture (; Coll and Bottrell, 1994). Population dynamics of mealybug differed with respect to plant species. Results revealed that population of *P. solenopsis* among the tested plant species varied from 11.0 to 146.6 CMB/plant. Least population (<30 mealybug) was recorded on *D. arvensis, A. aspera* that was at par with *P. solenopsis* population on *C. inerme* but high population (120-147/plant) on *A. esculentus, L. camara, L. nadicaulis, T. terrestris, T. partulacastrum, A. spinosus, E. prostrate, C. arvensis, C. frutescence, C. inerme, H. rosa-sinensis* and *W. somnifera*. The variation in results may be due to difference in plant species and existing environmental conditions. Hanchinal et al. (2010) and Dhawan et al. (2009) reported that maximum population was observed in 2nd to 3rd week of September. *P. solenopsis* infesting cotton and 29 other host plant species of 13 families were reported in the U.S (Fuchs et al., 1991). Aheer et al. (2009) demonstrated similar results and reported that *P. solenopsis* was observed between December 2006 to November 2007 in the area around Faisalabad and maximum prevalence of mealybug was observed on *H. chinensis* followed by *A. esculentus*. Arif et al. (2009) recorded 154 plant species belonging to 53 families with preference to plants from Malvaceaea, Solanaceae, Ficoidae, Amaranthaceae, Asteraceae, Convolvulaceae, Euphorbiaceae, Verbanaceae and Zygophyllaceae as host plants of *P. solenopsis* from the cotton agroecosystem of Punjab (Pakistan). *P. solenopsis* has been reported from a maximum of 183 plants in 52 families by (Ben-Dov et al., 2010). A total of 55 host-plants in 18 families were reported by Abbas et al.(2010) from Punjab and Sindh regions of Pakistan. These findings are well supported by Prishanthini and Laxmi (2009) who reported that primary host of *P. solenopsis* was *H. rosa sinensis* and other crops viz., okra, brinjal, tomato, chillies, amaranthus, sunflower, some ornamental and weed hosts from home gardens also were reported as host plants in Sri Lanka.

Among total 25 plant species, 14 were uncultivated plant species (weeds) i.e., *C. morale, C. arvensis, L. nudicaulis, W. somnifera, C. didimus, E. prostrate, C. bonariensis, C. album, A. spinosus, T. portulacastrum, P. oleracea, T. terrestris, E. prostrate* and *P. hysterophorus which* provided food, shelter and sustained *P. solenopsis* for most of the study period as compared to cultivated plants species being harvested for economic use. Based on the results of present study it was found that *W. somnifera* and *E. prostrate* supported mealybug almost throughout the year. Peak population of mealybug on *W. somnifera* was recorded (40mealybug/plant) during September, whereas on *E. prostrate* (25mealybug/plant) during May. Evergreen plants provide regular food supply and ground covering plants protect the mealybug from the climatic extremes. Contribution of host plants in the over wintering of whitefly has also been argued by (; Rafiq et al.,

2008) from cotton growing areas of the Punjab, Pakistan. Carryover of mealybug due to host plant species in Pakistan has been documented by (Abbas et al., 2010;). As a perennial host, hibiscus appears to play an important role in the population dynamics of *P. solenopsis* on cotton during the crop season. After harvest of rainy season cotton by December, *P. solenopsis* survives mostly on alternate hosts such as *A. indicum* (L.) and *P. hysterophorus* L. As these weeds dry up in the hot summer during April-May in the rainfed tracts, *P. solenopsis* is mostly found surviving on *H. rosa-sinensis*. With the onset of monsoon rains in June, *P. solenopsis* population spreads to adjacent weeds that spring up early, and subsequently appears in adjoining fields planted to cotton. This is due to different mechanisms of resistance including antixenosis, antibiosis and tolerance (Shahid *et al.*, 2017).

Plant species including *D. arvensis, A. aspera, C. inerme* were less supportive because of the availability of resistant traits. They also allowed pest to spent minimum duration as compared with susceptible hosts comprising of *T. partulacastrum, H. rosa-sinensis, W. somnifera*, *S. melongena, E. prostrate* and *P. oleraceae*. For proper management of cotton mealybug special attention should be given on eradication of susceptible host plants. It will reduce mealybug pest pressure on cotton and through better management of mealybug, there will be reduction of pesticide use on cotton. These studies are helpful to understand the status of host plant species and time-related population dynamics of mealybug. There is also diare need to identify the genetic make-up of resistant plants to identify resistant traits against mealybug (especially in *D. arvensis*) and their inoculation into economic crops through biotechnological approaches in future.

Table 1
List of plant species selected during study

	Common name	Botanical name	Family name		Common name	Botanical name	Family name
1	Lantana	*Lantana camara*	Verbenaceae	14	Chilies	*Capsicum frutescens*	Solanaceae
2	Peelidhodak	*Launea nudicaulis*	Euphorbiaceae	15	Hazardani	*Euphorbia prostrate*	Euphorbiaceae
3	Krund	*Chinopodium morale*	Chenopodiaceae	16	Brinjal	*Solamum melongena*	Solanaceae
4	Lehli	*Convolvulus arvensis*	Convulvulaceae	17	Puthkanda	*Achyranthes aspera*	Amaranthaceae
5	Parthenium	*Parthenium hysterophorus*	Asteraceae	18	Bathu	*Chenopodium album*	Chenopodiaceae
6	Aksun;	*Withania somnifera*	Solanaceae	19	Sunflower	*Helianthus annuus*	Asteraceae
7	Cholai	*Amaranthus spinosus*	Amaranthaceae	20	Tandla	*Digera arvensis*	Amaranthaceae
8	Janglihaloon	*Coronopus didimus*	Brassicaceae	21	Qulfa	*Portulaca oleracea*	Portulacaceae
9	Itsit	*Trianthema portulacastrum*	Aizoaceae	22	Daryiboti	*Eclipta prostrate*	Asteraceae
10	Bakhra	*Tribulus terrestris*	Zygophyllaceae	23	Gardenia	*Clerodendron inerme*	Amaranthaceae
11	Chinese rose	*Hibiscus rosa-sinensis*	Malvaceae	24	Cotton	*Gossypium hirsutum*	Malvaceae
12	Okra	*Abelmoschus esculentus*	Malvaceae	25	Leh	*Cirsium arvense*	Asteraceae
13	Loosenbooti	*Conyza bonariensis*	Asteraceae		-	-	-

Table 2
Cluster membership for infestation and population of *Phenacoccus solenopsis*

Independent variables	*d.f*	*F*	*P*	**Final Cluster Centers**		
				Cluster-1 *H. annus, H. rosasinensis, A.spinosus, W.somnifera, S.melongena, A.esculentus, T.terrestris, C. frutescens, E. prostrate, G. hirsutum, L. camara, P. oleracea,* and *T. partulacastrum*	**Cluster-2** *C. arvense, C. inerme,* and *P. hysterophorus,*	**Cluster-3** *D. arvensis E. prostrate, C. arvensis, C. didimus, C. bonariensis, C. album, C. morale, L. nudicaulis, A. aspera*
Infestation%	2/24	7.6	0.00	26.9	14.7	19.0
Population	2/24	9.0	0.00	127.7	96.7	90.0

Table 3
D^2 distance among different clusters

	Cluster-1	Cluster-2	Cluster-3
Cluster-1	0.000		
Cluster-2	96.0	0.000	
Cluster-3	33.3	63.5	0.000

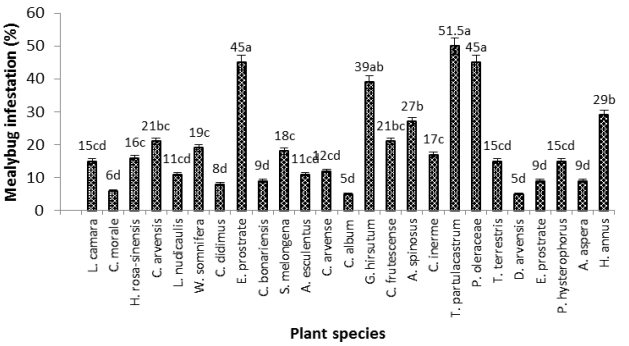


Fig. 2
Mealybug infestation (%±SE) among selected plant species.

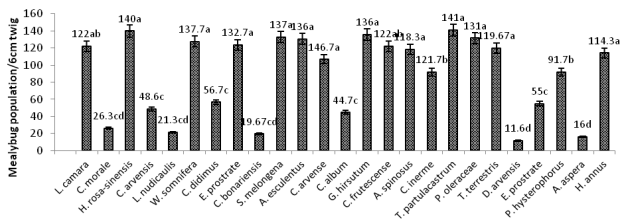


Fig. 3
Population of *Phenacoccus solenopsis* (n±SE=mealybug i.e., number±standard error) among selected plant species.

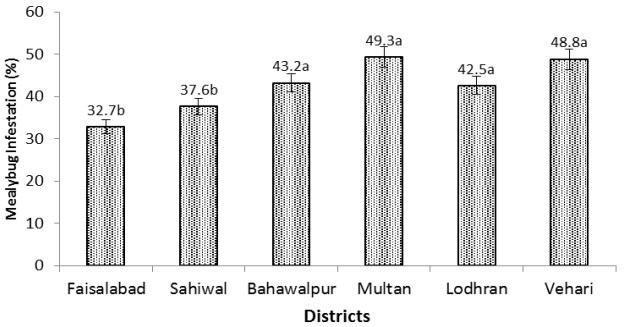
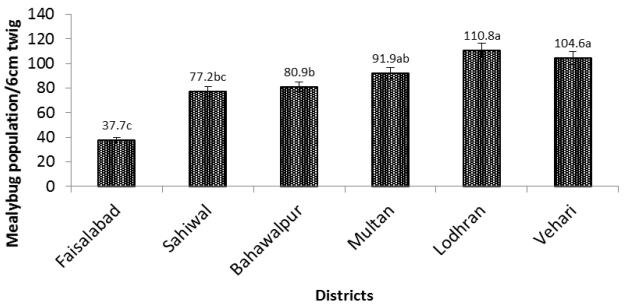


Fig. 4
Infestation of *Phenacoccus solenopsis* (%±SE) in selected districts.



F i g . 5
Population of *Phenacoccus solenopsis* (n±SE) in selected districts

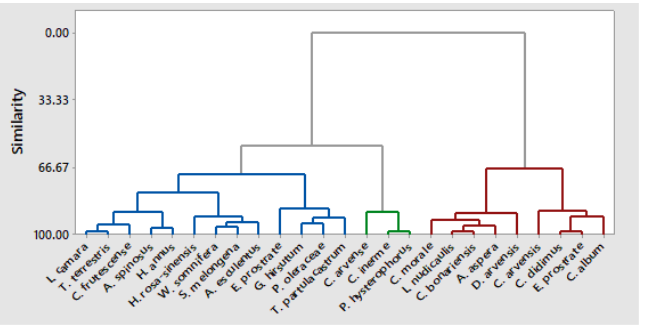


Fig. 6
Cluster diagram of the plant species on the basis of infestation and population of *Phenacoccus solenopsis*

CONCLUSION

It was concluded that incidence of *P. solenopsis* was more in cotton zone than in mixed cotton districts. Plants including *H. annuus, H. rosa-sinensis, A. spinosus, W. somnifera, S. melongena, A. esculentus, T. terrestris, C. frutescens, E. prostrate, G. hirsutum, L. camara, P. oleracea* and *T. partulacastrum* were considered as susceptible host plants of *P. solenopsis*. Among these plants evergreen and ground covering weeds due to regular food supply and protection from the climatic extremes proved as susceptible host plants of pest. Thus special consideration should be implemented on susceptible plants to avoid their shift on major economic crops whereas *D. arvensis, E. prostrate, C. arvensis, C. didimus, C. bonariensis, C. album, C. morale, L. nudicaulis* and *A. aspera* proved as resistant plants should be investigated for traits imparting their antixenotic role to keep pest population under control.

REFERENCES

Aheer, G.M., Z. Shah and M. Saeed, 2009. Seasonal history and biology of cotton mealy bug, *Phenacoccus solenopsis* Tinsley. J. Agric. Res., 47(4): 423-431.

Akintola, A.J., and A.T. Ande, 2008. First record of Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae) on Hibiscus rosa-sinensis in Nigeria. Agric. J., 3(1): 1-3.

Culik, M.P., and P.J. Gullan, 2005. A new pest of tomato and other records of mealybugs (Hemiptera: Pseudococcidae) from Espirito Santo, Brazil. Zootax., 964:1-8.

Dhawan A.K., K. Singh, A. Anand, S. Sarika, 2009. Distribution of mealybug, Phenacoccus solenopsis

Tinsley in cotton with relation to weather factors in South-Western districts of Punjab. J. Entomol., Res., 33(1):59-63.

Fuchs, T.W., J.W. Stewart, R. Minzenmayer and M. Rose, 1991. First record of *Phenacoccus solenopsis* Tinsley in cultivated cotton in the United States. Southwest Entomol., 16(3): 215-221.

Hanchinal, S.G., B.V. Patil, M. Bheemanna and A.C. Hosamani, 2010. Population dynamics of mealybug, *Phenacoccus solenopsis* Tinsley and it's natural enemies on Bt. cotton. Karnataka J. Agric. Sci., 23(1): 137-139.

Prishanthini, M., and M. Vinobaba, 2014. Efficacy of some selected botanical extracts against the Cotton mealybug *Phenacoccus solenopsis* (Tinsley) (Hemiptera: Pseudococcidae). Int. J. Sci. Res. Publ., 4(3).

Shahid, M.R., M.J. Arif, M.D. Gogi and N. Javed, 2017. Host-plant-preference and mortality analysis of *Phenacoccus solenopsis* in association with biochemical traits of different plant species. Int. J. Agric. Biol., 19: 211–218

Singh, A., and D. Kumar, 2012. Population dynamics, biology of mealybug *Phenacoccus solenopsis* (Tinsley) and its natural enemies in Vadodara, Gujarat. Recent Res. Sci. Technol., 4(11): 22-27 ISSN: 2076-5061 Available Online:http://recent-science.com/

Statsoft, 2005. Statistica: data analysis software system. Version 7.1. Tulsa: StatSoft,.

Suresh, S. and P. Kavitha, 2008. New records of Coccoidea in India. In: Proceedings of the XI International Symposium on Scale Insect Studies, Oeiras, Portugal, 24-27 September 2007 [ed. by Branco, M. \Franco, J. C. \Hodgson, C. J.]. Lisbon, Portugal: ISA Press, 155.

Abbas, G., M.J. Arif and S. Saeed, 2005. Systematic status of a new species of the genus *Phenacoccus Cockerell* (Pseudococcidae), a serious pest of cotton *Gossypium hirsutum* L. in Pakistan. Pak. Entomol., 27: 83-84.

Abbas, G., M.J. Arif, M. Ashfaq, M. Aslam and S. Saeed, 2010. Host plants distribution and overwintering of cotton mealybug (*Phenacoccus solenopsis*; Hemiptera: Pseudococcidae). Int. J. Agric. Biol., 12 (3): 421–425.

Andow, D.A., 1991. Vegetational diversity and arthropod population response. Ann. Rev. Entomol., 36, 561-568.

Arif, M.I., M. Rafiq and A. Ghaffar, 2009. Host plants of cotton mealybug (*Phenacoccus solenopsis*): a new menace to cotton agro-ecosystem of Punjab, Pakistan. Int. J. Agric. Biol., 11: 163–167.

Coll, M., and D.G. Bottrell. 1994. Effects of nonhost plants on an insect herbivore in diverse habitats. Ecol., 75:723-731.

Mohyuddin, A.I., A.G. Khan and A.A. Goraya, 1989. Population dynamics of cotton whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) and its natural enemies in Pakistan. J. Zool., 21: 273–88.

Rafiq, M., A. Ghaffar and M. Arshad, 2008. Population dynamics of whitefly (*Bemisia tabaci*) on cultivated crop hosts and their role in regulating its carry-over to cotton. Int. J. Agri. Biol., 10: 577–80

Sahito, H.A., G.H. Abro, R. Mahmood and A.Q. Malik, 2011. Survey of mealybug, *Phenacoccus solenopsis* (Tinsley) and effect of bio-ecological factors on its population in different ecological zones of Sindh. Pak. J. Agric., Agril. Engg. Vet. Sci., 27 (1): 51-65

Shahid, M.R., J. Farooq, A. Mahmood, F. Ilahi, M. Riaz, A. Shakeel, I.V. Petrescu-Mag and A. Farooq, 2012. Seasonal occurrence of sucking insect pest in cotton ecosystem of Punjab, Pakistan. Advanc. Agric. Bot., 4(1):26-30.

Shahid, M.R., M.J. Arif, M.D. Gogi and N. Javed, 2017. Host-plant-preference and mortality analysis of *Phenacoccus solenopsis* in association with biochemical traits of different plant species. Int. J. Agric. Biol., 19: 211–218.

Sharma, S.S., 2007. Aenasius sp. nov. effective parasitoid of mealy bug (Phenacoccus solenopsis) on okra. Haryana J. Hort. Sci., 36(3/4):412.

Singh, A., and D. Kumar, 2012. Population dynamics, biology of mealybug Phenacoccus solenopsis (Tinsley) and its natural enemies in Vadodara, Gujarat. Recent Res. Sci. Technol., 4(11): 22-27

Tinsley, J.D., 1898. Notes on Coccidae, with descriptions of new species. Canadian Entomol., 30, 317–320.