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Full Length Research Paper

Analysis of morphological traits in different host plants associated with resistance to *Phenacoccus solenopsis*- an invasive pest in Pakistan

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Phenacoccus solenopsis **Tinsley (Pseudococcidae: Hemiptera) is a sucking insect pest and is polyphagous in nature. Twenty five (25) different host plants were screened against *P. solenopsis* and their physicomorphic traits were determined to correlate their role against pest population. Among the tested plant species, most favorable host plants of mealy bug on the basis of population were *Gossypium hirsutum* (69.74±10.5), *Solamum melongena* (62.41±10.0), *Helianthus annuus* (61.83±10.0), *Hibiscus rosa-sinensis* (61.1±10.0) and *Lantana camara* (55.83±9.75), but the least preferred plants were tandla *Digera arvensis* (1.57±1.00) and *Conyza bonariensis* (3.83±1.75). Significant variations were observed in all the morphological plant characters recorded from different plant species. The maximum leaf thickness per plant was 2.04±0.23 µm in plant species *S. melongena* while minimum thickness of leaf was recorded from lehli (0.25±0.02 µm). Maximum trichome density per plant was 444±72.4 in sunflower followed by 411.6±19.6, 399±52, 391.6±22.0, in *C. bonariensis*, *Abelmoschus esculentus* and *Withania somnifera* respectively but minimum were 2.33±1.45 in *Chinopodium morale*, followed by 2.66±1.4, and 3±2.08 in *Portulaca oleracea* and *Trianthema portulacastrum* respectively. The maximum hair length per plant (2.62±0.07 mm) was of sunflower followed by 2.55±0.03 mm in okra, 2.53±0.06 mm in both *S. melongena* and *G. hirsutum*. It was concluded that plant characters including trichome density and hair length favor mealy bug population showing r-values of 0.357* and 0.190 respectively but leaf size and leaf width (leaf area and leaf thickness) exerted negative effect on pest population showing r-values of -0.172 and -0.285 respectively.**

Key words: *Phenacoccus solenopsis*, invasive species, physicomorphic traits, resistance.

INTRODUCTION

Phenacoccus solenopsis was originally discovered in U.S.A. by Tinsley (1898) on cotton and was considered as a minor pest of cotton until 1990 (Ben-Dov, 2008). It attained invasive status when reported from other countries. In Chile, from 1995 to 1997, it was seen as a pest of Papino (*Solanum muricatum* Aiton, Solanaceae), in Brazil, as a pest of tomato (*Lycopersicon esculentum* Miller, Solanaceae) (Culik and Gullan, 2005), and in Pakistan, it was reported in 2005 as a pest of cotton. Then, in India, cotton mealy bug (CMB) was reported from almost all the cotton-growing centres of India (NCIPM, 2008). The incidence and severity of the CMB outbreak in the Indian Punjab was worst in villages adjoining the Pakistan boundary (Yousuf et al., 2007; Saini and Ram, 2008) and Haryana (Monga et al., 2008),

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where the infestation consisted of a mixture of species, mostly *P. solenopsis* and *Meconellicoccus hirsutus* (Monga et al., 2008). *P. solenopsis* has had a devastating impact on cotton production in India (NCIPM, 2008; Nagrare et al., 2009), in Thailand on vegetables (USDA, 2008; Bambawale, 2008; Hodgson et al., 2008; Tanwar et al., 2007), in Nigeria on *Hibiscus rosa-sinensis* L. (Dicotyledones: Malvaceae) (Akintola and Ande, 2008) and most recently, *P. solenopsis* was reported to be a potential pest in 17 provinces of the Peoples' Republic of China (Wang et al., 2009). It has also been reported in Colombia (Kondo et al., 2008).

Based on this information, incidence of *P. solenopsis* on cotton is reported mainly from Pakistan (FBS, 2008) and India (Goswami, 2007). Its invasion in Pakistan and India is a great threat to cotton industry; intensity of pest remained higher in Pakistan as compared to India, because mealy bug devastated 60728.74 ha of cotton area across Pakistan (Muhammad, 2007), but nearly 809.7 ha in India (Goswami, 2007). Other than cotton, the mealy bug has been recorded to feed on 154 plant species belonging to 53 families, these host plants serve as carriers of pest to the main crop and provide feeding link throughout the year (Abbas et al., 2010).

Population of pest varies from plant to plant and may be due to external or internal physiology of the plant. This is because plants have the ability to alter the behavior of feeding insect (Karban and Baldwin, 1997) through accumulation and excretion of toxic exudates or host plants which create hindrance against insect pest due to morphological traits (Stadler, 2000; Hirota and Kato, 2001; Goncalves-Alvim et al., 2004), because thick waxy cuticular layer works as a defense against herbivory insect pests (Taiz and zeiger, 1998). These features impair the normal feeding or oviposition of insect pests (Morris and Dwyer, 1997; Underwood, 1999). This information is essential for understanding the morphological mechanisms underlying the resistance. In Pakistan, work done in this regard is still quite sketchy and needs more extensive research. Thus, owing to the lack of information on this side, the present study was undertaken to find out the relationship between the *P. solenopsis* population and morphological traits of different host plants.

MATERIALS AND METHODS

The study was conducted to investigate the role of morphological traits of various host plants against cotton mealy bug (*P. solenopsis*) at University of Agriculture, Faisalabad, during 2007 to 2008.

Tested plant material

A total of 25 host plant species viz., Lantana (*Lantana camara*) Verbenaceae, Krund (*Chinopodium morale*) Chenopodiaceae, chinese rose (*Hibiscus rosa-sinensis*) Malvaceae, Lehli (*Convolvulus arvensis*) Convulvulaceae, peeli dhodak (*Launea nudicaulis*) Euphorbiaceae, Aksun (*Withania somnifera*) Solanaceae, Jangli-haloon (*Coronopus didimus*) Brassicaceae, Hazardani (*Euphorbia prostrate)* Euphorbiaceae, Loosen booti (*Conyza bonariensis*) Asteraceae, Brinjal (*Solamum melongena*) Solanaceae, Okra (*Abelmoschus esculentus*) Malvaceae, Leh (*Cirsium arvense*) Asteraceae, Bathu (*Chenopodium album*) Chenopodiaceae, Cotton (*Gossypium hirsutum*) Malvaceae, Chilli (*Capsicum frutescens*) Solanaceae, Cholai (*Amaranthus spinosus*) Amaranthaceae, Gardenia (*Clerodendron inerme*), Itsit (*Trianthema portulacastrum*) Aizoaceae, Qulfa (*Portulaca oleracea*) Portulacaceae, Bakhra (*Tribulus terrestris*) Zygophyllaceae, Tandla (*Digera arvensis*) Amarantha-ceae, Daryaibooti (*Eclipta prostrate*) Asteraceae, Parthenium (*Parthenium hysterophorus*) Asteraceae, Puthkanda (*Achyranthes aspera*) Amaranthaceae and Sunflower (*Helianthus annuus*) Asteraceae were screened against cotton mealy bug during the cotton growing season of 2008 to 2009. Population of cotton mealy bug was calculated from a specific biomass as done by Abbas et al. (2010).

Physio-morphic plant character studies

These plant species were further studied in details for morphological characters for resistance against *P. solenopsis* (Tinsley). Morphological traits of the selected plant species were studied at Integrated Pest Management Laboratory, University of Agriculture, Faisalabad, Pakistan, during the same season. For this purpose, fully mature leaves of tested plant species were selected for the study of the thickness of leaf lamina (µm), trichome density from leaf lamina (per cm^2), as well as length of hair (mm) from the lower side of the leaf. By using Stereoscope binocular microscope, the observations were taken from three different places, whereas, leaf area was determined by using leaf area meter and reading of three observations were averaged for further statistical analysis.

Statistical analysis

The data was analyzed statistically using Statistical Package 5.5 to find the significance of the results within the host genotypes. Means were compared by Duncan multiple range (DMR) test at 5% probability by using Statistical Package 5.5. Pearson's correlation (r) coefficient and stepwise regression analysis was calculated between mealy bug population and morphological characters of plant in order to observe the role and contribution of morphological traits of tested plants in exhibiting resistance to the pest.

RESULTS

Susceptibility of tested plant species to cotton mealy bug (*Phenacoccus solenopsis*)

The mealy bug population among tested host plants during cotton growing season is presented in Table 1. The plant species arranged in descending order with respect to mealy bug population indicate that plant species viz., cotton, brinjal, sunflower, Chinese rose and lantana appeared to be highly susceptible in harboring maximum population of the pest, but leh, peelidhodak, bathu, jangli-haloon, loosenbooti and tandla expressed resistance that had lower mealy bug population (Table 2). All other tested plant species showed intermediate response against mealy bug.

Morphological plant characters

Significant variations were observed in all the morpholo-

Table 1. Analysis of variance regarding susceptibility of host plants against *Phenacoccus solenopsis* during 2008 to 2009 at Punjab, Pakistan.

Source	d.f	Mean square			
		*TD	*HL	*LT	*LA
Plants species	24	88347.35	0.51	0.68	2335.31
Error	50	1754.94	0.015	0.012	30.08
Total	74				

*TD: Trichome density; *HL: hair length; *LT: leaf thickness; *LA: leaf area.

gical plant characters recorded from different plant species with trichome density (F = 50.34; df = 24; p<0.00); hair length (F = 32.6; df = 24; p<0.00); leaf thickness (53.7) and leaf area (F = 77.6; df = 24; p<0.00) (Table 2). The maximum leaf thickness per plant was 2.04 ± 0.23 µm in plant species brinjal, while minimum thickness of leaf was recorded from lehli (0.25 ± 0.02 µm). Cotton, the most favorite host plant of the pest and aksen showed similar leaf thickness. Leaf thickness range of ≤ 0.5 to ≥ 1.5 µm was recorded in plant species Itsit, sunflower, chili, cotton, hazardani, leh, aksun, mohabat booti, bathu, okra, puthkanda, daryibooti, cholai, tandla, gardenia, bakhra, lantana, loosenbooti, peelidhodak, krund, janglihaloon and lehli. The tested plant species "sunflower" possessed the maximum leaf area (120.4 ± 3.2 cm^2) which showed significant difference from all other plant species.

The minimum leaf area was recorded to be that of jangli haloon (0.03 ± 0.006 cm^2). Maximum trichome density per plant was 444 ± 72.4 per cm^2 in sunflower, followed by 411.6 ± 19.6, 399 ± 52, and 391.6 ± 22.0 cm^2, in loosenbooti, okra and aksun respectively; minimum (2.33 ± 1.45 per cm^2) were found in krund, followed by 2.66 ± 1.4, and 3 ± 2.08 per cm^2 in Qulfa and Itsit respectively. The maximum hair length per plant (2.62 ± 0.07 mm) was of sunflower, followed by 2.55 ± 0.03 mm in okra, and 2.53±0.06 mm in both brinjal and cotton.

Correlation of morphological traits with population of *Phenacoccus solenopsis*

The results regarding the correlation coefficient values between population of *P. solenopsis* and morphological plant characters are given in Table 2. These results reveal that leaf area and leaf thickness exerted negative correlation with cotton mealy bug populations, showing r-values of -0.172, and -0.285 respectively. Trichome density per leaf and length of hair showed significant correlation with the pest population and there was positive response on the population of *P. solenopsis*, showing r-values of 0.357* and 0.190 respectively. Leaf thickness and area of leaf was negatively associated with population of mealy bug, while the reverse was true in the case of hair density and hair length.

Stepwise regression models among morphological characters and pest population

The roles of four morphological plant characters under study towards *P. solenopsis* population were worked out by processing the data through step wise regression (Table 3). It is evident from the result that trichome density contributed the maximum individual effect alone 12.71 (X1) in mealy bug population or host plant preference. With the addition of hair length contribution of 2 studied morphological characters, the average observed population of the pest on host plants could be expressed up to 13.95% (X2) in mealy bug population. Similarly, the expectancy of pest population with the contribution of third factor reached up to 23.75 (X3), when the data of leaf thickness were added to the data of hair density and hair length of the host plant leaf. The expectancy of the mealy bug population reached up to 29.27% (X4) when the data on leaf area were computed together with hair density, and length of hair on leaf were shown in the formula:

$$(Y)=48.69+0.073X1-7X2-7.7X3-0.24X4\ (R2=29.27\%)$$

Where, X1 is hair density, X2 is hair length, X3 is leaf thickness and X4 is leaf area. The data regarding individual role of each morphological factor showed that major significant contribution towards mealy bug population was attributed by hair density of leaf vain (12.71%) followed by that of leaf thickness (9.8%) as shown in Table 4.

DISCUSSION

The mealy bug is a polyphagous insect pest (Arif et al., 2009); its host range described by research is variable in Pakistan (Arif et al., 2009; Abbas et al., 2010). ICAC Recorder (2008) recorded it on 22 different plant species whereas Arif et al. (2009) reported the pest in 154 plant species. These plants serve as carriers and feeding link from the pest to the main crop (Abbas et al., 2010; Pandey and Johnson, 2006). *P. solenopsis* has been recorded on members of 31 major plant genera in 13 families (Ben-Dov et al., 2008). Based on the results of the present study, it was found that the population of mealy

Table 2. Susceptibility of plant species to *Phenacoccus solenopsis* Tinsley during 2008 to 2009 at Punjab, Pakistan.

Plant	Mealy bug (Number)	Leaf thickness (µm) ± S.E	Leaf area (cm2) ± S.E	Hair length (mm) ± S.E	Trichome density (Number) ± S.E
Cotton	69.74±10.5^{a}	1.33±0.05^{bc}	33.5±4.13^{cde}	2.53±0.05^{ab}	375±43.3^{a}
Brinjal	62.41±10.0^{ab}	2.04±0.23^{a}	68.7±8.53^{b}	2.53±0.06^{AB}	87±5.2^{bc}
Sunflower	61.83±10.0^{ab}	1.40±0.02^{bc}	120.4±3.2^{a}	2.62±0.07^{a}	411.6±19.6^{a}
Chinese rose	61.1±10.0^{ab}	1.82±0.07^{ab}	37.9±1.27^{cd}	1.7±0.14d^{efg}	14.3±4.8^{c}
Lantana	55.83±9.75^{ab}	0.71±0.04^{def}	17.1±1.18^{def}	2.46±0.09^{abc}	380.6±17.9^{a}
Lehli	49.08±8.2^{b}	0.25±0.028^{f}	1.6±0.05ef	1.83±0.13^{cdefg}	11.33±2.02^{c}
Aksun	45.08±8.0^{b}	1.3±0.05^{bc}	19.9±1.78^{def}	2.23±0.02^{abcd}	391.6±22.0^{a}
Mohabat booti	44.08±7.5^{b}	1.23±0.04^{cd}	60.0±10.9^{bc}	2.23±0.06^{abcd}	252.6±48.9^{ab}
Cholai	41.6±5.5^{b}	0.86±0.04^{de}	14.0±0.48^{def}	2.11±0.05^{abcde}f	14.6±3.38^{c}
Chili	40.91±5.5^{bc}	1.36±0.05^{bc}	9.6±1.38^{def}	1.53±0.14^{efg}	3.33±2.02^{c}
Itsit	38.41±5.2^{bc}	1.72±0.05^{abc}	0.5±0.04^{ef}	1.606±0.04^{defg}	3±2.08^{c}
Okra	36.6±5.15^{bc}	1.10±0.06^{cd}	25.4±3.9^{def}	2.55±0.03^{ab}	399±52^{a}
Qulfa	34.16±5.1^{bc}	1.78±0.03^{ab}	0.44±0.034^{f}	1.38±0.04^{g}	2.66±1.4^{c}
Hazardani	28.16±4.5^{c}	1.33±0.04^{bc}	0.1±0.01^{fg}	1.51±0.05^{fg}	8.66±1.2^{c}
Bakhra	26.08±4.5^{c}	0.72±0.02^{def}	3.3±0.63ef	2.42±0.05^{abc}	291±30.2^{ab}
Gardenia	24.49±4.5^{c}	0.79±0.04^{def}	14.5±1.12^{def}	1.9±0.05bcd^{efg}	20±4.9^{c}
Daryibooti	20.49±4.25^{c}	0.89±0.02^{de}	0.6±0.04^{ef}	2.17±0.04^{abcde}	28.66±8.2^{c}
Puthkanda	14.83±4.05^{cd}	1.00±0.04^{cd}	1.47±0.19^{ef}	2.27±0.06^{abcd}	25.66±4.8^{c}
Krund	11.41±4.00^{d}	0.37±0.025^{ef}	7.0±0.76^{ef}	1.44±0.05^{g}	2.33±1.45^{c}
Leh	10.74±3.75^{d}	1.31±0.04^{bc}	12.8±0.86^{def}	1.83±0.04^{cdefg}	13.3±6.0^{c}
Peelidhodak	7.08±3.55^{de}	0.61±0.06^{def}	17.2±1.16^{def}	1.96±0.02^{abcdefg}	5.33±2.0^{c}
Bathu	6.41±2.5^{de}	1.17±0.06^{cd}	6.4±0.26^{Ef}	1.45±0.02^{fg}	14.6±1.4^{c}
Janglihaloon	4.74±2.0^{de}	0.34±0.03^{ef}	0.03±0.006^{g}	2.42±0.04^{abc}	22.3±6.35^{c}
Loosenbooti	3.83±1.75^{de}	0.68±0.02^{def}	0.8±0.04^{ef}	2.46±0.09^{abc}	444±72.4^{a}
Tandla	1.57±1.00^{e}	0.84±0.04^{de}	4.45±0.51^{ef}	1.64±0.05^{defg}	8±4.3^{c}

Mean followed by same letter(s) in a column are not significantly different by DMRT P = 0.05.

bug was maximum on cotton, brinjal, sunflower, Chinese rose and lantana. These findings are in agreement to the findings of Ben-Dov et al. (2008) and Aheer et al. (2009) who had similar results. The information regarding maximum prevalence of *P. solenopsis* on Chinese rose (*Hibiscus chinensis*), okra (*Abelmoschus esculentus* (L.), Malvaceae), sunflower (*Helianthus annuus* L., Compositae), brinjal (*Solanum melongena* L., Solancaeae), tomato (*Lycopersicon esculentum*) and other weeds throughout the year in Pakistan was shared in popular articles for the awareness of all concerned (Abbas et al., 2007). Another study documented all the hosts (154 species) on which cotton mealy bug was found incidentally or in low, medium or high intensity in the agro-ecological conditions of Multan, Pakistan (Arif et al., 2009).

The results of this study revealed that population of cotton mealy bug among tested plant species was variable due to host plant mechanisms particularly morphological factors which contribute significantly towards host plant resistance, which is an important component of pest management. The indication of resistance against insect pest and diseases is measured either by the occurrence of a population of insect pests on the plant, observing damage due to feeding and oviposition or by providing plants for overall development of offspring (Abrahamson and Weiss, 1997); however, insect selection and utilization of a host plant depends upon both biophysical and biochemical factors (Bernays and Chapman, 1994). The additive effects of these factors enable the plants to provide barrier to normal feeding or by repelling insect pests via volatile exudates (Van- Emden and Peakall, 1996).

Although none of the tested plant species were reported as immune, they have low pest population progress when compared to susceptible host plants. The study confirms that plant species tandla and loosenbooti' are highly resistant to cotton mealy bug (*P. solenopsis*). These results are in partial agreement with the findings of Heng-Moss et al. (2002) who screened buffalo grass germplasm Cody, Tatanka, Bonnie Barae, NE91-118 Against chinch bug, Blisus occiduus and reported that NE91-118 possessed resistance against pest. Based on the present results, a positive association was observed

Table 3. Correlation studies between *Phenacoccus solenopsis* and morphological traits of plants at Punjab, Pakistan.

Variable	Cotton mealy bug	Hair density	Hair length	Leaf thickness	Leaf area
Cotton mealy bug	1.000				
Hair density	0.357*	1.000			
Hair length	0.190	0.742**	1.000		
Leaf thickness	-0.285	0.008	-0.113	1.000	
Leaf area	-0.172	0.459*	0.460*	0.413*	1.000

** Correlation is significant at the 0.01 level; *correlation is significant at the 0.05 level.

Table 4. Step wise regression of *Phenacoccus solenopsis* and morphological traits of plants at Punjab, Pakistan.

Regression model	Overall effect	Individual effect
Y1=26.38+0.044X1	12.71	12.71
Y2=41.58+0.059X1 -8X2	13.95	1.24
Y3=64.47+0.067X1-13X2-14.1X3	23.75	9.8
Y4=48.69+0.073X1-7X2-7.7X3-0.24X4	29.27	5.52

X1: Trichome density; X2: HAIR length; X3: leaf thickness; X4: leaf area.

between hair density and hair length to mealy bug population; results are supported by Johnson-Cicalese et al. (1998) who found that mealy bug damage ratings were positively correlated with pubescence level because hairs may provide foothold for early instar mealy bugs, whereas leaf thickness, leaf size and leaf width responded negatively with mealy bug population. These results are in partial agreement with Baker et al. (1981), Reinert (1982), Smith et al. (1994) and Heng-Moss et al. (2002) who suggested that plant defenses result in reduced oviposition, extended life cycle and pest mortality. The morphological factors influence the nutrition and/or ovipostion of the pest-insects by limiting the amount of feeding and/or oviposition (Dhaliwal and Arora, 2003). These mechanisms of resistance have proved to be effective tools against the insect pests in many crops and vegetables (Eigenbrode and Trumble, 1994; Johnson - Cicalese et al., 1998; Smith et al., 1994; Felkl et al., 2005). However, Bartlett and Clancy (1972) stated that an integration of chemical, biological and mechanical control is essential for long-term management of mealy bugs.

Conclusion

P. solenopsis is a polyphagous insect pest. Among tested host plants, the most favorable host plants of mealy bug are cotton, brinjal, sunflower, Chinese rose and lantana, but the least preferred plants are tandla and loosen booti. Plant characters including trichome density and hair length favor mealy bug population but leaf size, leaf width and leaf thickness exert negative effect on pest population.

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