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A record of host plants of mealybug, *Phenacoccus solenopsis* Tinsley for devising ecofriendly management strategies

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ABSTRACT

A record of 166 host plants of mealybug *Phenacoccus solenopsis* Tinsley belonging to 51 families comprising 78 weeds, 27 ornamentals, 18 trees, 17 vegetables, 12 field crops, 8 fruit plants and 4 spice plants was made in three cotton agro-ecosystems of India. Maximum number of host plants were recorded from Malvaceae (10.24%) followed by Asteraceae (9.64%), Fabaceae (9.04%), Amaranthaceae (6.63%), Euphorbiaceae (6.63%), Solanaceae (6.02), Poaceae (4.22) and Lamiaceae (3.61%). Quite a high number of host plants compared to cotton season were recorded during off season in North, Central, South and across India. Among the host plants, *Hibiscus rosa-sinensis* Linn., *Abutilon* spp., *Malvastrum coramandelinum* Garcke (Malvaceae), *Lantana camara* (Verbenaceae); *Withania somnifera* (Solanaceae) harboured this pest round the year and acted as a persistent source for spread of mealybug to cotton and other crops. Besides cotton, papaya and tomato; cultivated crops viz., sunflower, brinjal, cluster bean and green gram were found to be severely infested in North Zone; chilli, okra, brinjal and potato in Central Zone while potato in South Zone. Promoting pigeon pea intercropping and discouraging weeds especially *Acmella uliginosa* (SW.) Cass., *Helianthus* sp., *Parthenium hysterophorus* Linn., *Pentanema indicum* (L.) Y. Ling, *Taraxacum officinale* Linn., *Xanthium strumarium* Linn. (Asteraceae); *Abelmoschus ficulneus* (Linn.), *Abutilon indicum* Sweet, *Malvastrum coramandelinum* G., *Sida cordifolia* Linn. (Malvaceae); *Euphorbia heterophylla* Linn., *Euphorbia hirta* Linn., *Phyllanthus amarus* Linn. (Euphorbiaceae); *Corchorus trilocularis* Linn., *Triumfetta rhomboidea* Linn. (Tiliaceae), *Trianthema portulacastrum* Linn. (Aizoaceae), *Asteracantha longifolia* Nees (Acantheaceae), *Digera muricata* (Linn.) (Amaranthaceae), *Clitoria ternatea* Linn. (Fabaceae), *Boerhavia diffusa* Choisy. (Nyctaginaceae) and *Portulaca oleracea* Linn. (Portulacaceae) during cotton season as well as off-season as a part of cultural component of Integrated Pest Management holds the key in the ecofriendly mealybug suppression besides avoiding other malvaceous and solanaceous crops in the vicinity of previously mealybug affected fields.

Key words : Mealybug, *Phenacoccus solenopsis*, Host plants, Cotton agro-ecosystems, India

Widespread outbreak of solenopsis mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) on cotton in India during 2007 (Nagrare *et al.* 2009) caused economic damage ranging from US \$16-20 million while reducing yields up to 50% in affected cotton fields. Infestation of *P. solenopsis* was seen over large areas with different cropping systems across the three cotton growing regions of India aggressively. In the absence of comprehensive management strategies pesticide companies promoted the sale of pesticides. Pesticides

worth US \$ 140 million in a progressive state like Punjab alone was sold within three months time during 2007 (Dutt, 2007) to save the standing crops from the dreaded pest. A similar situation was also seen adjoining states like Haryana, Rajasthan and rest parts of the country. Among the different pesticides carbaryl, thiodicarb of carbamate group; quinalphos, profenophos, chlorpyrifos and acephate of organophosphate group and their cocktails were used widely for the control of mealybugs. Some of the insecticides with high eco-toxicity such as methyl parathion classified by the World Health Organization (WHO) as Class 1a: (extremely hazardous), monocrotophos, dichlorvos, methomyl, triazophos and metasystox (Class 1b:

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highly hazardous) were also recommended (Tanwar *et al.* 2007, Jhala and Bharpoda, 2008;) despite the ecological repercussions. Farmers were ignored of the alternate host plants that harboured the pest near cotton fields and on road sides on weeds which accounted for spread of mealybugs in cotton fields.

P. solenopsis is known for its high reproduction capacity producing 812 offsprings per female parthenogenetically with 95% female progeny on host cotton with several generations in a year (Vennila *et al.* 2010). The pest is polyphagous in nature with wide host adaptability in different climatic conditions around globe; hence they establish and spread readily on other crops of economic importance. In the country of origin the US, host range of *P. solenopsis* includes several ornamental plants, fruit crops, vegetables and field crops belonging to at least 14 families. In other countries *P. solenopsis* was reported to cause damage on *Solanum muricatum* (Ait.) (Solanaceae) in Chile (Larraín, 2002), *Solanum lycopersicum* Linn., (Solanaceae) in Brazil (Culik and Gullan, 2005), false ragweed *Ambrosia tenuifolia* Spreng. (Asteraceae) in Argentina (Granara de Willink, 2003), *Hibiscus rosa-sinensis* (Malvaceae) in Nigeria (Akintola and Ande, 2008), ornamentals, vegetable crops and weeds in Sri Lanka (Prishanthini and Laxmi, 2009). Its occurrence on a wide range of host plants-154 plant species including field crops, vegetables, ornamentals, weeds, bushes and plants; most of these belong to the families Malvaceae, Solanaceae, Asteraceae, Euphorbiaceae, Amaranthaceae and Cucurbitaceae from Pakistan was documented by Arif, *et al.* 2009. Economic damage on cotton, brinjal, okra, tomato, sesame, sunflower and China rose was recorded. A comprehensive report also indicated that 183 host plants of 52 families occurred worldwide (Ben-Dov *et al.* 2009). A recent study on CLIMEX modelling indicated that *P. solenopsis* presents a significant threat to agriculture and horticulture in many tropical and subtropical countries, posing severe threat to cotton production in Asia; the climate of many of these cotton-producing areas is at least as suitable for *P. solenopsis* colonization and establishment as is its native territory in the U.S.A. (Wang *et al.* 2010). This study also revealed that economic impact of *P. solenopsis* that has become a major problem not only in Asian countries, but its spread suggests a significant threat to cotton production worldwide. With inherent considerable plasticity, morphology and ability to live under a wide variety of environmental

conditions by *P. solenopsis* (Hodgson *et al.* 2008), identification and recording of host plants that support its multiplication and spread prior to its shift onto crop plants (Nagrare *et al.* 2009) assume significance. This is important to help initiate prophylactic measures that suppress population of mealybug – eg. discouraging alternate host plants especially during off-season and initiation of season. Thus far, there are no comprehensive studies on the record of host plants of *P. solenopsis* in India. Therefore, it was felt necessary to identify and record the host plant species that play a significant role in carry-over of this pest to cotton. Management of alternate host plants can be incorporated as an essential tool of cultural management while devising eco-friendly strategies for the management of mealybugs so that quantum of pesticide load can be minimized in the ecosystem. This will enormously encourage proliferation of natural enemies especially *Aenasius bambawalei* Hayat (Hayat, 2009) which exerts a natural control on the pest.

MATERIALS AND METHODS

The study was conducted during cotton season and off-seasons of years 2008-09 and 2009-10 in three representative states of cotton growing agro-ecosystems viz. Haryana of North zone (cotton–wheat cropping system), Maharashtra of Central zone (cotton + pigeon pea-fallow cropping system) and Tamil Nadu of South zone (cotton + pulse cropping system). In the North zone, cotton is grown between May to October (almost irrigated). Central zone is rainfed where cotton is grown from June to February (23% area irrigated), and accounts for 60% of the total cotton area of India. Cotton growing period is September to April in South zone (40% area irrigated). Observations were recorded by visiting infested plants at random in each of these cotton agro-ecosystems. Observations encompassed cultivated cotton fields, field boundaries, road-side and near water source to the agro eco-system. Maximum number of plants in a grade was accorded based on visuals observing severity of infestation by *P. solenopsis* for a particular host plant. Severity of infestation used the following grades.

Grade I (G-I) : About 1-10 mealybugs scattered over the plant

Grade II (G-II) : One branch infested heavily with mealybugs

Grade III (G-III) : Two or more branches infested heavily with mealybugs, and up to 50% plant infested.

Grade IV (G-IV) : Plant infested severely with mealybugs, preferred host.

The infested host plants were categorized according to the plant type (weeds, ornamentals, trees, vegetables, field crops, fruit plants and spices). Each recorded host plant was classified according to the infestation grade (G-I to G-IV); during and off-season occurrence; growth stage of infested host plant (vegetative, flowering and maturity) and location of the host (within field, field boundary, road side, near water source) for assessment.

RESULTS AND DISCUSSION

Host plants of *P. solenopsis* were classified into major families. Share of each family, infestation stage, season and off-season occurrence and location of the host plants is summarised in Table 1. While grade wise infestations on hosts plants G-IV, G-III, G-II and G-I are summarized in Tables 2, 3, 4 and 5, respectively. Graphical figures indicating host distribution, share of families and gradewise host distribution are given as Figs. 1, 2 and 3 respectively.

Total number of hosts and botanical families : Agro-ecosystem wise host distribution

North zone : Seventy host plants belonging to 28 botanical families were recorded from plant categories of weeds (26), ornamentals (11), trees (10), vegetables (12), field crops (5), fruit plants (5) and a spice plant. Maximum host plants were recorded from Solanaceae (14.28%), followed by Malvaceae (12.85%). Asteraceae and Fabaceae had share of 7.14% and 4.28% respectively while Amaranthaceae and Poaceae had equal share of 5.71%. Euphorbiaceae had a marginal share (2.85%). Remaining belong to diverse family group (37.18%). Seventeen host plants recorded G-IV infestation, 13 host plants demonstrated G-III while 12 and 28 host plants recorded G-II and G-I, Respectively.

Central zone : Diverse host plants of *P. solenopsis* have been recorded in Central India's rainfed cotton agro-ecosystem, comprising 129 host plants belonging to 45 families out of which 64 were weeds, 17 ornamentals, 12 vegetables, 11 trees, 9 field crops, 7 fruit plants and 5 spice plants. The decreasing order of host plants according to families was Asteraceae (10.85%) > Malvaceae (10.07%) > Fabaceae (8.52%) > Solanaceae (6.20%) > equal share of Amaranthaceae and Euphorbiaceae (5.42%) > Lamiaceae (4.65%) > Poaceae (3.10%). Remaining

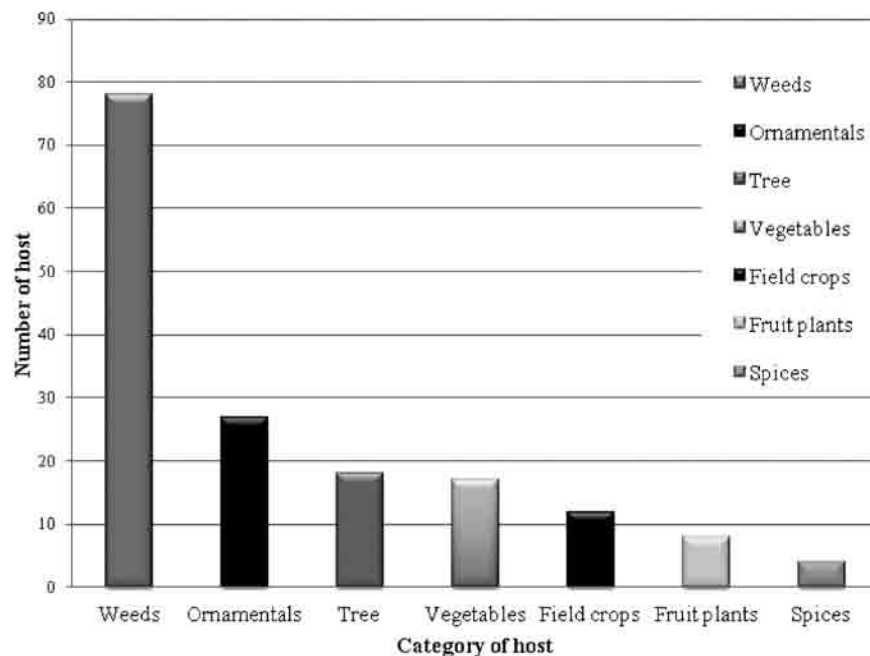


Fig. 1. Number of hosts distributed into different categories

Table 1. Cotton agro-ecosystem wise classification of host plants of *P. solenopsis* in to plant type, botanical families, share of major families and grade wise host distribution.

Sl. No.	Particulars of host plants	Cotton agro-ecosystems			India
		North Zone	Central Zone	South Zone	
1.	Total records	70	129	104	166
a.	Weeds	26	64	38	78
b.	Ornamentals	11	17	20	27
c.	Tree	10	11	15	18
d.	Vegetables	12	12	10	17
e.	Field crops	5	9	11	12
f.	Fruit plants	5	7	7	8
g.	Spices	1	5	3	4
2.	Families of host plants	28	45	41	51
3.	% Share of major families				
	Amaranthaceae	5.71(4)*	5.42(7)	7.69 (8)	6.63 (11)
	Asteraceae	7.14 (5)	10.85 (14)	7.69 (8)	9.64 (16)
	Cucurbitaceae	10.00 (7)	2.32 (3)	3.84 (4)	4.21 (7)
	Euphorbiaceae	2.85 (2)	5.42(7)	9.62 (10)	6.63 (11)
	Fabaceae	4.28 (3)	8.52 (11)	12.50 (13)	9.04 (15)
	Lamiaceae	-	4.65 (6)	2.88 (3)	3.61 (6)
	Malvaceae	12.85 (9)	10.07 (13)	7.69 (8)	10.24 (17)
	Poaceae	5.71 (4)	3.10 (4)	0.96 (1)	4.22 (7)
	Solanaceae	14.28 (10)	6.20 (8)	7.69 (8)	6.02 (10)
	Others	37.18 (26)	43.45 (56)	39.44 (41)	39.76(66)
4.	Grade wise host distribution				
	G-IV	17	30	17	39
	G-III	13	10	11	27
	G-II	12	29	27	46
	G-I	28	60	50	87
5.	Hosts of cotton season	43	63	51	100
6.	Off season hosts	45	88	80	120
7.	G-IV hosts of cotton season	14	23	14	34
8.	G-IV hosts of off season	10	20	11	24
9.	G-IV hosts in both during season and off season	8	13	8	19
10.	G-IV hosts as cultivated plants	9	11	7	14
11.	Host infested in all the stages i.e. vegetative, flowering and maturity	41	51	42	76
12.	Hosts as cultivated crops (Economic crops)	23	34	31	43
13.	Location of G-IV Hosts other than cultivated crops				
	Field	5	15	7	18
	Field boundaries	2	14	8	17
	Road side	7	14	10	19
	Water Source	3	4	5	9

*In parenthesis no. of hosts

hosts (43.45%) belonged to other families. Thirty host plants were G-IV; while 10, 29 and 60 fell into category G-III, G-II and G-I, respectively.

South zone : South India's partial irrigated cotton agro-ecosystem harboured 104 hosts belonging

to 41 botanical families containing 38 weeds, 20 ornamentals, 15 trees, 11 field crops, 10 vegetables, 7 fruit plants and 3 spice plants. Maximum host plants were recorded from Fabaceae (12.50%) followed by Euphorbiaceae (9.62%). Equal share

Record of host plants of *Phenacoccus solenopsis*

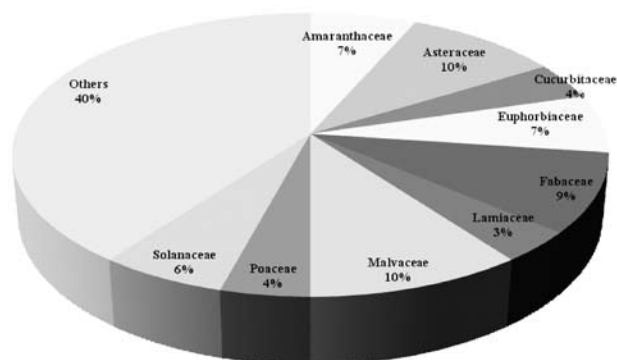


Fig. 2. Per cent share of families of host plants of *P. solenopsis*

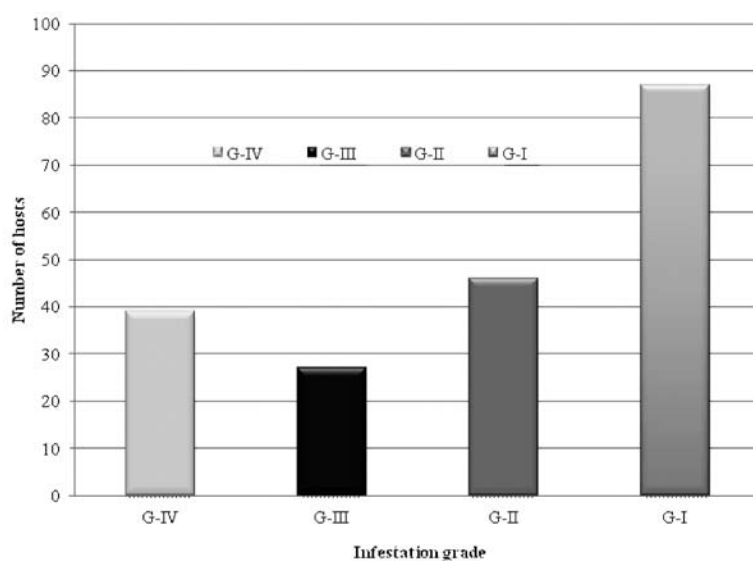


Fig. 3. Grade wise host distribution

Table 2. G-IV (Severely infested) host plants of *P. solenopsis*.

Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3 ^s	Growing season ^{##}	Growth stage*	Location of the host**
	Aizoaceae						
1.	<i>Trianthema portulacastrum</i> Linn.	Giant pigweed	Weed	1, 2, 3	S, Os	v, f, m	F, B, R W
	Acantheceae						
2.	<i>Asteracantha longifolia</i> Nees	Water spiny ball	Weed	2	S	v, f, m	F, B, R
	Amaranthaceae						
3.	<i>Digera muricata</i> (Linn.)	False amaranth	Weed	2	S	v, f, m	F, B
	Asteraceae						
4.	<i>Acmella uliginosa</i> (SW.) Cass.	Marsh para cress	Weed	2	S, Os	v, f	F,B
5.	<i>Helianthus debilis</i> Linn.	Beach sunflower	Ornamental	1	S	f, m	F
6.	<i>Helianthus</i> sp.	Wild sunflower	Weed	1	S, Os	v, f, m	F, R, W
7.	<i>Parthenium hysterophorus</i> Linn.	Congress grass	Weed	1, 2, 3	S, Os	v, f, m	F,B,R
8.	<i>Pentanema indicum</i> (L.) Y. Ling	Sonkadi	Weed	2	Os	f, m	F,B

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3 ^s	Growing season ^{##}	Growth stage*	Location of the host**
9.	<i>Taraxacum officinale</i> Linn.	Dandelion	Weed	2	Os	v, f	R
10.	<i>Xanthium strumarium</i> Linn. Caricaceae	Common cocklebur	Weed	1, 2	S	v, f, m	F, R, W
11.	<i>Carica papaya</i> Linn. Euphorbiaceae	Papaya	Fruit plant	1, 2, 3	S, OS	v, f, m	F
12.	<i>Euphorbia heterophylla</i> Linn	Wild Poinsettia	Weed	2, 3	S, Os	v, f, m	F,B,R,W
13.	<i>Euphorbia hirta</i> Linn.	Common spurge	Weed	2, 3	Os	v, f, m	F,B,R,W
14.	<i>Phyllanthus amarus</i> Linn. Fabaceae	Niruri	Weed	3	S,Os	v, f	F,B,R
15.	<i>Clitoria ternatea</i> Linn.	Butterfly Pea	Weed	2	Os	v, f, m	F, R
16.	<i>Cyamopsis tetragonoloba</i> (Linn.)	Cluster bean	Vegetable	1	S	v, f, m	F
17.	<i>Vigna radiata</i> Linn. Malvaceae	Green gram	Field crop	1	S	v, f, m	F
18.	<i>Abelmoschus esculentus</i> Linn.	Okra, Lady's finger	Vegetable	1, 2	Os	v, f, m	F
19.	<i>Abelmoschus ficulneus</i> (Linn.)	Native rosella	Weed	2	S, Os	f, m	F, B
20.	<i>Abutilon indicum</i> Sweet	Indian mallow	Weed	2, 3	S, Os	v, f, m	F, B, R, W
21.	<i>Gossypium arborium</i> Linn.	Indian cotton	Field crop	1, 2, 3	S	v, f, m	F
22.	<i>Gossypium barbadense</i> Linn.	Egyptian cotton	Field crop	3	S	v, f, m	F
23.	<i>Gossypium herbaceum</i> Linn.	Mexican cotton	Field crop	1, 2	S	v, f, m	F
24.	<i>Gossypium hirsutum</i> Linn.	American cotton	Field crop	1, 2, 3	S	v, f, m	F
25.	<i>Hibiscus rosa-sinensis</i> Linn.	China rose	Ornamental	1, 2, 3	S, Os	-	R
26.	<i>Hibiscus sabdariffa</i> Linn.	Roselle	Vegetable	2	S, Os	v, f, m	F
27.	<i>Malvastrum coramandelinum</i> G.	False mallow	Weed	2	S, Os	v, f, m	F,B
28.	<i>Sida cordifolia</i> Linn. Nyctaginaceae	Heart-leaf sida	Weed	1	S, Os	v, f, m	R
29.	<i>Boerhavia diffusa</i> Chois. Portulacaceae	Red hogweed	Weed	2	S, Os	v, f	F,B, R
30.	<i>Portulaca oleracea</i> Linn. Rutaceae	Purslane	Weed	3	S	f, m	B, R, W
31.	<i>Murra koenigii</i> Spreng Solanaceae	Curry leaf	Spice	2, 3	Os, S	-	B, R
32.	<i>Capsicum annum</i> Linn.	Chilly	Spice	2	S	v, f, m	F
33.	<i>Lycopersicon esculentum</i> Mill.	Tomato	Vegetable	1, 2, 3	S, Os	v, f, m	F
34.	<i>Solanum melongena</i> Linn.	Brinjal	Vegetable	1, 2	S, Os	v, f, m	F
35.	<i>Solanum tuberosum</i> Linn.	Potato	Vegetable	2, 3	S	v, f, m	F
36.	<i>Withania somnifera</i> (L.) Dunal. Tiliaceae	Winter cherry	Ornamental	1	S, Os	v, f, m	R, W
37.	<i>Corchorus trilocularis</i> Linn.	Wild jute	Weed	2, 3	S, Os	v, f, m	F,B,R
38.	<i>Triumfetta rhomboidea</i> Linn. Verbenaceae	Chinese burr	Weed	2			
39.	<i>Lantana camara</i> Linn.	Lantana	Ornamental	2, 3	Os	-	B,R, W

^sCotton agro-ecosystems: ¹Irrigated cotton agro-ecosystem of North India, ²Rainfed cotton agro ecosystem of Central India and ³Partially irrigated cotton agro-ecosystem of South India

^{##}Growing season: S = Cotton season. Os = Off-season

*Growth stage of infested hosts: v = vegetative, f = flowering and m = maturity, **Location of hosts: F = field, B = field boundary, R = road side, W = near water source, (Legend common for Tables 2-5)

Table 3. G-III infested host plants of *P. solenopsis*.

Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3\$	Growing season##	Growth stage*	Location of the host**
Amaranthaceae							
1.	<i>Achyranthus aspara</i> Linn.	Devil's horsewhip	Weed	1, 2, 3	S, Os	v, f, m	F,B, R W
2.	<i>Aerva lanata</i> (L.) Juss	Mountain knot grass	Weed	2	S	v, f	F,B,R
3.	<i>Alternanthera paronychioides</i> A.St.Hil.	Smooth chaff flower	Weed	2	S,Os	v, f, m	F,B,R,W
Annonaceae							
4.	<i>Annona squamosa</i> Linn.	Custard apple	Fruit plant	2, 3	Os	-	R
Apocynaceae							
5.	<i>Nerium oleander</i> Linn.	Oleander	Ornamental	2, 3	S, Os	-	R
Asteraceae							
6.	<i>Chrysanthemum indicum</i> Linn.	Chrysanthemum	Ornamental	1	S, Os	v, f, m	-
7.	<i>Tagetes erecta</i> Linn.	Marigold	Ornamental	1	S	v, f, m	F
8.	<i>Tridax procumbens</i> Linn.	Tridax daisy	Weed	2, 3	Os	v, f	F,B,R
Capparidaceae							
9.	<i>Cleome viscosa</i> Linn.	Yellow spider flower	Weed	3	S,Os	v, f, m	F,B,R
Commelinaceae							
10.	<i>Commelina benghalensis</i> Linn	Whiskered commelina	Weed	2, 3	Os	f, m	R
Convolvulaceae							
11.	<i>Convolvulus arvensis</i> Linn.	Field bind weed	Weed	2, 3	Os	v, f, m	F, B, R,W
Euphorbiaceae							
12.	<i>Euphorbia granulate</i> Forssk	Hazardani	Weed	1	Os	v, f, m	R
Fabaceae							
13.	<i>Gliricidia sepium</i> (Jacq.) Kunthex. Walp.	Gliricidia	Tree	3	S, Os	v, f, m	F, R
Malvaceae							
14.	<i>Abutilon indicum</i> Sweet	Indian mallow, Country mallow	Weed	1	S, Os	v, f, m	B, R
15.	<i>Alcea rosea</i> Linn.	Hollyhock	Ornamental	1	Os	-	R
16.	<i>Althaea</i> sp.	Hollyhock	Ornamental	1	Os	-	R
17.	<i>Malvastrum coramandelinum</i> Garcke	False mallow	Weed	3	Os	v, f, m	F,B
Mimaceae							
18.	<i>Acacia</i> spp.	Acacia	Tree	1	S, Os	v, f, m	R
Moraceae							
19.	<i>Ficus indica</i> (L.) Mill.	Indian fig	Tree	1	S, Os	v, f, m	R
Phyllanthaceae							
20.	<i>Phyllanthus fraternus</i> Linn.	Gulf leaf-flower	Weed	2	Os	f, m	B
Portulacaceae							
21.	<i>Portulaca grandiflora</i> Hook	Moss-rose	Weed	1	S	v, f, m	F, R
Solanaceae							
22.	<i>Datura fastuosa</i>	Datura	Weed	1	S, Os	v, f, m	R, W
23.	<i>Solanum melongena</i> Linn.	Brinjal, Egg plant	Vegetable	3	S	v, f, m	F
24.	<i>Solanum tuberosum</i> Linn.	Potato	Vegetable	1	S, Os	v, f, m	F

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3\$	Growing season##	Growth stage*	Location of the host**
Verbenaceae							
25.	<i>Duranta erecta</i> Linn.	Sky flower	Weed	2	S,Os	-	R
26.	<i>Tectona grandis</i> Linn. F.	Teak	Tree	3	S, Os	-	R
Zygophyllaceae							
27.	<i>Tribulus terrestris</i> Linn.	Puncture vine, Yellow vine	Weed	1	S	v, f, m	F, B, R W

Table 4. G-II infested host plants of *P. solenopsis*.

Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3\$	Growing season##	Growth stage*	Location of the host**
Acantheceae							
1.	<i>Rungia repens</i> Nees.	Creeping rungia	Weed	2	S	v, f, m	F, B, R
Amaranthaceae							
2.	<i>Alternanthera paronychioides</i> A.St.Hil.	Smooth chaff flower	Weed	3	S,Os	v, f, m	F,B,R,W
3.	<i>Alternanthera sessilis</i> (Linn) R. Br.	Joyweed	Weed	2, 3	Os	f, m	R
4.	<i>Amaranthus viridis</i> Linn.	Green amaranth	Weed	2, 3	S	v, f, m	F, B
5.	<i>Celosia argentea</i> Linn.	Silver cockscomb	Ornamental	2, 3	S	f, m	F, R
6.	<i>Celosia cristata</i> Linn.	Cockscomb	Ornamental	3	S, Os	f, m	R
7.	<i>Digera muricata</i> (Linn.)	False amaranth	Weed	1	S	v, f, m	F, B
Apiaceae							
8.	<i>Centella asiatica</i> Linn.	Indian pennywort	Weed	2, 3	S, Os	-	F, B, R
9.	<i>Daucus carota</i> Linn.	Carrot	Vegetable	2	Os	v, f, m	F
Asteraceae							
10.	<i>Chrysanthemum indicum</i> Linn.	Chrysanthemum	Ornamental	2,3	S	v, f, m	F
11.	<i>Helianthus annuus</i> Linn.	Sunflower	Field crop	2,3	S	v, f, m	F
12.	<i>Tagetes erecta</i> Linn.	Marigold	Ornamental	2, 3	S, Os	v, f, m	F,B , R
13.	<i>Taraxacum officinale</i> Linn.	Dandelion	Weed	3	S,Os	v, f	F,R
Brassicaceae							
14.	<i>Raphanus raphanistrum</i> Linn.	Wild radish	Weed	1	Os	v, f, m	F
Capparidaceae							
15.	<i>Cleome viscosa</i> Linn.	Yellow spider flower	Weed	2	Os	v, f, m	F, R
Chenopodiaceae							
16.	<i>Beta vulgaris</i> Linn.	Sugarbeet	Vegetable	2	S	f, m	F
17.	<i>Spinacea oleracea</i> Linn	Spinach	Vegetable	2	S, Os	v	F,B
18.	<i>Chenopodium albam</i> Linn.	Pigweed	Weed	2, 3	S	f, m	F, R
Convolvulaceae							
19.	<i>Ipomoea indica</i> Linn..	Morning glory plant	Weed	2, 3	Os	-	W
Cucurbitaceae							
20.	<i>Citrullus lanatus</i> (Thumb) Mansf.	Watermelon	Vegetable	2, 3	Os	f, m	F

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3\$	Growing season##	Growth stage*	Location of the host**
Euphorbiaceae							
21.	<i>Croton sparciflorum</i> Morong	Croton	Ornamental	2, 3	Os	-	F
22.	<i>Phyllanthus amarus</i> Linn.	Niruri, Otheite	Weed	2	S	v, m	F,B
Fabaceae							
23.	<i>Clitoria ternatea</i> Linn.	Butterfly Pea	Weed	3	Os	v, f, m	F, R
24.	<i>Cyamopsis tetragonoloba</i> (Linn.) Taub.	Cluster bean	Vegetable	2, 3	S	v, f, m	F
25.	<i>Leucaena leucocephala</i> Linn.	Wild tamarind	Tree	3	Os	-	R
26.	<i>Prosopis juliflora</i> Linn.	Algaroba, Vilayat babul	Tree	2, 3	S	-	R
Malvaceae							
27.	<i>Abelmoschus esculentus</i> Linn.	Okra, Lady's finger	Vegetable	3	Os	v, f, m	F
28.	<i>Abelmoschus manihot</i> Linn.	Yellow hibiscus	Weed	2, 3	Os	-	R
29.	<i>Abutilon hirtum</i> (Lam) Sweet var. <i>heterotrichum</i> (Hochst. Ex. Mattei)	Indian mallow, Country mallow	Weed	2	Os	v, f, m	R
30.	<i>Abutilon theophrasti</i> Sweet	Velvetleaf, China jute	Weed	2	Os	v, f, m	F, B
Moraceae							
31.	<i>Ficus religiosa</i> Linn.	Peepal, holy plant	Tree	1	Os	-	R
Moringaceae							
32.	<i>Moringa oleifera</i> Linn.	Drumstick plant	Tree	2, 3	S	-	R
Myrtaceae							
33.	<i>Melaleuca leucadendron</i> Linn	Bottle brush	Tree	3	Os	-	R
Papaveraceae							
34.	<i>Argemone mexicana</i> Linn.	Mexican prickly poppy	Weed	2, 3	Os	v, f, m	B, R
Poaceae							
35.	<i>Acrachne racemosa</i> (B.Heyne ex. Roemer & Schult)	Makhra grass	Weed	1	S	v, f, m	F, B, R, W
36.	<i>Eleusine indica</i> (L.) Gaertn.	Indian cowfoot grass	Weed	1	Os	v, f, m	F, B, R, W
Punicaceae							
37.	<i>Punica granatum</i> Linn.	Pomegranate	Fruit plant	1	S, Os	-	B
Rhamnaceae							
38.	<i>Ziziphus mauritiana</i> Lamk.	Ber	Fruit plant	1	S, Os	-	F
Sapindaceae							
39.	<i>Cardiospermum halicacabum</i> Linn.	Balloon vine	Weed	2	Os	f, m	B, R
Solanaceae							
40.	<i>Capsicum annum</i> Linn.	Chilly	Spice	1, 3	S	v, f, m	F
41.	<i>Datura metel</i> Linn.	Devil's trumpet	Weed	1, 2, 3	Os	f, m	B
42.	<i>Solanum nigrum</i> Linn.	Black-berry night shade	Weed	1, 2, 3	S, Os	v, f, m	F, B, R, W

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3\$	Growing season##	Growth stage*	Location of the host**
43.	<i>Solanum virginianum</i> Linn. Verbenaceae	Thorny nightshade, Yellow berried	Weed	2, 3	S,	v, f, m	R
44.	<i>Lantana camara</i> Linn.	Lantana	Ornamental	1	S	-	R,W
45.	<i>Tectona grandis</i> Linn. F. Vitaceae	Teak	Tree	2	Os	-	R
46.	<i>Vitis vinifera</i> Linn.	Grape	Fruit plant	1	Os	-	F

Table 5. G-I infested host plants of *P. solenopsis*.

Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3\$	Growing season##	Growth stage*	Location of the host **
	Acantheceae						
1.	<i>Crossandra infundibuliformis</i> Linn. Amaranthaceae	Crossandra	Ornamental	2,3	S, Os	f	F
2.	<i>Alternanthera cruentus</i> Linn.	Red amaranth	Weed	1	S	v	R
3.	<i>Digera muricata</i> (Linn.)	False amaranth	Weed	3	S	v, f, m	F,B
4.	<i>Gomphrena globosa</i> Linn.	Bachelors button	Ornamental	3	S	v, f	R, F, B
5.	<i>Rumex retroflexus</i> Linn. Anacardiaceae	Wild spinach	Weed	1	Os	v, f, m	W
6.	<i>Mangifera indica</i> Linn. Apiaceae	Mango	Fruit plant	2, 3	Os	-	R
7.	<i>Foeniculum vulgare</i> Miller	Sweet fennel	Spice	2	S,Os	v, f, m	F, R
8.	<i>Trachyspermum ammi</i> (Linn) Sperg.	Carom, Bishop's weed	Spice	2	S,Os	v, f, m	F, R
	Asclepiadaceae						
9.	<i>Calotropis gigantia</i> R. Br.	Calotropis	Weed	2, 3	Os	-	R
10.	<i>Calotropis procera</i> R. Br.	Rubber bush	Weed	1, 2, 3	S,Os	-	R
11.	<i>Hemidesmus indicus</i> (Linn.) R.Br.	Indian sarsaparilla	Weed	2	Os	-	R
	Asteraceae						
12.	<i>Baccharoides anthelmintica</i> (L.) Moench	Iron weed	Weed	2	Os	f, m	F, B, R
13.	<i>Bidens pilosa</i> Linn.	Beggar tick	Weed	2	Os	v, f, m	F, R
14.	<i>Gaillardia pulchella</i> Fouger	Blanket flower	Ornamental	2	S	v, f, m	F
15.	<i>Lactuca sativa</i> Linn.	Lettuce	Weed	2, 3	S	v, f, m	F
16.	<i>Sonchus arvensis</i> Linn.	Field sow-thistle	Weed	2, 3	S, Os	v, f, m	F, R
	Basellaceae						
17.	<i>Basella alba</i> Linn.	Malabar spinach,	Vegetable	3	Os	v, f	F,R
	Bombacaceae						
18.	<i>Salmaalma malabarica</i> (DC.) Schott & Endl.	Silk cotton	Tree	3	S,Os	-	R
	Boraginaceae						
19.	<i>Trichodesma indicum</i> R. Br.	Indian borage	Weed	2	S	v, f, m	F, R

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3 ^s	Growing season ^{##}	Growth stage*	Location of the host **
Brassicaceae							
20.	<i>Brassica sp.</i>	Wild mustard	Weed	1	Os	v, f, m	W
Caesalpiniaceae							
21.	<i>Bauhinia purpurea</i> Linn.	Butterfly plant	Tree	2,3	Os	-	R
22.	<i>Cassia fistula</i> Linn.	Golden shower plant	Tree	1, 2, 3	Os	-	R
23.	<i>Senna tora</i> Linn.	Coffee weed	Weed	2,3	S	v, f, m	F,B,R,W
Convolvulaceae							
24.	<i>Argyreia hookeri</i> C.B. Clarke	Hooker's morning Glory	Weed	2	S	v, f	B
25.	<i>Convolvulus arvensis</i> Linn.	Field bind weed	Weed	1	Os	v, f, m	F, R
Cucurbitaceae							
26.	<i>Citrullus lanatus</i> (Thumb) Mansf.	Watermelon	Vegetable	1	Os	v, f, m	F
27.	<i>Citrullus vulgaris</i> Sch.	Round melon	Vegetable	1	S	v, f, m	F
28.	<i>Cucumis melo</i> Linn.	Muskmelon	Vegetable	1	S, Os	v, f, m	F
29.	<i>Lagenaria siceraria</i> Linn.	Bottle gourd	Vegetable	1, 3	S, Os	v, f, m	F
30.	<i>Luffa aegyptiaca</i> Mill.	Sponge gourd	Vegetable	1, 2, 3	Os	f, m	F
31.	<i>Luffa spp.</i>	Ridge gourd	Vegetable	1	S	f, m	F
32.	<i>Memordica charantia</i> Linn.	Bitter guard	Vegetable	1, 2, 3	S, Os	f, m	F
Cyperaceae							
33.	<i>Cyperus rotundus</i> Linn.	Nut grass	Weed	1, 2	S	v, f, m	F, B, R,W
Euphorbiaceae							
34.	<i>Acalypha lanceolata</i> Linn.	Indian copperleaf	Ornamental	2, 3	Os	v, f, m	F, B R
35.	<i>Codiaeum variegatum</i> (L.) A.Juss	Croton	Ornamental	3	S, Os	v	R
36.	<i>Croton petra</i>	Croton	Ornamental	3	S, Os	v	R
37.	<i>Euphorbia pulcherrima</i> Linn.	Poinsettia	Ornamental	2, 3	Os	-	F
38.	<i>Jatropha curcas</i> Linn.	Jatropha	Tree	1, 3	Os	-	R, F
39.	<i>Ricinus communis</i> Linn.	Castor	Field crop	2, 3	Os	f, m	F
Fabaceae							
40.	<i>Butea monosperma</i> Roxb.	Flame of forest	Tree	2, 3	Os	-	R
41.	<i>Cajanus cajan</i> (Linn) Mill.	Pigeon pea	Field crop	2, 3	S	v, f, m	F
42.	<i>Cicer arietanum</i> Linn.	Chickpea	Field crop	2, 3	Os	v, f, m	F
43.	<i>Crotalaria verrucosa</i> Linn.	Sunhemp	Field crop	2, 3	Os	v, f, m	R
44.	<i>Dalbergia sissoo</i> Roxb.	Indian rosewood	Tree	1, 3	Os	v, m	R, W
45.	<i>Desmodium dichotomum</i> Linn.	Chikta	Weed	2	S	f, m	R
46.	<i>Lablab purpureus</i> Isweet	Lablab bean	Field crop	2, 3	S	f, m	F
47.	<i>Leucaena leucocephala</i> Linn.	Wild tamarind	Tree	2, 3	Os	-	R
48.	<i>Plumeria acutifolia</i> Linn.	Temple tree	Ornamental	3	Os	-	R
49.	<i>Rhynchosia minima</i> DC	Burn-mouth Vine	Weed	2, 3	Os	v, f, m	R
Lamiaceae							
50.	<i>Leucas ciliata</i> Linn.	Tufted leucas	Weed	2	Os	v, f, m	R
51.	<i>Anisomeles heyneana</i> Benth	Western hill catmint	Weed	2	Os	v, f	B,R

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3 ^s	Growing season ^{##}	Growth stage*	Location of the host **
52.	<i>Mentha piperita</i> Linn.	Peppermint	Spice	2, 3	S, Os	-	
53.	<i>Ocimum tenuiflorum</i> Linn.	Holy basil	Ornamental	2, 3	Os	-	R
54.	<i>Ocimum basilicum</i> Linn.	Basil	Ornamental	2, 3	Os	-	R
55.	<i>Salvia officinalis</i> Linn. Lythraceae	Salvia	Ornamental	2	Os	-	R
56.	<i>Lawsonia inermis</i> Linn. Malvaceae	Henna	Ornamental	1, 2, 3	Os	-	R
57.	<i>Thespesia lampas</i> Linn. Meliaceae	Common mallow	Weed	2	Os	v, f, m	R
58.	<i>Azadirachta indica</i> A. Juss. Menispermaceae	Neem	Tree	1, 2, 3	Os	-	R
59.	<i>Cocculus hirsutus</i> Linn. Moraceae	Broom creeper	Ornamental	2	Os	-	R
60.	<i>Ficus religiosa</i> Linn.	Peepal	Tree	2, 3	Os	-	R
61.	<i>Morus alba</i> Linn. Myrtaceae	Silkworm mulberry	Tree	1, 2, 3	Os	-	R
62.	<i>Eucalyptus</i> spp.	Eucalyptus	Tree	1	Os	-	R
63.	<i>Melaleuca leucadendron</i> Linn.	Bottle brush	Tree	1, 2	S, Os	-	R
64.	<i>Psidium guajava</i> Linn. Nyctaginaceae	Guava	Fruit plant	1, 2, 3	Os	-	F
65.	<i>Bougainvillea glabra</i> Linn. Oxalidaceae	Bougainvillea	Ornamental	1, 2, 3	S, Os	-	R
66.	<i>Oxalis corniculata</i> Linn. Papilionaceae	Creeping wood sorrel	Weed	2	Os	v, f, m	F
67.	<i>Psoralea corylifolia</i> Linn. Pedaliaceae	Babchi seeds	Weed	2	Os	v, f, m	B, R
68.	<i>Sisamum indicum</i> Linn. Poaceae	Sesame	Field crop	2, 3	S	f, m	F
69.	<i>Cynodon dactylon</i> Pers.	Doob grass	Weed	1, 2	S, Os	v, f, m	F, B, R, W
70.	<i>Dinebra retroflexa</i> Linn.	Viper grass	Weed	2	S	f, m	F, R
71.	<i>Eragrostis cilianensis</i> Linn.	Candy grass	Weed	2	S	f, m	B, R
72.	<i>Sorghum bicolor</i> (L.) Moench	Sorghum	Field crop	1, 3	S, Os	v, f, m	F
73.	<i>Urochloa panicoides</i> Linn. Portulacaceae	Garden grass	Weed	2	S	f, m	B, R, W
74.	<i>Portulaca grandiflora</i> Hook	Moss-rose	Weed	3	S, Os	v, f, m	R
75.	<i>Portulaca oleracea</i> Linn.	Purslane	Weed	2	S	f, m	B, R, W
76.	<i>Portulaca quadrifida</i> Linn. Punicaceae	Wild purslane	Weed	2	S	f, m	B, R
77.	<i>Punica granatum</i> Linn. Rhamnaceae	Pomegranate	Fruit plant	2, 3	Os	-	B
78.	<i>Ziziphus mauritiana</i> Lamk. Rosaceae	Ber	Fruit plant	2, 3	Os	-	B

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Sl. No.	Family/ Botanical name	Common name	Host type	Cotton agro-ecosystems 1, 2, 3 ^s	Growing season [#]	Growth stage*	Location of the host **
79.	<i>Rosa indica</i> Linn. Sapindaceae	Rose	Ornamental	1, 2, 3	Os	-	R, F
80.	<i>Cardiospermum halicacabum</i> Linn. Sapotaceae	Balloon vine	Weed	3	S,Os	v, f, m	R
81.	<i>Achras zapota</i> Linn. Solanaceae	Sapota	Fruit plant	2, 3	S, Os	-	F
82.	<i>Physalis minima</i> Linn.	Ground cherry	Weed	1, 2, 3	S, Os	v, f, m	F, B, R W
83.	<i>Solanum virginianum</i> Linn.	Thorny nightshade	Weed	1	S	v, f, m	R
84.	Verbenaceae						
85.	<i>Duranta erecta</i> Linn.	Sky flower	Weed	3	Os	-	R

of Amaranthaceae, Asteraceae, Malvaceae and Solanaceae (7.69%) and reduced host were recorded in Lamiaceae (2.88%) and Poaceae (0.96%), while 39.44% belonged to diverse plant families. Corresponding host plants were 17, 11, 27 and 50 recorded with infestation G-IV, G-III, G-II and G-I, respectively.

Across India : In three cotton agro-ecosystems of India where cotton cultivation is exposed different growing period and irrigation facilities, 166 host plants of *P. solenopsis* belonging to 51 families, of which 78 were weeds, 27 ornamentals, 18 trees, 17 vegetables, 12 field crops, 8 fruit plants and 4 spice plants were recorded. A maximum host plants were recorded on Malvaceae (10.24%) followed by Asteraceae (9.64%), Fabaceae (9.04%), equal number of hosts from Amaranthaceae and Euphorbiaceae (6.63%), Solanaceae (6.02%), Poaceae (4.22%) and Lamiaceae (3.61). In total 39 different host plants exhibited G-IV infestation whereas 27, 46, and 87 demonstrated G-III, G-II and G-I, respectively.

Agro-ecosystem wise Status of G-IV hosts

North zone : Recorded the occurrence of 17 host plants demonstrating G-IV. These were distributed at Malvaceae [6-nos.: *Abelmoschus esculentus* Linn., *Gossypium arboreum* Linn., *Gossypium herbaceum* Linn., *Gossypium hirsutum* Linn., *Hibiscus rosa-sinensis* Linn., *Sida cordifolia* Linn.], Asteraceae [4-nos.: *Helianthus debilis* Linn., *Helianthus* spp., *Parthenium hysterophorus* Linn., *Xanthium strumarium* Linn.], Solanaceae [3 nos.:

Lycopersicon esculentum Mill., *Solanum melongena* Linn., *Withania somnifera* (Linn.) Dunal], Fabaceae [2 nos.: *Cyamopsis tetragonoloba* (Linn.) Taub., *Vigna radiata* Linn.] and one each from Aizoaceae [*Trianthema portulacastrum* Linn.] and Caricaceae [*Carica papaya* Linn.]. Many of G-IV hosts were recorded during cotton season (14) as compared to off-season (10) and 8 hosts were common to both the seasons. Nine hosts were cultivated crops.

Central zone : Among 30 host plant recorded with G-IV infestation, Malvaceae contributed (9) [*Abelmoschus esculentus* Linn., *Abelmoschus ficulneus* (L.) Wight & Arn Ex. Wight, *Abutilon indicum* Sweet, *Gossypium arborium* Linn., *Gossypium herbaceum* Linn., *Gossypium hirsutum* Linn., *Hibiscus rosa-sinensis* Linn., *Hibiscus sabdariffa* Linn., *Malvastrum coramandelinum* Garcke] followed by Asteraceae (5) [*Acmella uliginosa* (SW.) Cass, *Parthenium hysterophorus* Linn., *Pentanema indicum* (L.) Y. Ling, *Taraxacum officinale* Linn., *Xanthium strumarium* Linn.], Solanaceae (4) [*Capsicum annum* Linn., *Lycopersicon esculentum* Mill., *Solanum melongena* Linn., *Solanum tuberosum* Linn.], two each from Euphorbiaceae [*Euphorbia heterophylla* Linn., *Euphorbia hirta* Linn.] and Tiliaceae [*Corchorus trilocularis* Linn., *Triumfetta rhomboidea* Linn.]. A single host from Aizoaceae [*Trianthema portulacastrum* Linn.], Acanthaceae [*Asteracantha longifolia* Nees], Amaranthaceae [*Digera muricata* (Linn.)], Caricaceae [*Carica papaya* Linn.], Fabaceae [*Clitoria ternatea* Linn.], Nyctaginaceae [*Boerhavia diffusa* Chois.], Rutaceae [*Murra koenigii* Spreng] and Verbanaceae [*Lantana camara* Linn.] was also

recorded with G-IV infestation. During cotton season 23 hosts were recorded with G-IV infestation and 20 during off season among them 13 hosts were common during both season and off-season. Eleven cultivated crops were seen to be severely infested with mealybugs.

South zone : Partial irrigated cotton agro-ecosystem of South Zone harbours 17 G-IV hosts, Malvaceae shared 5 [*Abutilon indicum* Sweet, *Gossypium arboreum* Linn., *Gossypium barbadense*, *Gossypium hirsutum* Linn., *Hibiscus rosa-sinensis* Linn.] followed by 3 Euphorbiaceae [*Euphorbia heterophylla* Linn., *Euphorbia hirta* Linn., *Phyllanthus amarus* Linn.], Solanaceae 2 [*Lycopersicon esculentum* Mill., *Solanum tuberosum* Linn.]. A single G-IV host was recorded in each of the following -Aizoaceae [*Trianthema portulacastrum* Linn.], Asteraceae [*Parthenium hysterophorus* Linn.], Caricaceae [*Carica papaya* Linn.], Portulacaceae [*Portulaca oleracea* Linn.], Rutaceae [*Murrya koenigii* Spreng.], Tiliaceae [*Corchorus trilocularis* Linn.] and Verbanaceae [*Lantana camara* Linn.]. During cotton season 14 hosts were recorded with G IV infestation while 11 during off season of which 8 were common during both season and off-season. A record of severely infested 7 cultivated crops was made in South Zone.

Across India : Thirty-nine host plants showing G-IV incidence were recorded across India. Central India's rainfed cotton agro-ecosystem harboured highest number of host plants (30), almost doubles that of North or South India (17 each). It indicated that intensive cropping system harboured comparatively lesser host diversity than rainfed agro-ecosystem.

Across agro-ecosystems; host plants from families Malvaceae, Asteraceae, Fabaceae, Solanaceae, Euphorbiaceae, Amaranthaceae, Tiliaceae, Aizoaceae, Acantheceae, Caricaceae, Nyctaginaceae, Portulacaceae, Rutaceae and Verbenaceae were found as preferred hosts of *P. solenopsis*. Among these *Trianthema portulacastrum* Linn. (Aizoaceae); *Parthenium hysterophorus* Linn. (Asteraceae); *Carica papaya* Linn. (Caricaceae); *Gossypium hirsutum* Linn., *Hibiscus rosa-sinensis* Linn. (Malvaceae); *Lycopersicon esculentum* Mill. (Solanaceae) were common hosts in all the three cotton agro-ecosystem. Among the host plants, *Hibiscus rosa-sinensis* Linn., *Abutilon* spp.,

Malvastrum coramandelinum Garcke (Malvaceae), *Lantana camara* (Verbenaceae); *Withania somnifera* (Solanaceae) harboured this pest round the year and acted as a persistent source for spread of mealybugs to cotton and other crops. Heavily infested hosts from families viz., Malvaceae (7) [*Abelmoschus esculentus* Linn., *Abelmoschus ficulneus* (L.), *Abutilon indicum* Sweet, *Hibiscus rosa-sinensis* Linn., *Hibiscus sabdariffa* Linn. *Malvastrum coramandelinum* Garcke, *Sida cordifolia* Linn.], Asteraceae (5) [*Acmella uliginosa* (SW.) Cass, *Helianthus* spp., *Parthenium hysterophorus* Linn., *Pentanema indicum* (L.) Y. Ling, *Taraxacum officinale* Linn.], Solanaceae (4) [*Lycopersicon esculentum* Mill., *Solanum melongena* Linn., *Solanum tuberosum* Linn., *Withania somnifera* (L.) Dunal.], Euphorbiaceae (3)[*Euphorbia heterophylla* Linn., *Euphorbia hirta* Linn., *Phyllanthus amarus* Linn.] and single host from Aizoaceae [*Trianthema portulacastrum* Linn.], Carecaceae [*Carica papaya* Linn.], Fabaceae [*Clitoria ternatea* Linn], Nyctaginaceae [*Boerhavia diffusa* Chois.], Rutaceae [*Murrya koenigii* Spreng], Tiliaceae [*Corchorus trilocularis* Linn.] and Verbenaceae [*Lantana camera* Linn.] helped in the dissemination of this pest during cotton season. Whereas, hosts from Asteraceae (6) [*Acmella uliginosa* (SW.) Cass, *Helianthus debilis*, *Helianthus* sp., *Parthenium hysterophorus* Linn. (L.) Y. Ling, *Taraxacum officinale* Linn., *Xanthium strumarium* Linn] followed by Malvaceae (5) [*Abutilon indicum* Sweet, *Hibiscus rosa-sinensis* Linn., *Hibiscus sabdariffa* Linn., *Malvastrum coramandelinum* Garcke, *Sida cordifolia* Linn.], Solanaceae (5)[*Capsicum annnum* Linn., *Lycopersicon esculentum* Mill., *Solanum melongena* Linn., *Solanum tuberosum* Linn., *Withania somnifera* (L.) Dunal] helped the spread of pest in off-season. In addition, two hosts each from Euphorbiaceae [*Euphorbia heterophylla* Linn., *Phyllanthus amarus* Linn.], Fabaceae [*Cyamopsis tetragonoloba* (Linn.) Taub., *Vigna radiata* Linn.] and Tiliaceae [*Corchorus trilocularis* Linn., *Triumfetta rhomboidea* Linn.] and a single host from Aizoaceae [*Trianthema portulacastrum* Linn.], Acantheceae [*Asteracantha longifolia* Nees], Amaranthaceae [*Digera muricata* (Linn.)], Caricaceae [*Carica papaya* Linn.], Nyctaginaceae [*Boerhavia diffusa* Chois], Rutaceae [*Murrya koenigii* Spreng], Verbenaceae [*Lantana camera*] also helped in the dissemination of this pest during off-season. In all the three cotton agro-ecosystems *Trianthema portulacastrum* Linn.

(Aizoaceae), *Parthenium hysterophorus* Linn. (Asteraceae), *Carica papaya* Linn. (Caricaceae), *Abutilon indicum* Linn., *Hibiscus rosa-sinensis* Linn., *Abelmoschus esculentus* (Malvaceae), *Lycopersicon esculentum* Mill., *Physalis minima* (Solanaceae) were the preferred and major hosts of mealybugs.

Hosts of cotton season and off-season; G-III, G-II, G-I and host plants as cultivated crops

There were 43, 63, 51, 100 host plants prevalent during cotton season while higher numbers of 45, 88, 80 and 120 were recorded during off season, in North, Central, South and across India, respectively. The number of host plants that fall into the category of G-III were 13, 10, 11, 27; G-II 12, 29, 27, 46 and G-I 28, 60, 50, 87 observed in North, Central, South and across India, respectively. These hosts also play important role in the spread of mealybugs and hence needs to be monitored in the previously infested fields. Corresponding cultivated host plants recorded were 23, 34, 31 and 43 in North, Central, South and across India, respectively. A list in detail is provided in Tables 3, 4 and 5.

Stage of infestation and Location of G-IV host plants other than cultivated crops

About 41 (North India), 51 (Central India), 42 (South India) and 76 (across India) host plants belonging largely to annual weeds showed mealybug infestation at all the stages viz., vegetative, flowering and maturity. Other than cultivated crops, five, 3, 7 and 2 G-IV hosts were recorded from field, roadside, near water source and field boundaries from North Zone while the corresponding number 15, 14, 14, 4; 7, 8, 10, 5 and 18, 17, 19, 9 were recorded from Central, South Zone and across India, respectively.

Cultivated crops as host plants with G-IV infestation

Cotton species, *G. hirsutum* and *G. arboreum* in all the three cotton agro-ecosystems, *G. herbaceum* in North and Central, *G. barbadense* in south zone were seen to be severely infested with mealybugs. Among other cultivated crops sunflower, tomato, brinjal, cluster bean, green gram and papaya were found to be severely infested in North Zone; chilli, okra, brinjal, potato, papaya and tomato in Central Zone while tomato, potato and papaya in South Zone. In total 14 crops including cotton species were seen to be severely infested with mealybugs.

India with three cotton agro-ecosystems spreading in North, Central and South Zone with varying conditions in relation to soil, rainfall and irrigation; harbour diverse plant species adapted to that agro-ecosystem. *P. solenopsis* was not known to occur in India prior to 2007 and no records are available on the host range of its infestation. The host plants listed by ICAC (2008) included 22 plant species, of which 20 are reported in the present study. A total of 55 host-plants belonging to 18 families were reported by (Hodgson *et al.*, 2008) out of which 5 hosts viz., *Gossypium hirsutum* Linn., *Solanum melongena* Linn., *Hibiscus rosa-sinensis* Linn., *Whithamia somnifera* (L.) Dunal, *Parthenium hysterophorus* were observed to be with G-IV infestation. In the recent study conducted in Pakistan by Arif *et al.* (2009) who documented 154 host-plant species including 20 economically important field crops, 64 weeds, 45 ornamental plants and 25 shrubs and trees, belonging to a total of 53 plant families. Across the Indian subcontinent 166 host plants belonging to 51 families across weeds (78), ornamentals (27), trees (18), vegetables (17), field crops (12), fruit plants (8) and spice plants (4); indicated diverse host range.

Out of recorded 154 host plants by Arif *et al.* (2009), 41 hosts are common with the present study; however in India mealybug infestation on remaining 113 host plants were not recorded. That only 41 hosts were common between two countries may be attributed to geography of India and Pakistan. Nevertheless, an additional 125 host plants were recorded other than reported by them with varying degree of infestation. Arif *et al.* (2009) divided the host plants into four categories: Incidental, Low, Medium and High; 72 species fell in category incidental, 58 in category low, 15 in category medium and 9 in category high. In our study hosts plant were divided into grades based on the severity, recorded 87, 46, 27 and 40 host plants in G-I, G-II, G-III and G-IV, respectively indicated dissimilar trend with more number of host plants in low severity category. The present study reported hosts plant with grades (G-I to G-IV) for ease of assessment of pest infestation when no other system existed and also where individual insect counting was not feasible. Nevertheless categorization based on incidence as in Pakistan and on severity of damage as in India aim at understanding the infestation level on that particular host at a given point of time and both

the studies supplement the findings of each other. All the plants reported in category high by Arif *et al.* (2009) [i.e., *Xanthium strumarium* (Asteraceae); *Trianthema portulacastrum* (Aizoaceae); *Abutilon indicum*, *Gossypium hirsutum*, *Hibiscus rosa-sinensis* (Malvaceae) *Solanum melongena* and *Withania somnifera* (solanaceae)] are also observed in G-IV in the present findings. *P. solenopsis* exhibit similar host preference to cotton and some host plants in both countries. In a study conducted by Aheer *et al.* (2009) on 22 hosts plants for the prevalence of *P. solenopsis* in Pakistan from December 2006 to November 2007, 8 host plants were common and maximum prevalence was observed on China rose (*Hibiscus*) followed by okra (*Abelmoschus esculentus*) which also support the present findings.

Abbas *et al.* (2010) indicated that the host plants that were heavily infested were most conducive to the pest. The host plants viz., *Hibiscus rosa-sinensis* Linn., *Withania somnifera* (L.) Dunal, *Lantana camera* Linn., *Gossypium hirsutum* Linn., *Portulaca grandiflora* Hook, *Abelmoschus esculentus* Linn. *Xanthium*, *strumarim* Linn. having severe infestation were reported by Abbas and co-workers (2010) are in consonance with the present study. Other plants having lower infestation (below G-IV) were comparatively less preferred; assuming that the degree of spread was the same. The level of infestation is an important parameter for decision-making in pest management. The observations made in this study are similar to the conclusion drawn by Ben-Dov *et al.* (2009).

Pigeon pea [*Cajanus cajan* (Linn) Mill.] is the least preferred- host plant category (G-I) in cotton cropping system (Table 5) and has been suggested by Nagrare and Co-workers (2009) to be cultivated as border and/or intercrop. It was found good in restricting movement of *P. solenopsis* especially in Central zone. Therefore is acceptable refugia for Bt-cotton. It also ensures nutritional security of the rainfed cotton farmers. Thus promoting cultivation of pigeon pea as border of 2 rows all around the field and 2 rows intercropped after 6-8 rows of cotton wherever feasible would immensely help in preventing spread of *P. solenopsis* population.

The diverse group of host plants found in the eco-systems requires attention for minimizing the spread of pest. Information regarding biological

parameters of insects and their host preference for feeding and oviposition are very important to develop alternate strategies effective for its control (Greenberg *et al.* 2001 and 2002; Azidah and Sofian, 2006). Parameters like host range and preference of pest for feeding may serve as an effective tool for their quantitative analysis (Scriber and Slansky, 1981). The mealybug having vast host range may infest many more species globally with the passage of time. Management of hosts plants bears significance for the restricting spread of *P. solenopsis* and effective manipulation of alternate hosts, especially of weeds, would suppress its population below economic damage. CLIMEX modelling indicated that *P. solenopsis* presents a significant threat to agriculture and horticulture in many tropical and subtropical countries. It is a severe threat to cotton production in Asia; the climate of much of these cotton-producing areas is at least as suitable for *P. solenopsis* colonization and establishment as is its native territory in the U.S.A. (Wang *et al.* 2010) owing to its acclimatization in variety of climates and its prolific spread. In this context the present study has immense importance in locating preferred host plants and their management especially of weed hosts coupled with crop rotation with other non preferred crops.

It is to be stated that promoting pigeon pea intercropping wherever feasible and discouraging weeds viz., *Acmella uliginosa* (SW.) Cass., *Helianthus* sp., *Parthenium hysterophorus* Linn., *Pentanema indicum* (L.) Y. Ling, *Taraxacum officinale* Linn., *Xanthium strumarium* Linn. (Asteraceae); *Abelmoschus ficulneus* (Linn.), *Abutilon indicum* Sweet, *Malvastrum coramandelinum* G., *Sida cordifolia* Linn., *Boerhavia diffusa* Chois. (Malvaceae); *Euphorbia heterophylla* Linn, *Euphorbia hirta* Linn., *Phyllanthus amarus* Linn. (Euphorbiaceae); *Corchorus trilocularis* Linn., *Triumfetta rhomboidea* Linn. (Tiliaceae), *Trianthema portulacastrum* Linn. (Aizoaceae), *Asteracantha longifolia* Nees (Acantheceae), *Digera muricata* (Linn.) (Amaranthaceae), *Clitoria ternatea* Linn. (Fabaceae), *Boerhavia diffusa* Chois. (Nyctaginaceae) and *Portulaca oleracea* Linn. (Portulacaceae) during cotton season as well as off-season as a part of cultural component of Integrated Pest Management holds the key in mealybug suppression. Avoiding cultivation of other malvaceous and solanaceous crops in the vicinity of previously mealybug affected

fields is a helpful strategy. Timely suppression of preferred weed hosts will not only reduce the dependency on the chemical pesticides against the pest; but also effects the ecosystem and consequently the parasitoid *Aenasius bambawalei* Hayat on *P. solenopsis*. *A. bambawalei* has very good potential up to an average of 30% parasitization under natural condition.

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