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Spatio-temporal Distribution of Host Plants of Cotton Mealybug, *Phenacoccus solenopsis* Tinsley in India

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Research into Decision Support System for Insect Pests of Major Rice and Cotton Based Cropping Systems

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Top–*Hibiscus rosa-sinensis* L. Bottom–*Lycopersicon esculentum* Mill.
Left–*Parthenium hysterophorus* L. Right–*Hibiscus sabdariffa* L.
Center–*Gossypium hirsutum* L.

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FOREWORD

Invasive pest especially on an economically important crop often leads to serious social economic and environmental hardships to growers and the nation. The invasion and wide spread infestation of the polyphagous mealybug *Phenacoccus solenopsis* Tinsley emerged as a potential threat to the important commercial crop Cotton since 2005 across North, Centre and South cotton growing zones of India. Immediate and intensive research undertaken to understand the biology, host range and natural control of the species besides evaluation of insecticides against the pest for their efficacy led to formulation of management strategies for different agro-ecologies. The wider and quicker spread of the *P. solenopsis* across varied cropping systems and differing agro climatic conditions of the country required holistic approach to understand the host range over space and time, respectively. The readily available information so far on the host range of the pest in India has been specific to a geographical location. However, documentation of the host range and its analyses for commonality and exclusiveness based on distribution, seasonality and severity at the national level are expected to provide not only insights into the credentials of *P. solenopsis* ability to be a pest but more importantly the formulation of general and specific management strategies that could be preventive and most economical.

The bulletin on "Spatio-temporal distribution of host plants of cotton mealybug, *Phenacoccus solenopsis* in India" not only documents the host plants across the country but also makes a comprehensive analysis that leads to the overall and zone specific information on host plant diversity along with their location in the agro ecosystem. Additionally, the seasonality of the host plants supporting the insect development measured in terms of severity has brought out the narrow range of hosts on which monitoring and cultural management options should be done. While spread of the pest on Cotton from North through Central to South Zones could be visualized to be due to the sequentially placed cotton seasons, the large number (194) of host plants especially of weed category (108) across the country is suggestive of weed management as a pivotal option towards an attempt for eradication of the pest. The extreme severity of the pest on the ornamentals and vegetables in urban landscapes/backyards conveys the possibility of the increased travel and trade as one of the reasons for invasion. The large number of offseason hosts documented implies the pest's adaptability to varied climate and hence demanding attention throughout the season. The elucidated information for the location of host plants on road-side and field borders in all cotton agro ecosystems largely contributing to pest build is a revelation enforcing the essentiality of off-field sanitation also.

The work is a projection of the cumulative efforts of many cotton researchers across the country and such a team work deserves special appreciation. I earnestly hope that this bulletin can be a resource book for global researchers.

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SPATIO-TEMPORAL DISTRIBUTION OF HOST PLANTS OF COTTON MEALYBUG, *PHENACOCCUS SOLENOPSIS* TINSLEY IN INDIA

1. INTRODUCTION

1.1. Scenario of cotton cultivation in India

Area under the commercial cultivation of cotton in India is 10.1 million hectares. Three designated cotton growing zones *viz.,* North, Central and South grow cotton under varied agro climatic conditions such as seasons and cropping systems. Traditionally designated North (*Hirsutum* and *Arboreum*) zone comprising States of Punjab, Haryana and Rajasthan, Central (*Hirsutum, Arboreum, Herbaceum* and hybrid) zone with States of Gujarat, Madhya Pradesh and Maharashtra, and South (*Hirsutum, Arboreum, Herbaceum, Barbadense* and hybrid) zone spread across Karnataka, Andhra Pradesh and Tamil Nadu are largely growing Bt cotton hybrids at present. The general growing seasons and cropping systems in North, Central and South zones are April-November, June-December and August-February, and cotton-wheat, cotton+ pigeon pea-fallow and cotton + pulse – maize, respectively. The cotton cultivation at North zone is completely under irrigation. Near to 65% of cotton grown in South and Central zones is rainfed. The productivity levels of cotton zones during 2009-10 were of the order South (661 kg/ha) > Central (471 kg/ha) > North (448 kg/ha). Commercial production of Bt transgenic cotton hybrids started since 2002 at Central and South zones. The North zone largely cultivating only cotton varieties shifted to Bt transgenic hybrids since 2005. Bt transgenic hybrid cultivation across all cotton growing zones brought out drastic reduction in pesticide use against bollworms. However, the need for management of sucking pests *viz.*, jassids, aphids, thrips and whitefly was imminent almost across all the zones of country. The changing cultivation profile of Bt cotton hybrids also provided niche for the development of an exotic mealybug species.

1.2. Scenario of cotton mealy bug

The cotton mealybug *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) with its origin in Central America (Williams & Granara de Willink, 1992) has its spread at the Caribbean and Ecuador (Ben-Dov,1994), Chile (Larrain, 2002), Argentina (Granara de Willink, 2003), Brazil (Culik & Gullan, 2005), Pakistan and India (Hodgson *et al*., 2008) and Nigeria (Akintola & Ande, 2008), Sri Lanka (Prishanthini and Laxmi, 2009), China (Wang *et al.* 2009; Wu & Zhang, 2009) and Australia (Admin, 2010). Such a vast and fast distribution of *P. solenopsis* across the globe largely during the past few years and its economic damage to several crops make it necessary to characterize the ecological factors associated with the pest. In India, reports of mealybugs on cotton were made at Gujarat during the 2004-05, 2005-06, and 2006-07 crop seasons although species identity as *P. solenopsis* could be established only during 2008 (Jhala and Bharpoda, 2008a and Jhala *et al.* 2008). Hodgson *et al.* (2008) confirmed the presence of *P. solenopsis* in India and Pakistan based on taxonomic comparisons of specimens gathered across geographical locations. All nine States of the three cotton growing zones having *P. solenopsis* was noticed during 2008-09 crop season (Dharajyoti *et al.* 2008; Dhawan *et al*. 2008 and 2009; Jhala and Bharpoda, 2008 b & c; Suresh and Kavitha, 2008 a&b; Nagrare *et al.* 2009). Information on its biology,

host range (Vennila *et al.* 2010 a & b), and management (Nagrare *et al.* 2011) are well documented.

1.3. Importance of alternate hosts

Geographic range and species abundance as well as severity and timing of attack of an invasive polyphagous herbivore are directly dependent on organism's ability to feed and reproduce on wide range of host plants besides its adaptability to other biotic and abiotic environmental resistant forces. Arif *et al.* (2009) recorded 154 plant species from 53 families comprising 20 field and horticultural crops, 45 ornamentals, 64 weeds and 25 bushes and trees as hosts of *P. solenopsis* in Pakistan. The species *P. solenopsis* commonly described as cotton mealybug due to its large scale occurrence on cotton attained damaging populations simultaneously across many fields. Sudden and large scale occurrence of the pest among the States of Northern Indian cotton growing zone required preparedness for restriction of its spread to other parts of the country. Since the study of host range over space and time constitutes foundation for understanding the source and time of pest spread, investigation was undertaken to document host plants at different parts of the country. Existence of many alternate hosts in cotton–wheat of Haryana (Saini *et al.,* 2009), cotton + pigeon pea cropping system Maharashtra (Vennila *et al.*, 2010b) have been documented. Although such studies brought in focus the role of host range of *P. solenopsis* at specific geographical regions, a wider scale of documentation across all cotton growing zones *vis a vis* analysis for exclusiveness and commonality in distribution, seasonality and severity of hosts is important for formulation of a general and specific management strategies towards the containment of this pest. Current report presents comprehensive analysis on the host plants of *P. solenopsis* based on studies carried out between 2007 and 2010 across cotton growing zones of India.

2. ZONAL AND ALL INDIA SCENARIO

2.1. Distribution of host plants

2.1.1. Host records

Seventy one, 141, 124 and 194 species of plants belonging to 27, 45, 43 and 50 families served as hosts for *P. solenopsis* at North, Central, and South and across all cotton growing zones, respectively (Annexure I). The diversity of hosts for *P. solenopsis* was greater at Central (72.6%) followed by South (63.9%) and North (36.6%) zones. Weed hosts constituted 38, 58.9 and 47.5 per cent in respect of North, Central and South zones. Out of the total 194 hosts of *P. solenopsis* documented across the country, 55.6% were weeds (Fig. 1).

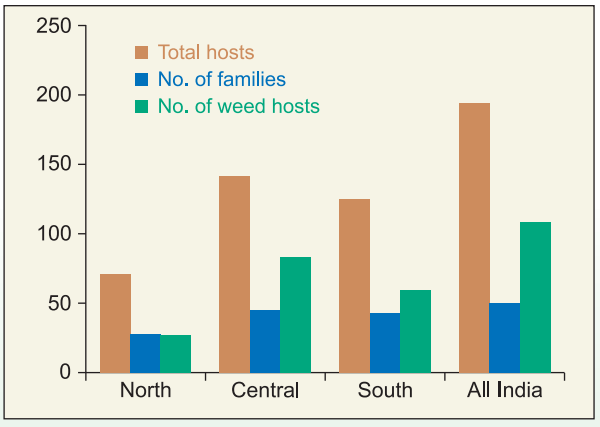


Fig.1. Distribution of host plants of *P. solenopsis*

2.1.2. Familial distribution of host plants

Highest number of host plants of *P. solenopsis* in respect of North, Central, South, and all cotton growing zones belonged to Solanaceae (10), Asteraceae (17), Fabaceae (14) and Malvaceae (23) (Table 1). The order of importance of hosts of *P. solenopsis* from the documented families was Malvaceae>Asteraceae>Fabaceae>Euphorbiaceae> Amaranthaceae>Lamiaceae & Solanaceae, wherein ten or more hosts were recorded. The number of hosts within a family ranged from one to 17 (Annexure II).

Table 1. Major families of host plants of *P. solenopsis*

S. No.	Families	No. of hosts			
		North	Central	South	All India
1.	Malvaceae	9	15	12	23
2.	Asteraceae	6	17	10	20
3.	Fabaceae	5	10	14	17
4.	Euphorbiaceae	2	10	12	14
5.	Amaranthaceae	4	8	10	13
6.	Lamiaceae	0	8	5	10
7.	Solanaceae	10	8	8	10
8.	Cucurbitaceae	7	3	5	7
9.	Poaceae	4	4	1	7
10.	Acanthaceae	0	3	3	5
11.	Verbenaceae	1	4	4	5
12.	Others*	23 (***18***)	51 (***34***)	40 (***32***)	63 (***39***)
Total number of families		**27**	**45**	**43**	**50**

*: number of hosts (number of families)

2.1.3. Host plant categories

Largest number of hosts of *P. solenopsis* was from weeds followed by ornamentals, trees and vegetables and field crops. Fruit plants and spice crops also served as hosts of *P. solenopsis* (Table 2).

Table 2. Distribution of host plants of *P. solenopsis* across plant categories

S. No.	Host category	Cotton growing zone			All India
		North	Central	South	
1.	Weeds	27	83	59	108
2.	Ornamentals	10	14	17	24
3.	Trees	10	11	15	18
4.	Vegetables	12	12	12	18
5.	Field crops	6	9	11	13
6.	Fruit plants	5	7	7	8
7.	Spices	1	5	3	5
Total		**71**	**141**	**124**	**194**

The order of hosts of *P. solenopsis* across plant categories at North, Central and South zones was similar, with weeds occupying the top position. Field crops, fruit crops and spices in their decreasing order represented lower end of host spectrum (Fig. 2). The spread of host range largely across weeds, ornamentals, trees and vegetables over field crops indicate the priority of monitoring and management of *P. solenopsis* on these categories of plants in the cotton production system across zones.

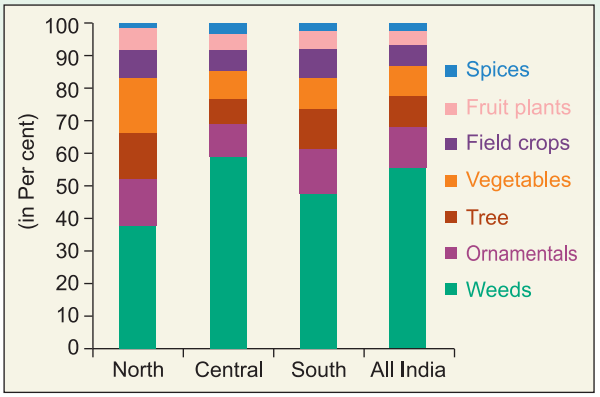


Fig. 2. Distribution of hosts of *P. solenopsis* across plant categories

2.2. Seasonality of host plants

Distribution of host plants of *P. solenopsis* was equal (26) during crop and off seasons at North zone. However at Central and South zones, off season (73 &52) hosts dominated over crop season hosts (43). Number of hosts of crop and off seasons was greater at South (29) over Central (25) and North (19) zones (Table 3). Highest number of off season hosts at Central zone indicated higher possibility of pest carry-over than other two zones.

Table 3. Seasonal distribution of hosts of *P. solenopsis*

S. No.	Seasonality	Cotton growing zone		
		North	Central	South
1.	Crop season	26	43	43
2.	Off season	26	73	52
3.	Crop and off seasons	19	25	29
	Total	**71**	**141**	**124**

2.3. Severity of *P. solenopsis* on host plants

The trend of *P. solenopsis* severity among host plants across zones was clearly different although G1 plants were the highest at all zones. More number of Grade 1 hosts at all three zones indicated their possible role in carryover than perpetuation of *P. solenopsis*. The host plants with extreme severity (G4) were of the order: Central>South>North and a total of 47 (24.2%) hosts had G4 severity among the total host plants documented for the country (Table 4).

Table 4. Distribution of severity of *P. solenopsis* among hosts plants

S. No.	Severity	Cotton growing zone			All India
		North	Central	South	
1.	Grade I (G1)	29	61	57	81
2.	Grade II (G2)	12	31	35	42
3.	Grade III (G3)	13	12	13	24
4.	Grade IV (G4)	17	37	19	47
	Total	**71**	**141**	**124**	**194**

2.4. Seasonality *versus* severity

G4 hosts during crop and crop + off seasons were more at Central (14) over other two zones. North zone had less off season G4 hosts (2) over other two zones. Among the hosts with extreme severity (G4) of *P. solenopsis* the off season hosts were less than the crop season or crop +off season hosts across all zones. Considering the preference of *P. solenopsis* for cotton and the lesser frequency of G4 hosts during offseason, it becomes clear that the wider host range during offseason aids in providing the species with the continuum over space and time. The hosts belonging to different plant categories *viz., Carica papaya* (fruit), *Lycopersicon esculentum* (vegetable), *Parthenium hysterophorus* (weed) and *Hibiscus rosa - sinensis* (ornamental) were common across zones during crop and off seasons. The cultivated species of cotton were the only common host across zones during the crop season (Table 5).

Table 5. Seasonality *versus* extreme severity (G4) hosts of *P. solenopsis*

S. No.	Seasonality	Cotton growing zone		
		North	Central	South
1.	Crop season	7	13	7
2.	Off season	2	10	3
3.	Crop and off seasons	8	14	9
	Total	**17**	**37**	**19**

The G4 host plants of *P. solenopsis* was 23.9, 26.2 and 15.3 per cent of the total recorded hosts at North, Central and South zones, respectively.

3. ZONE SPECIFIC AND COMMON SCENARIO OF HOST PLANTS

3.1. Host records exclusive and common across cotton growing zones

Number of North, Central and South zone specific (exclusive) host plants was 22, 45 and 24 belonging to 13, 21 and 13 families, respectively. Weed hosts specific to zones were 11, 36 and 13 in respect of North, Central and South zones indicating the dominance of weeds as exclusive hosts at Central zone. While common hosts were minimal between North and Central (3), and North and South (7) zones, and the highest commonality was observed between Central and South (54) zones (Fig. 3). Thirty nine hosts were common across all zones dominated again by weeds (13) followed by vegetables (8) and ornamentals (6). Common hosts put together outnumbering the exclusive hosts across zones (Table 6) indicated the regional similarity in preference of hosts by *P. solenopsis.*

Although weeds dominated the exclusive hosts of all three zones and common hosts of North-Central, Central-South and North-Central-South, only one weed host *Portulaca grandiflora* was common between North-South zones. Field crops, vegetables and trees outnumbered weeds among common hosts of North-South zone.

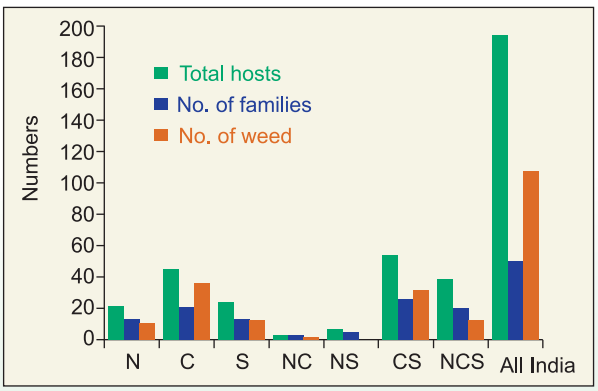


Fig.3. Exclusive and common hosts of *P. solenopsis* among cotton growing zones

Table 6. Distribution of zone specific and common hosts of *P. solenopsis*

Category	North (N)	Central (C)	South (S)	NC	NS	CS	NCS	Total
Weeds	11	36	13	2	1	32	13	108
Ornamentals	4	3	6	-	-	5	6	24
Trees	3	-	2	-	2	6	5	18
Vegetables	2	4	2	-	2	-	8	18
Field crops	1	-	1	1	2	6	2	13
Fruit plants	1	-	-	-	-	3	4	8
Spices	-	2	-	-	-	2	1	5
Total	**22**	**45**	**24**	**3**	**7**	**54**	**39**	**194**

3.1.1. Familial distribution of zone specific and common host plants

Malvaceous plants (3) outnumbered as hosts of *P. solenopsis* over other families at North zone (Fig. 4). However, more number of species from Asteraceae (8), Malvaceae (7), Lamiaceae (5), Apiaceae (3) and Poaceae (3) also served as hosts of *P. solenopsis* at Central zone (Fig. 5). Plant species representation was greater from Malvaceae (5) followed by Amaranthaceae (3) and Fabaceae (3) among South zone specific hosts of *P. solenopsis*(Fig. 6).

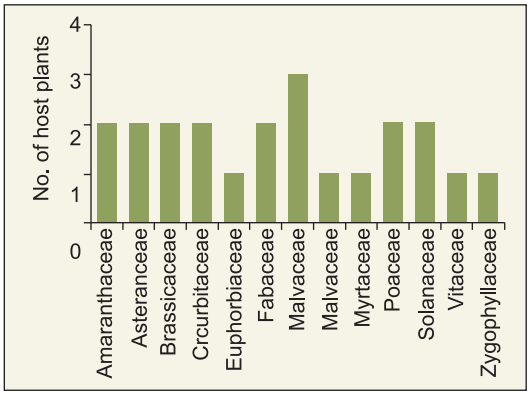


Fig.4. North zone specific hosts of *P. solenopsis* across families

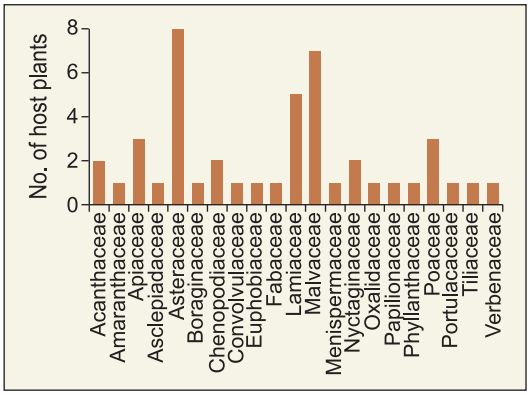


Fig. 5. Central zone specific hosts of *P. solenopsis* across families

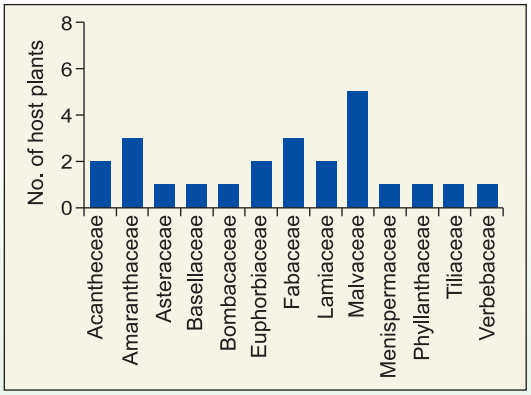


Fig. 6. South zone specific hosts of *P. solenopsis* across families

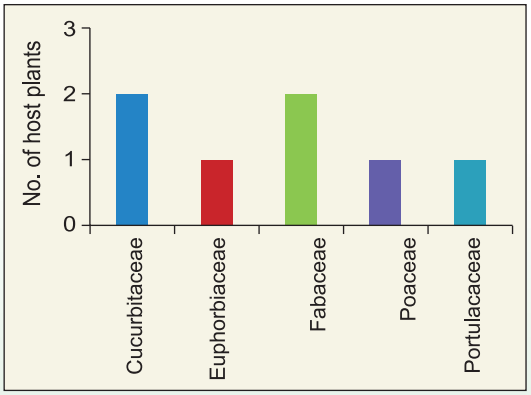


Fig. 7. Common hosts of North and South zones of *P. solenopsis* across families

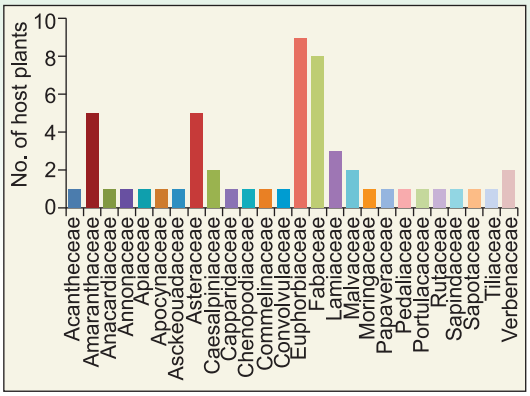


Fig. 8. Common hosts of Central and South zones of *P. solenopsis* across families

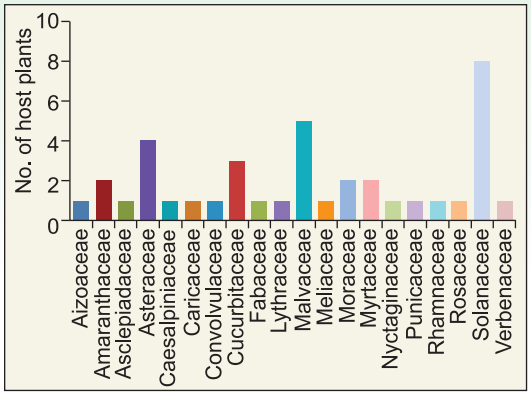
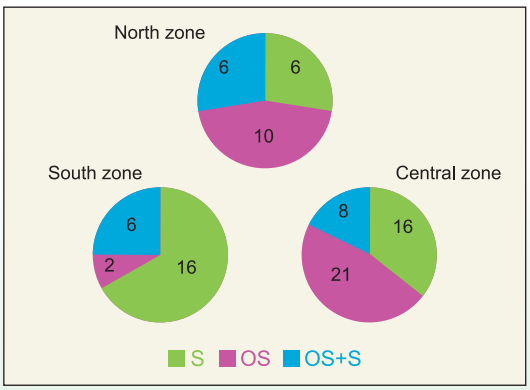


Fig. 9. Common hosts of North, Central and South zones of *P. solenopsis* across families

The two monocots *viz., Cyperus rotundus*. and *Cynodon dactylon* were the only common hosts of *P. solenopsis* other than cotton between North and Central zones. *Jatropha curcas*, *Dalbergia sissoo, Lagenaria siceraria*, *Luffa acutangula, Lablab purpureus*, *Sorghum bicolor* and *Portulaca grandiflora* were common hosts between North and South zones. Among these, two hosts belonged to Cucurbitaceae and Fabaceae, and one each to Euphorbiaceae, Poaceae and Portulacaceae (Fig. 7). Highest number of common hosts between Central and South zones belonged to Euphorbiaceae (9) followed by Fabaceaea (8), and Amaranthaceae and Asteraceae (5). Families *viz.*, Caesalpiniaceae, Malvaceae and Verbanaceae had two common hosts. At least 18 families had single host that were common between Central and South zones (Fig. 8). Among the universal hosts of *P. solenopsis* across all cotton growing zones, eight, five, four and three hosts belonged to Solanaceae, Malvaceae, Asteraceae and Cucurbitaceae, respectively. Two hosts each from Amaranthaceae, Moraceae and Myrtaceae and single host from additional 13 families were common among all zones (Fig. 9) (Annexure III).

3.2. Seasonality of *P. solenopsis* among exclusive hosts

Exclusive hosts of North and Central zones were higher during off season. On the contrary, seasonal hosts were dominant among South zone. The number of exclusive hosts



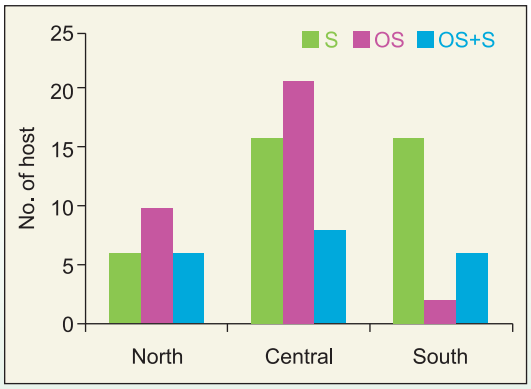


Fig.10. Seasonality of exclusive hosts of *P. solenopsis*

of *P. solenopsis* present during crop as well as off seasons was six, eight and six in respect of North, Central and South zones. Although hosts of *P. solenopsis* were different, the number of hosts during the season were equal (16) at Central and South zones (Fig.10).

Host plants of Zygophyllaceae (*Tribulus terrestris*) exclusive to crop season and of Brassicaceae (*Brassica sp* and *Raphanus raphanistrum*) exclusive to off season were noted at North zone (Fig.11). Distribution of the hosts of *P. solenopsis* within the same family had either crop and off seasons (Amaranthaceae and Poaceae) or crop as well as both seasons (Asteraceae and Febaceae), and off and both seasons (Malvaceae). Among Central zone specific hosts of *P. solenopsis*, seasonality was exclusive during crop season among families of Poaceae (3), Acanthaceae (2), Boraginaceaea (1), Convolvulaceae (1), Fabaceae (1), Portulacaceae (1) and Tiliaceae (1). Five species of plants from Lamiaceae and one each from Asclepiadaceae, Menispermaceae, Oxalidaceae, Papilionaceae, and Phyllanthaceae were off seasonal hosts at Central zone (Fig.12). At South zone, 14 hosts from eight families were exclusive to crop season and a single vegetable host from Basellaceae (*Basella alba*) was exclusive to off season. Five plant species from Malvaceae, two of Acanthaceae and Lamiaceae, and one each from Asteraceae, Menispermaceae, Phyllanthaceae, Tiliaceae and Verbanaceae were exclusive during crop season among South zone specific hosts (Fig.13).

The seasonality of the common hosts indicated the dominance of off season hosts between Central and South and among all three zones (Table 7). Variations of seasonality of same hosts across zones were also noticed. Exactly 50% of hosts of all seasons at North zone were weeds and the proportion of weeds was higher at Central zone. No weed exclusively served as *P. solenopsis* host during off season or during

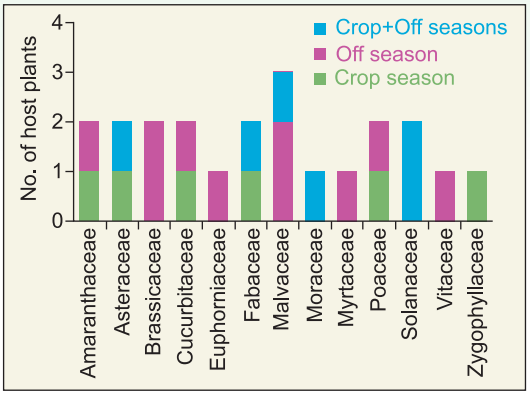


Fig.11. Seasonality North zone specific hosts of *P. solenopsis* across families

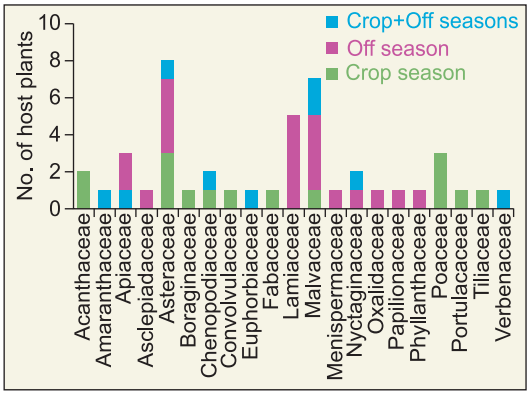


Fig.12. Seasonality of Central zone specific hosts of *P. solenopsis* across families

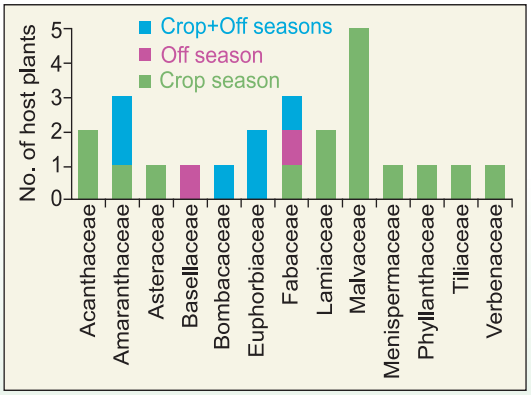


Fig.13. Seasonality of South zone specific hosts of *P.solenopsis* across families

Table 7. Seasonality of exclusive and common hosts

Season	Exclusive hosts (nos.)			Common hosts (nos.)			
	North	Central	South	NC	NS	CS	NCS
Crop season	6(3)	16(13)	16(13)	2(1)	2	11(6)	7(3)
Off season hosts	10(5)	21(17)	2(0)	-	2	23(12)	12(3)
Crop in parenthesis and off seasons	6(3)	8(6)	6(0)	-	-	6(2)	6(2)

Figures are number of weed hosts out of total exclusive and common hosts

both crop and off seasons at South zone. This indicated non necessity of focus on off season weed management at South zone for *P. solenopsis* management. *Cyperus rotundus* is the only weed host common between North and Central zones during crop season. The common weeds between Central and South zones were greater over the three zones put together. The only weed host *(Portulaca grandiflora:* Portulacaceae) between North and South zones had differential seasonality *viz.,* crop as well as crop + off seasons, respectively (Annexure IV).

Digera muricata (Amaranthaceae), *Xanthium strumarium* (Asteraceae) and *Solanum virginianum* (Solanaceae) during crop season, and *Lawsonia inermis* (Lythraceae), *Convolvulus arvensis* (Convolvulaceae) and *Datura metel* (Solanaceae) during off season, and *Physalis minima* (Solanaceae), *Parthenium hysterophorus* (Asteraceae) and *Abutilon indicum* (Malvaceae) during both seasons were the common weed hosts across all three zones (Fig.14).

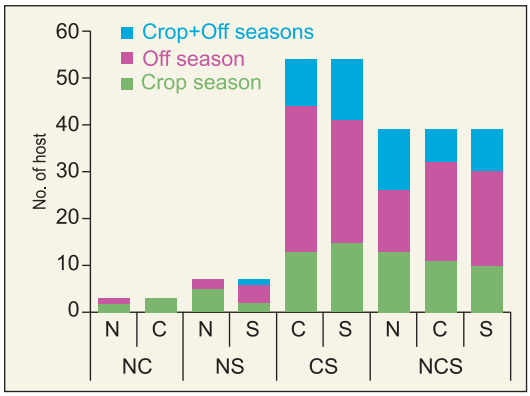
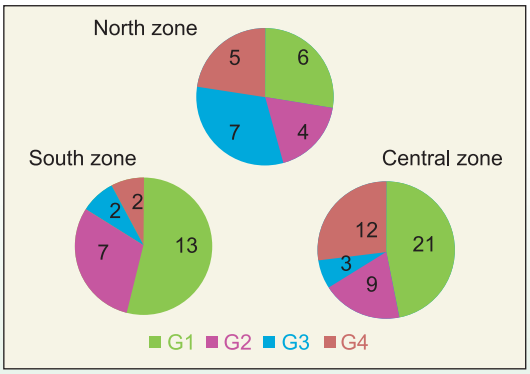


Fig.14. Seasonality of common hosts of cotton growing zones

3.3. Severity of *P. solenopsis* among exclusive hosts

Data on severity of *P. solenopsis* indicated that 27, 18.2, 31.8 and 22.7 % of North zone specific host plants had grades of G1, G2, G3 and G4 respectively. The percentage of G1,



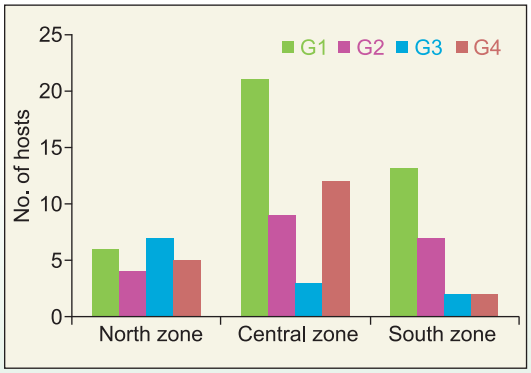


Fig. 15. Severity among exclusive hosts of *P. solenopsis*

G2, G3 and G4 severity among exclusive hosts in respect of Central and South zones was 46.7, 20, 6.6 and 26.7, and 54.2, 29.2, 8.3 and 8.3, respectively. While host plants with extreme severity (G4) were highest at Central zone, they were lowest at the South zone. In general, similarity of severity among the common hosts was of the order North-Central > Central-South> North-Central-South> North-South (Fig. 15).

The North zone specific host plants that had the highest severity were *Vigna radiata* (Fabaceae), *Withania somnifera* (Solanaceae), *Helianthus debilis* and *Helianthus* sp. (Asteraceae) and *Sida cordifolia* (Malvaceae). Plants of Malvaceae and Asteraceae families had shown *P. solenopsis* extreme severity at North and Central zones, only former family at South zone had G4 (Fig. 16). Host plants with severity G3 and G4 at North zone belonged to Asteraceae, Euphorbiaceae, Fabaceae, Malvaceae, Moraceae, Solanaceae and Zygophyllaceae.

The plant species *viz., Vicoa indica* (Asteraceae), *Abelmoschus ficulneus , Hibiscus sabdariffa* and *Azanza lampas* (Malvaceae), *Portulaca quadrifida* (Portulacaceae), *Phyllanthus niruri* (Euphorbiaceae), *Lactuca runcinata*, *Acmella uliginosa* and *Pentanema indicum* (Asteraceae), *Boerhavia diffusa* (Nyctaginaceae), *Asteracantha longifolia* (Acantheceae) and *Triumfetta rhomboidea* (Tiliaceae) were the exclusive Grade 4 hosts at the Central zone (Fig. 17). At the Central zone, the G3 and G4 severity was noted with members of Amaranthaceae, Asteraceae, Euphorbiaceae, Malvaceae, Nyctaginaceae, Phyllanthaceae, Protulacaceae, and Tiliaceae. *Sida acuta* was the only Malvaceous weed host other than Sea Island cotton, *Gossypium barbadense* that had extreme severity at the South zone (Fig. 18). One host each from Fabaceae and Phyllanthaceae, and two from Malvaceae had G3 and G4 severity, respectively at South zone.

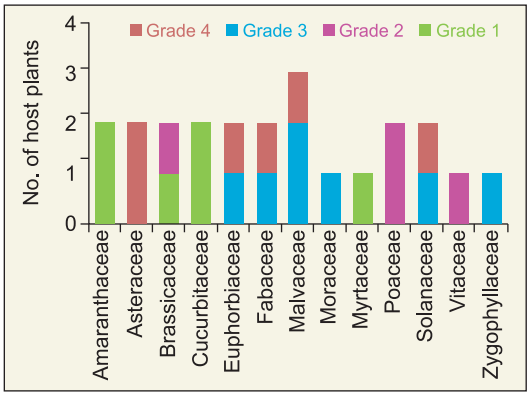


Fig.16. Severity among North zone specific hosts of *P. solenopsis* across families

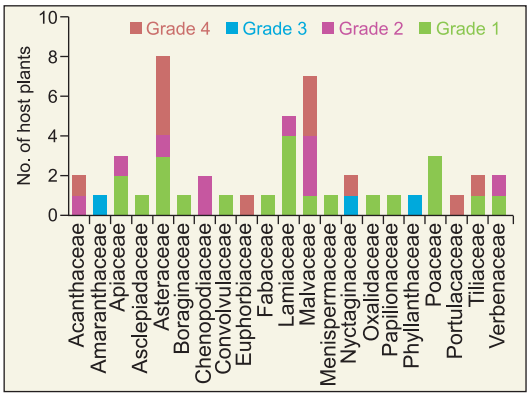


Fig.17. Severity among Central zone specific hosts of *P.solenopsis* across families

Among three common hosts between North and Central zones, cotton had Grade 4 severity and the other two hosts *viz., Cyperus rotundus* and *Cynodon dactylon* had severity of Grade 1.

While the frequency of common hosts across zones with similar severity are depicted in Figure 19, those with dissimilar severity are furnished in Annexure V . Three weed hosts *viz.*,

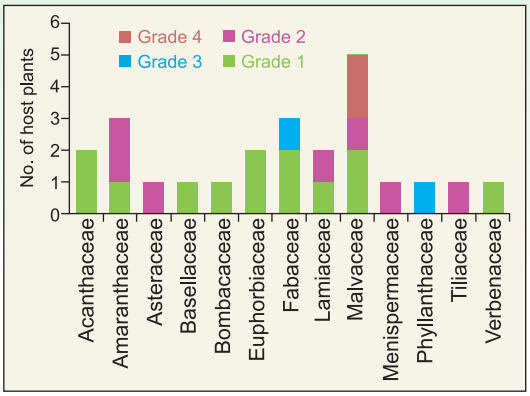


Fig.18. Severity among South zone specific hosts of *P. solenopsis* across families

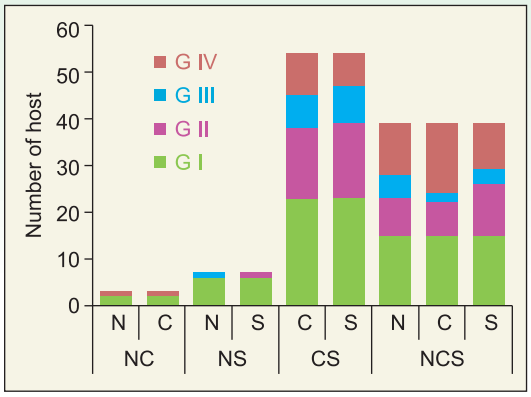


Fig.19. Severity among common hosts of cotton growing zones

Euphorbia hirta and Euphorbia heterophylla (Euphorbiaceae), and *Corchorus trilocularis* (Tiliaceae) besides *Murrya koenigii* (Rutaceae) had Grade 4 severity at both Central and South zones. Twenty one, eleven and three of the common hosts had Grade 1, Grade 2 and Grade 3 severities of *P. solenopsis*, respectively at Central and South zones (Fig. 20).

Differential severity was highly obvious among the common hosts between Central and South zones implying the ecological influences on the biology of *P. solenopsis*. No common hosts between North and South zones had extreme severity (Fig.21). The weed host *Portulaca grandiflora* (Portulacaceae) had a *P. solenopsis* severity of Grade 3 at North zone, but only Grade1 at South zone. *Jatropha urcas* (Euphorbiaceae), *Dalbergia sissoo* and *Lablab purpureus* (Fabaceae), *Lagenaria siceraria* (Cucurbitaceae) and *Sorghum bicolor* (Poaceae) had a maximum severity of Grade 1 implying their insignificant role in aiding the buildup of *P. solenopsis* in North and South zones.

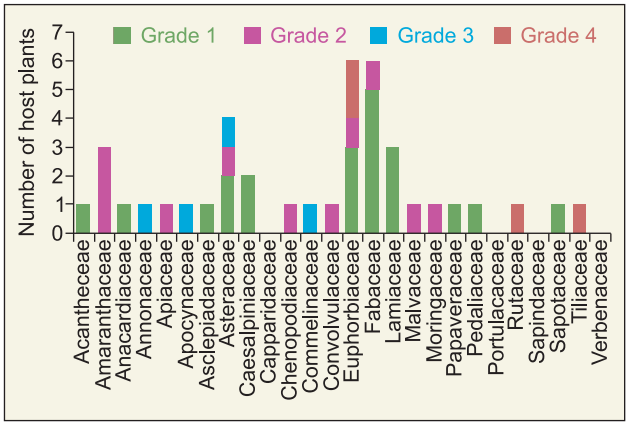


Fig.20. Severity among common hosts of Central and South zones across families

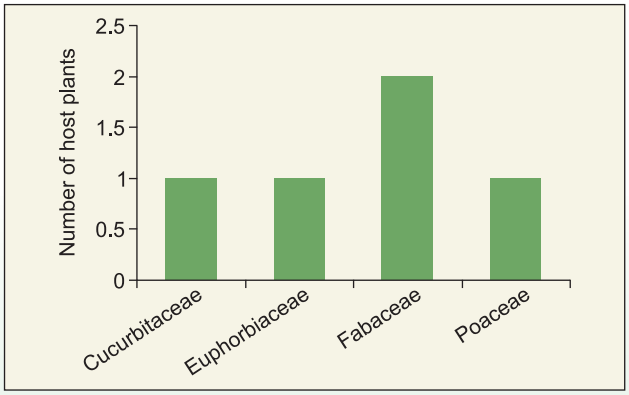


Fig. 21. Severity among common hosts of North and South zones across families

Out of 39 common hosts across all the three cotton zones three hosts of Malvaceae (*Hibiscus rosa-sinensis*, *Gossypium arboreum* and *Gossypium hirsutum)* and one each from Asteraceae (*Parthenium hysterophorus*), Solanaceae (*Lycopersicon esculentum*), Caricaceae (*Carica papaya*) and Aizoaceae (*Trianthema portulacastrum*) had shown G4 severity of *P. solenopsis* (Fig. 22).

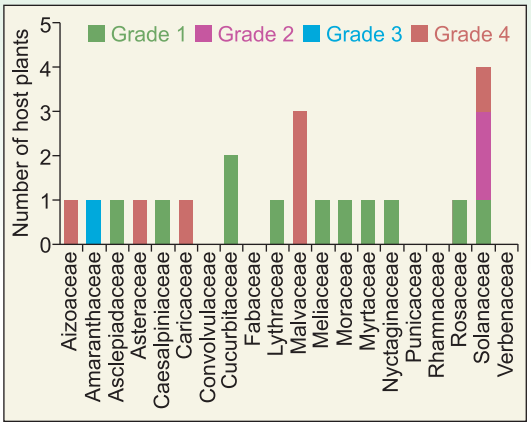


Fig. 22. Severity among common hosts of North, Central and South zones across families

Eleven, two and single host that were common among North, Central and South zones had G1, G2 and G3 severity, respectively. Difference in severity of same hosts across zones was also obvious. Eighteen of the hosts from different families had differential severity at least with one of the zones.

3.4. Seasonality *versus* severity of the exclusive and common hosts of *P. solenopsis*

All scales (G1 to G4) of severity of *P. solenopsis* during the crop season was noticed among North zone specific host plants. No exclusive hosts in North zone had extreme severity during off season although number of host species in other severity scales (G1 to G3) were equal or higher than crop or crop + off seasons. Crop + off season hosts (6) of *P. solenopsis* had equal share of G3 and G4 severity (Fig.23). *Helianthus debilis* (Asteraceae) and *Vigna radiata* (Fabaceae) during crop season, and *Helianthus* spp.(Asteraceaea), *Sida cordifolia* (Malvaceae) and *Withania somnifera* (Solanaceaea) during both crop and off seasons had G4 severity. *P. solenopsis* had extreme severity of G4 among exclusive hosts across all seasons at Central zone (Fig.24). Five hosts each during crop and crop+off seasons had extreme severity. While G1 hosts were dominant during off season only two hosts (*Portulaca quadrifida* (Portulacaceae) and *Triumfetta rhomboidea* (Tiliaceae)) had G4 severity. It is notable that all of the exclusive hosts except one of ornamentals (*Vicoa indica* (Asteraceae)) of Central zone during off season were weeds.

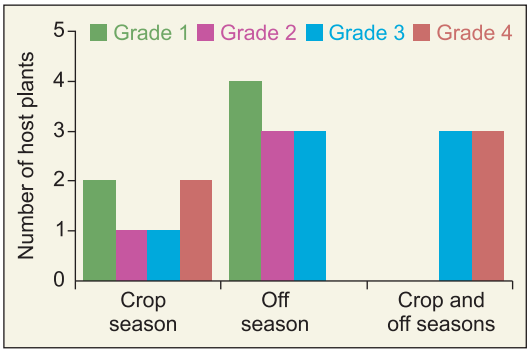


Fig. 23. Seasonality *versus* severity among North zone specific hosts of *P. solenopsis*

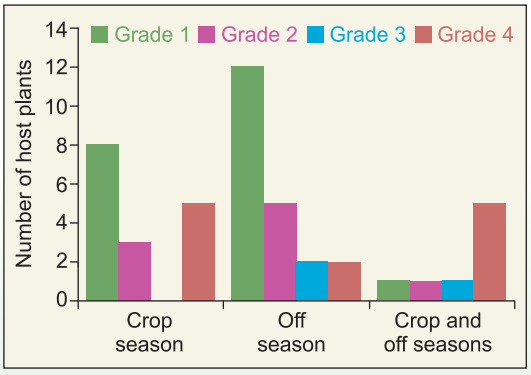


Fig. 24. Seasonality *versus* severity among Central zone specific hosts of *P. solenopsis*

Among the South zone specific hosts of *P. solenopsis*, large numbers (16) occurred during the crop season with the dominance of G1 and G2 severity (Fig. 25). Only two of the South exclusive off season hosts (*Basella alba* (Bacellaceae) and *Plumeria acutifolia* (Febaceae)) had lowest G1 severity. No South zone specific host plants of *P. solenopsis* that occurred during both crop and off seasons had G4 severity. Overall, all South specific hosts had transient and carry over role over supporting *P. solenopsis* perpetuation.

Among the two common hosts of *P. solenopsis*, only *G. herbaceum* grown at North and Central zones had G4 severity during crop season (Fig. 26). There were no common hosts between North and South zones either during off or crop + off seasons (Fig. 27). Only three and a single host common between North and South zones during crop and off seasons respectively had the lowest severity (G1). Common hosts of Central and South (15) and across all three zones (7) during offseason had G1 severity implying their significance in carryover of *P. solenopsis* (Fig. 28).

A weed host (*Euphorbia hirta*: Euphorbiaceae) and a spice crop *Murrya koenigii* (Rutaceae) common between Central and South zones during off and crop+off seasons, respectively had G4 severity. Out of the six common hosts with G4 severity across all three

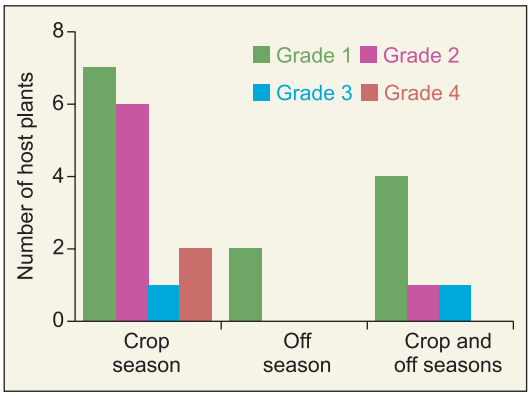


Fig. 25. Seasonality *versus* severity among South zone specific hosts of *P. solenopsis*

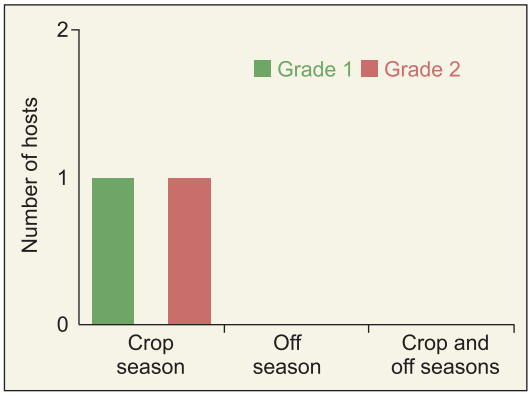


Fig. 26. Sesonality *versus* Severity among common hosts of *P. solenopsis* between North and Central zones

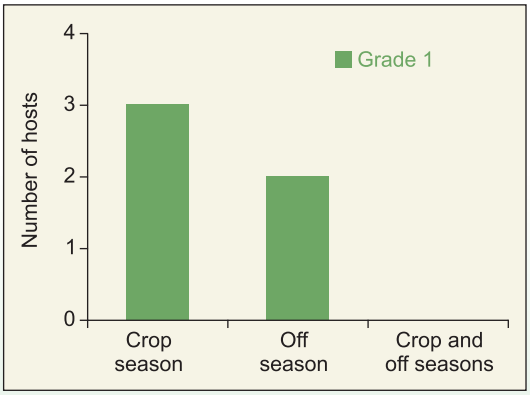


Fig. 27. Sesonality *versus* Severity among common hosts of *P. solenopsis* between North and South zones

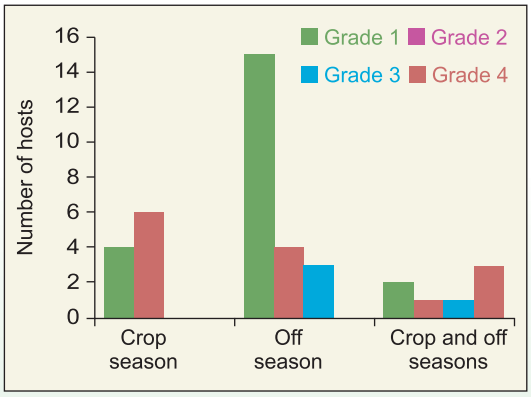


Fig. 28. Sesonality *versus* Severity among common hosts of *P. solenopsis* between Central and South zones

zones, cotton crop of *G. hirsutum* and *G. arboreum* are the common hosts during crop season (Fig. 29).

There was no common host across zones during off season with *P. solenopsis* G4 severity. One species each from fruit, ornamental, vegetable and weed plant categories *viz.*, *Carica papaya* (Caricaceae), *Hibiscus rosa-sinensis* (Malvaceae), *Lycopersicon esculentum* (Solanaceae) and *Parthenium hysterophorus* (Asteraceae) had G4 severity of *P. solenopsis* during crop as well as off seasons, thus deserving attention towards monitoring and management in farm as well as urban landscapes across the country.

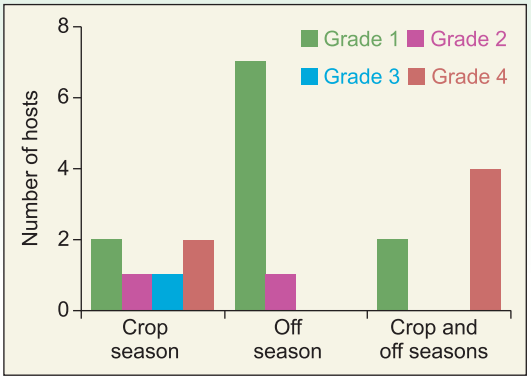


Fig. 29. Sesonality *versus* Severity among common hosts of *P. solenopsis* among North, Central and South zones

Trianthema portulacastrum (Aizoaceae), a weed host with G4 severity of *P. solenopsis* across all three zones had off season distribution at North and Central zones but occurred during crop and off seasons at South zone (Table 8).

Table 8. Seasonality *versus* severity of G4 hosts exclusive and common across zones

Details of hosts	Exclusive hosts			Common hosts			
	North	Central	South	NC	NS	CS	NCS
G4 hosts of cotton season	2	5 (5)	2	1	-	-	2
G4 hosts of off season	0	2 (1)	-	-	-	1 (1)	-
G4 hosts of both cotton and off seasons	3	5 (4)	-	-	-	1	4 (1)

(Figures in parenthesis imply the number of weed hosts)

4. SPATIAL DISTRIBUTION OF HOSTS OF *P. SOLENOPSIS*

Host plants of *P. solenopsis* were largely located at roadside in South (54) and North (38) zones over other locations. Field located host plants were the highest at Central zone (36) followed by South (34) and North (26) zones. However, among all the host plants of *P. solenopsis* at North zone, their distribution at fields was the highest (26) followed by roadside (38). The host plants exclusively distributed at border of fields (6), within fields (36), border of fields and roadside (10), within fields and field borders (12), within fields+field borders+roadside (14) and within fields +field borders+roadside+water channels (7) were the highest at Central zone. Host plant distribution at within fields +roadside (19) and roadside (54) was the highest for South zone (Fig. 30).

The host plants of *P. solenopsis* exclusive to roadside+water channels and within fields +roadside+water channels were only at North zone besides the two exclusive hosts *viz.*, *Rumex retroflexus* (Amaranthaceae) and *Brassica sp.* (Brassicaceae) located alongside water channels.

The exclusive host plants of *P. solenopsis* were distributed among eight, seven and three diverse locations at Central, North and South zones. Weeds at roadside dominated as hosts of *P. solenopsis* among Central and South specific hosts, and common hosts of Central and South, and all three zones. Such a situation implied requirement of utmost focus on roadside weed management at Central and South zones in particular and across all three zones, in general (Fig.31).

The common hosts of Central and South zones were distributed across 9 out of the 12 locations documented. The common hosts across all three zones were found distributed within fields (13), roadside (10), borders of fields (2) and one each at within fields +field borders and within fields +field borders+roadside. The hosts common at North and South zones were from Cucurbitaceae (*Lagenaria siceraria* and *Luffa acutangula*), Fabaceae *(Lablab purpureus*) and Poaceae (*Sorghum bicolor*) that were only present within cotton fields (Annexure VI).

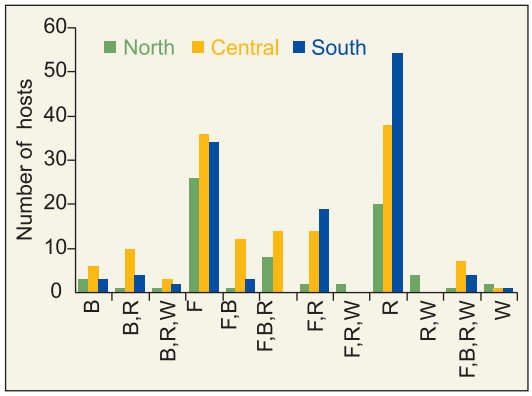


Fig. 30. Spatial distribution of host plants of *P. solenopsis*

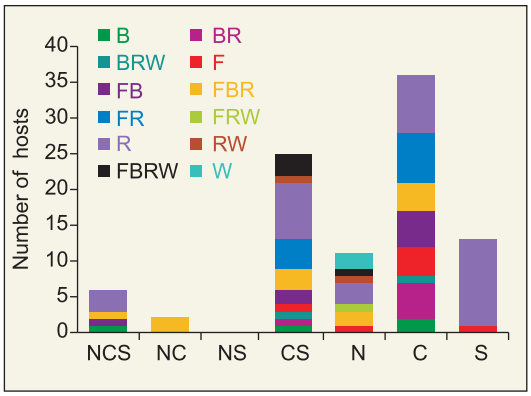


Fig. 31. Spatial distribution of exclusive and common weed hosts of *P. solenopsis*

4.1. Severity and seasonality of exclusive and common hosts in relation to spatial distribution

North zone specific hosts with extreme severity were from roadside (*Sida cordifolia*: Malvaceae), within fields + roadside+water channels (*Helianthus* spp.:Asteraceae), within fields (*Helianthus debilis* (Asteracaea) and *Vigna radiata* (Fabaceaea) and roadside + water channels (*Withania somnifera*: Solanaceaea). The only host seen across locations of within fields +field borders+roadside+water channels was *Acrachne racemosa* (Poaceae) and had G2 with its occurrence during crop season. Higher number of North zone specific off season hosts of *P. solenopsis* had their distribution at water channels, roadside, within fields and within fields+field borders+roadside (Fig. 32).

Among the nine roadside located Central zone specific hosts, seven and two hosts were present during off and crop seasons, respectively. Only one roadside weed host *Triumfetta rhomboidea* (Tiliaceae) had G4 severity during crop season. *Portulaca quadrifida* (Portulacaceae) and *Azanza lampas* (Malvaceae) weeds distributed at field borders and roadside had *P. solenopsis* severity of G4 during crop season. *Phyllanthus niruri* (Euphorbiaceae) and *Hibiscus sabdariffa* (Malvaceae) occurring during crop as well as off

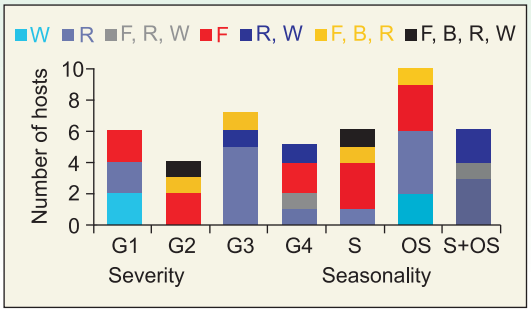


Fig. 32. Severity and seasonality of *P. solenopsis* hosts over space at North zone

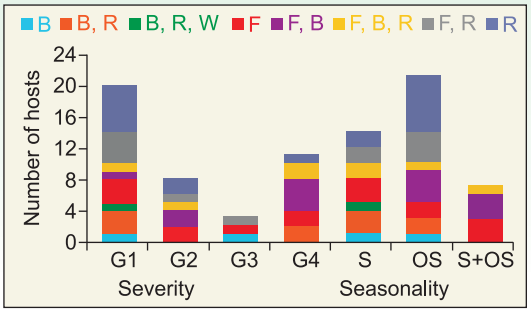


Fig. 33. Severity and seasonality of *P. solenopsis* hosts over space at Central zone

seasons with G4 severity were located within cotton fields (Fig. 33). Weed hosts *Acmella uliginosa* (Asteraceae) and *Abelmoschus ficulneus* (Malvaceae) located at fields and borders during crop and off seasons too had G4 severity of *P. solenopsis*. *Asteracantha longifolia* (Acanthaceae) and *Boerhavia diffusa* (Nyctaginaceae) present during crop and both seasons, respectively having G4 severity were located at within fields +field borders+roadside.

Sida acuta (Malvaceae) other than cotton crop during the crop season located on roadside alone had G4 severity of *P. solenopsis* among 24 South zone specific hosts. Roadside hosts of *P. solenopsis* had all severity levels of G1 to G4 across seasons (Fig. 34).

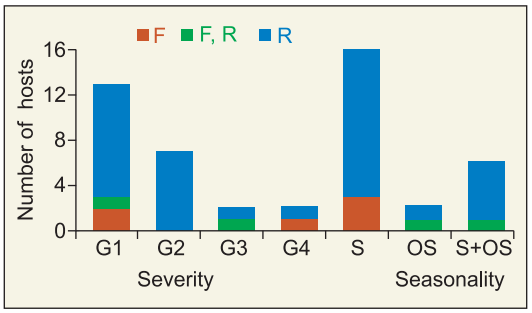


Fig. 34. Severity and seasonality of *P. solenopsis* hosts over space at South zone

Two monocot weeds *viz.*, *Cyperus rotundus* (Cyperaceae) and *Cynodon dactylon* (Poaceae) located within fields +field borders+roadside had *P. solenopsis* severity of G1 with the former host occurring during crop season and the later with differential seasonality between North and Central zones (Fig. 35).

Three common hosts between North and South zones with *P. solenopsis* severity of G1 were located within fields (*Lagenaria siceraria* (Cucurbitaceae); *Lablab purpureus* (Fabaceae) & *Sorghum bicolor* (Poaceae)). Among these only *L. purpureus* had similar seasonality. Additional host *Luffa acutangula* (Cucurbitaceae) had differential severity but similar seasonality was located within fields at both the zones (Fig. 36).

Higher similarity among common hosts of Central and South zones for seasonality and severity of *P. solenopsis* analysed in terms of spatial distribution indicated eight each of G1 hosts were located on roadside and within fields. While common hosts of Central and South zones with G4 severity were located at field borders+roadside (*Murrya koenigii* : Rutaceaea), fields+borders+roadside (*Corchorus trilocularis*:Tiliaceae) and within fields+field borders+roadside+water channels (*Euphorbia hirta* and *Euphorbia heterophylla* : Euphorbiaceae), 13 of the offseason hosts were located on roadside. Four of crop season

common hosts were located within fields *viz.*, *Sesamum indicum* (Pedaliaceae), *Cajanus cajan* (Fabaceae), *Lactuca sativa* (Asteraceae) and *Senna tora (*Caesalpiniaceae) (Fig. 37).

The common hosts of *P. solenopsis* across all three zones were found across five locations *viz.,* within fields, field borders, within fields+field borders, within fields +field borders+roadside and roadside. While G1 hosts of *P. solenopsis* were restricted to roadside and within fields, G4 hosts were additionally found within fields +field borders+roadside across zones. Distribution of large number of hosts within fields during crop as well as off seasons, and along roadside during off season forms the basis for successful spread of *P. solenopsis* across fields in the same locality/region, and over wider area across many regions (Fig. 38).

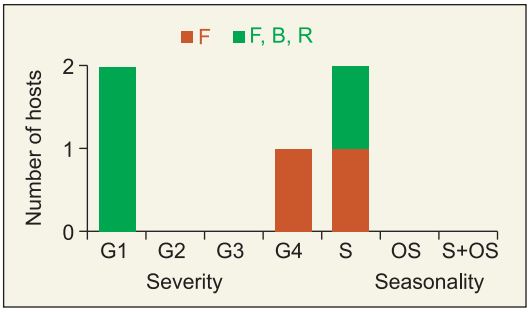


Fig. 35. Severity and seasonality of common hosts of *P. solenopsis* over space between North and Central zones

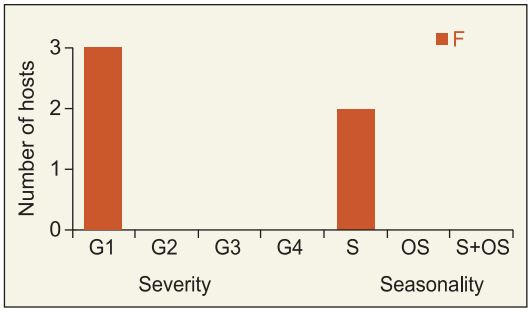


Fig.36. Severity and seasonality of common hosts of *P. solenopsis* over space between North and South zones

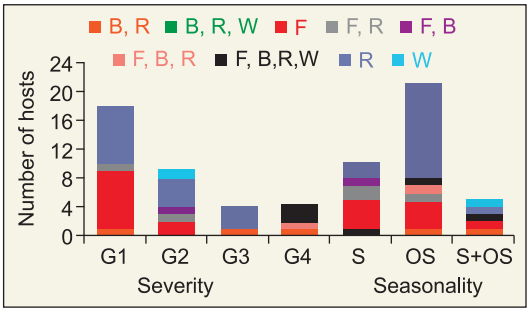


Fig. 37. Severity and seasonality of common hosts of *P. solenopsis* over space between Central and South zones

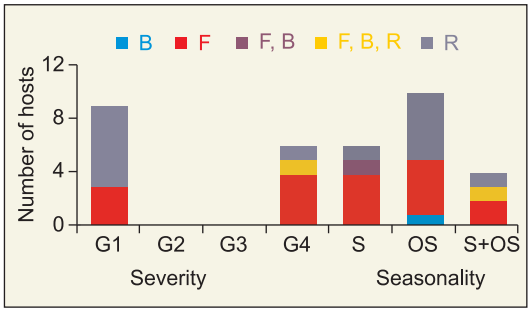


Fig.38. Severity and seasonality of common hosts of *P. solenopsis* over space among North, Central and South zones

5. CULTURAL MANAGEMENT STRATEGIES FOR *P. SOLENOPSIS*

Since *P. solenopsis* is a pest of exotic origin, its prevalence and spread can be limited with a through temporal and spatial understanding of the factors responsible for its perpetuation and carryover in different agroecosystems. While the features of polyphagy and high reproductive potential associated with *P. solenopsis* provide innate capacity to be a pest of economic significance. The vast range of alternate host plants available seasonally or yearlong offer sustenance to the species. It becomes a pest on cotton grown contiguously in larger areas during the sequentially placed cotton seasons of the Indian continent.

The comprehensive analysis on the alternate host plants in each of the cotton growing zones and India as a whole, in addition to investigation of exclusive and common hosts for individual and between cotton growing zones, respectively brought out not only the similarities of *P. solenopsis* host plant interactions but also the need to follow region specific cultural management strategies. The highlights of the management strategies evolved hereunder have been based on the seasonality, severity and spatial distribution of host plants of *P. solenopsis.* This would serve as a reminder for exercising what, when and where to monitor for its host plants for early detection and their cultural management. Cultural management for *P. solenopsis* in the current context implies need for monitoring and field sanitation by removal of alternate hosts of *P. solenopsis* and their proper disposal. Disposal of *P. solenopsis* infested hosts should be through burying or burning that would result in complete destruction of pest stages. While burial practice can be practiced for host plants of herb categories with severity one and two, for hosts with extreme severity burning is advocated. In case of trees and perennial plants, removal of *P. solenopsis* infested portion and burning are to be followed.

Recommendations for the management of *P. solenopsis*

1. Large number of incidental hosts that have low population of *P. solenopsis* found within fields, field borders and roadside during offseason should be removed and disposed by burial or burning.
2. Management of *P. solenopsis* on weed hosts on roadside and field borders should be a priority in all zones to prevent spatial spread and limit severity on cotton crop.
3. Ornamentals and vegetables in urban landscapes and home backyards should be monitored closely.
4. The extent of offseason management determines the magnitude of incidence and severity of *P. solenopsis.*
5. Cotton season cultural practices should focus on field sanitations and proper weed management.

Table 9 outlines the cultural management strategies to be followed for effectively managing *P. solenopsis* in different cotton growing zones of India.

Table 9. List of alternate host plants to be monitored for *P. solenopsis* cultural management

Region	Host plants	Season	Location
All cotton growing zones	Papaya *Carica papaya*	Throughout the year	Orchards and kitchen gardens
	Shoe flower *Hibiscus rosa-sinensis*		Backyards and roadside
	Tomato *Lycopercicon esculentum*		Cultivated fields
	Congress grass *Parthenium hysterophorus*		Fields, field borders and roadside

Region	Host plants	Season	Location
	Indian Mallow, Kanghi *Abutilon indicum*		Within fields, field borders, roadside and irrigation channels
	Potato *Solanum tuberosum*	Cotton season	Cultivated fields
	Brinjal *Solanum melongena*		
	Giant pigweed *Trianthema portulacastrum*	Off season	Within fields and roadside
North and Central zones	Burdock datura *Xanthium strumarium*	Cotton season	Within fields, field borders and roadside
	Bhindi *Abelmoschus esculentus*	Off season	Cultivated fields
Central and South zones	Curry leaf *Murrya koenigii*	Throughout the year	Backyards and roadside
	Oleander *Nerium oleander*	Roadside	
	Common spurge *Euphorbia hirta*	Off season	Within fields, field borders, roadside and irrigation channels
	Lantana *Lantana camara*		Field borders, roadside and irrigation channels
	Coat buttons *Tridax procumbens*		Within fields, field borders and roadside
	Custard apple *Annona squamosa*		Roadside
	Whiskered commelina *Commelina benghalensis*		
North zone	Country mallow khareti *Sida cordifolia*	Throughout the year	Roadside
	Ashwagandha *Withania somnifera*		Roadside and irrigation channels
	Gule dupehri *Portulaca grandiflora*	Cotton season	Within fields and roadside
	Moong, Moss rose *Vigna radiata*		Cultivated fields
	Beach sunflower *Helianthus debilis*		
	Guar *Cyamopsis tetragonoloba*		
Central	Wild Jute *Corchorus trilocularis*	Throughout the year	Within fields, field borderszone and roadside
	Red hogweed *Boerhavia diffusa*		
	Hazardani *Phyllanthus niruri*		Within fields

Region	Host plants	Season	Location
	Ambadi *Hibiscus sabdariffa*		
	Marsh Para Cress *Acmella uliginosa*		Within fields and field borders
	Ran bhendi *Abelmoschus ficulneus*		
	Jangli-bhendi *Azanza lampas*	Cotton season	Border and roadside
	Wild purslane *Portulaca quadrifida*		
	Pathari *Lactuca runcinata*		Within fields
	Chilly *Capsicum annum*		
	False Amaranth *Digera muricata*		Within fields and field borders
	Water spiny ball *Asteracantha longifolia*		Within fields, field borders and roadside
	Burr Bush *Triumfetta rhomboidea*		Roadside
	Ran shevanti *Vicoa indica*	Off season	Within fields and field borders
	Sonkadi *Pentanema indicum*		
	Pala aku, Wild poinsettia *Euphorbia geniculata*		Within fields, field borders, roadside and water channels
South zone	Mountain knot grass *Aerva lanata*	Throughout the year	Within fields and roadside
	Jangali amla *Phyllanthus amarus*		Within fields, field borders and roadside
	Gliricidia *Gliricidia sepium*		Within fields and roadside
	Chilaka paraka, Common wire weed, *Sida acuta*	Cotton season	Roadside
	Pulicheru, Black honey shrub *Phyllanthus reticulatus*		
	Wild Jute *Corchorus trilocularis*		Within fields, field borders and roadside
	Wild poinsettia *Euphorbia geniculata*		Within fields and roadside
	Purslane *Portulaca oleracea*		Field borders, roadside and water channels

CONCLUSIONS

The vast diversity of host plants of *P. solenopsis* suggests the possibility of its yearlong presence in different agroecosystems. Although the vast host range of *P. solenopsis* poses risk in terms of quicker and large scale spread, equal opportunities exists to exploit them for management of the pest when their exact role is identified. Since the mode of dispersal is also wide and varied, pest status needs continuous monitoring. Abbas *et al.* (2010 a) reported 173 plant species across 54 families from 26 countries representing different ecological zones. Current records from India would alter the host dimension across the globe. Host range analysis clearly indicated the larger monoculture of cotton *vis a vis P. solenopsis* for malvaceous hosts as one reason for the increased incidence and severity on the crop. Host plants *viz., H. rosa-sinensis*, *Withania somnifera, portulaca grandiflora, Abelmoschus esculentus* and *Xanthium strumarium* have been among the top ten hosts infested by *P. solenopsis* in Pakistan (Abbas *et al.* 2010b) and all of them had extreme (G4) severity in India, indicating similarities of host range and developmental attributes of the pest within Asian continent. Compilation and comparison of the exclusive and common hosts of *P. solenopsis* across continents through a global mealybug network would prove useful for understanding the ecological and evolutionary aspects of the pest over time and space that can prevent invasion into other countries in addition to doing a pest risk analysis. Effective control of *P. solenopsis* by *Aenasius bambawalei* Hayat (Encyrtidae), on cotton in India has been observed (Nagrare *et al.* 2011). *P.solenopsis* parasitizing by *A. bambawalei* observed among alternate hosts (Rishi Kumar *et al.* 2009) is also expected to sustain the biological balance over time and is a research gap at present.

Current analysis of the significant life history aspects of seasonality, severity and spatial distribution of *P. solenopsis vis a vis* host plants brought out clearly the carry over hosts common and specific across cotton growing zones. The diversity of hosts largely weeds offer scope for a feasible cultural method of management. Management of alternate hosts having moderate to high severity located along roadside, within fields and field borders would effectively suppress the pest. Continued practice of such recommendations has the potential to eradicate the pest from India, if practised simultaneously over cotton growing regions. The general and specific recommendations of the current study distilled out at individual zonal and all India level would serve as an "user's guide" for cultural management of *P. solenopsis*.

Host plants of *P. solenopsis*

Crossandra infundibuliformis
(Acanthaceae)

Andrographis echioides
(Acanthaceae)

Peristrophe bicalyculata
(Acanthaceae)

Amaranthus viridis
(Amaranthaceae)

Alteranthera triandra
(Amaranthaceae)

Achyranthes aspera
(Amaranthaceae)

Aerva lanata
(Amaranthaceae)

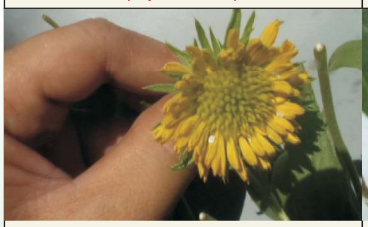
Digera arvensis
(Amaranthaceae)

Foeniculum vulgare
(Apiaceae)

Centella asiatica
(Apiaceae)

Calotropis gigantean
(Asclepiadaceae)

Hemidesmus indicus
(Asclepiadaceae)



Gaillardia pulchella
(Asteraceae)

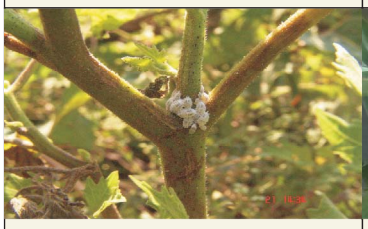
Parthenium hysterophorus
(Asteraceae)

Sonchus sarvensis
(Asteraceae)

Sonchus oleraceus
(Asteraceae)

Tridax procumbens
(Asteraceae)

Vicoa indica
(Asteraceae)



Xanthium strumarium
(Asteraceae)

Lactuca runcinata
(Asteraceae)

Helianthus annuus
(Asteraceae)

Lagascea mollis
(Asteraceae)

Vernonia cinerea
(Asteraceae)

Trichodesma indicum
(Boraginaceae)

Convolvulus arvensis
(Convolvulaceae)

Luffa acutangula
(Cucurbitaceae)

Euphorbia hirta
(Euphorbiaceae)

Phyllanthus niruri
(Euphorbiaceae)

Acalypha indica
(Euphorbiaceae)

Euphorbia geniculata
(Euphorbiaceae)

Butea monosperma
(Fabaceae)

Cajanus cajan
(Fabaceae)

Cicer arientanum
(Fabaceae)

Leucaena leucocephala
(Fabaceae)

Desmodium diffusium
(Fabaceae)

Psoralea corylifolia
(Fabaceae)

Tephrosia purpurea
(Fabaceae)

Cyamopsis tetragonoloba
(Fabaceae)

Leucaena leucocephala
(Fabaceae)

Leucas urticaefolia
(Laminaceae)

Hyptis sauveolens
(Laminaceae)

Ocimum canum
(Laminaceae)

Abelmoschus esculentus
(Malvaceae)

Abutilon indicum
(Malvaceae)

Azanza lampas
(Malvaceae)

		
Gossypium arboreum (Malvaceae)	*Gossypium hirsutum* (Malvaceae)	*Malvastrum coramandelinum* (Malvaceae)
		
Hibiscus sabdariffa (Malvaceae)	*Hibiscus rosasinensis* (Malvaceae)	*Hibiscus cannabinus* (Malvaceae)
		
Hibiscus micranthus (Malvaceae)	*Sida acuta* (Malvaceae)	*Urena sinuate* (Malvaceae)
		
Cochlospermum helicacabum (Menispermaceae)	*Ficus religiosa* (Moraceae)	*Psidium guajava* (Mytaceae)
		
Oxalis corniculata (Oxalidaceae)	*Argemone Mexicana* (Pepavaraceae)	*Portulaca oleracea* (Portulacaceae)

		
Phyllanthus reticulatus (Phyllanthaceae)	*Dinebra sp.* (Poaceae)	*Cynodon dactylon* (Poaceae)
		
Ziziphus mauritiana (Rhamnaceae)	*Cardiospermum helicacabum* (Sapinadaceae)	*Capsicum annum* (Solanaceae)
		
Lycopersicon esculentum (Solanaceae)	*Physalis minima* (Solanaceae)	*Solanum melongena* (Solanaceae)
		
Solanum nigrum (Solanaceae)	*Corchorus olitorius* (Tiliaceae)	*Lantana camara* (Verbenaceae)

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Annexure I : Host plants of *P. solenopsis* across cotton growing zones

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
1.	**Acanthaceae**	*Andrographis echioides* L.	False water willow	Weed	I					S			R
2.		*Asteracantha longifolia* Nees	Water spiny ball	Weed		IV			S			F,B,R	
3.		*Crossandra infundibuliformis* L.	Crossandra, Firecracker Flower	Ornamental		I	I		OS	OS, S		F	F
4.		*Peristrophe bicalyculata Retz.*	Chebura/Panicled/ peristrophe	Weed			I			S			R
5.		*Rungia repens* Nees.	Creeping Rungia	Weed		II			S			F,B,R	
6.	**Aizoaceae**	*Trianthema portulacastrum* L.	Itsit, Sanrai, Desert Horse Purslane, Giant pigweed	Weed	IV	IV	IV	OS	OS	OS, S	F,B,R	F, R	F, R
7.	**Amaranthaceae**	*Achyranthes aspera* Linn.	Puthkanda, Crocus stuff, Devil's horsewhip	Weed	III	III	III	S	OS, S	OS, S	B,R,W	F,B,R	F,B,R
8.		*Aerva lanata* (L.) Juss	Mountain Knot Grass, Chhaya, kapurmadhuri	Weed		III	IV		S	OS, S		F,B,R	F, R
9.		*Aerva sativa*	Safed bui	Weed	I			S			R		
10.		*Alternanthera paronychioides* A. St. Hil.	Smooth Chaff Flower, Reshimkata.	Weed		III	II	OS, S	OS, S			F,B, R,W	F,B, R,W
11.		*Alternanthera sessilis* (L.) R. Br.	Joyweed	Weed		II	II		OS	OS		R	R
12.		*Alternanthera triandra* Lam.	Reshimkata	Weed		III			OS,S			F	
13.		*Amaranthus viridis* L.	Green Amaranth, pigweed	Weed		II	II		S	S		F,B	F,B
14.		*Celosia argentea* L.	Silver Cockscomb	Weed		II	II		S	S		F, R	F, R
15.		*Celosia cristata* L.	Cockscomb	Ornamental			II			OS, S			R
16.		*Digera arvensis*	False amaranth/ Jonna chenchala kura	Weed			II			S			R
17.		*Digera muricata* (L.)	Tandla, False Amaranth	Weed	II	IV	I	S	S	S	F,B	F,B	F,B

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
18.		*Gomphrena globosa* L.	Globe Amaranth, Bachelors button	Ornamental			I			OS, S			R
19.		*Rumex retroflexus* L.	Jangali palak	Weed	I			OS			W		
20.	**Anacardiaceae**	*Mangifera indica* L.	Mango	Fruit plant		I	I		OS	OS		R	R
21.	**Annonaceae**	*Annona squamosa* L.	Sugar Apple, Custard apple	Fruit plant		III	III		OS	OS		R	R
22.	**Apiaceae**	*Centella asiatica* L.	Indian Pennywort, Coinwort, Asiatic coinwort,	Weed		II	II		OS, S	OS, S		F,B,R	F,B,R
23.		*Daucus carota* L.	Carrot, Gajar	Vegetable		II			OS			F	
24.		*Foeniculum vulgare* Miller	Fennel, Sweet fennel	Spice		I			OS			F, R	
25.		*Trachyspermum ammi* (L.) Sperg.	Ajwain	Spice		I			S			F	
26.	**Apocynaceae**	*Nerium oleander* L.	Oleander	Ornamental		III	III		OS, S	OS, S		R	R
27.	**Asclepiadaceae**	*Calotropis gigantea* R. Br.	Crown Flower, Calotropis	Weed		I	I		OS	OS		R	R
28.		*Calotropis procera* R. Br.	Rubber bush, apple of Sodom	Weed	I	I	I	S	OS	OS	R	R	R
29.		*Hemidesmus indicus* (L.) R.Br.	Indian Sarsaparilla	Weed		I			OS			R	
30.	**Asteraceae**	*Acmella uliginosa* (SW.) Cass.	Marsh Para Cress	Weed		IV			OS, S			F,B	
31.		*Baccharoides anthelmintica* (L.) Moench	Iron weed	Weed		I			OS			F,B,R	
32.		Bidens pilosa L.	Beggar Tick,	Weed		I			OS			F,R	
33.		*Chrysanthemum indicum* L.	Chrysanthemum, Shewanti.	Ornamental	III	II	II	OS, S	S	S	B	F	F
34.		*Gaillardia pulchella Fouger*	Blanket Flower, Firewheel, Indian blanket flower	Ornamental		I			S			F	

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
35.		*Helianthus annuus* L.	Sunflower, Surajmukhi	Field crop		II	II		S	S		F	F
36.		*Helianthus debilis* L.	Beach Sunflower, Cucumber leaf Sunflower	Ornamental		IV		S			F		
37.		*Helianthus* spp..	Jangali surajmukhi	Weed	IV			OS, S			F,R,W		
38.		*Lactuca runcinata* L.	Pathari / Cabbage lettuce	Weed		IV			S			F	
39.		*Lactuca sativa* L.	Lettuce	Weed		I	I		S	S		F	F
40.		*Lagascea mollis* Cav.	Silk leaf	Weed			II			S			R
41.		*Parthenium hysterophorus* L.	Carrot Grass, Congress grass, Vishapoondu	Weed	IV	IV	IV	OS, S	OS, S	OS, S	F,B,R	F,B,R	F,B,R
42.		*Pentanema indicum* (L.) Y. Ling	Sonkadi	Weed		IV			OS			F,B	
43.		*Sonchus arvensis* L.	Field Sow-Thistle,	Weed		I	I		OS	S		F,R	F,R
44.		*Sonchus oleraceus* L.	Pachar/ Sow thistle	Weed		II			S			F,R	
45.		*Tagetes erecta* L.	Marigold, Genda	Ornamental	III	II	II	S	S	OS,S	F	F,B	R
46.		*Taraxacum officinale* Wigg.	Dandelion	Weed		IV	II		OS	OS,S		R	F,R
47.		*Tridax procumbens* L.	Tridax Daisy, Coat Buttons	Weed		III	III		OS	OS		F,B,R	F,B,R
48.		*Vicoa indica* (L.) DC.	Ran shevanti/ Sonkadi	Ornamental		IV			OS			F,B	
49.		*Xanthium strumarium* L.	Common Cocklebur, broad bur, burdock datura	Weed	IV	IV	II	S	S	S	F,R,W	F,B,R	R
50.	**Basellaceae**	*Basella alba* L.	Malabar spinach, Creeping spinach, Kodi pasalai	Vegetable			I			OS			F,R
51.	**Bombacaceae**	*Salmalia malabarica* (DC.) Schott & Endl.	Silk cotton	Tree			I			OS, S			R
52.	**Boraginaceae**	*Trichodesma indicum* R. Br.	Indian borage	Weed		I			S			F,R	

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
53.	**Brassicaceae**	*Brassica* sp.	Wild mustard	Weed	I			OS			W		
54.		*Raphanus raphanistrum* L.	Wild radish	Weed	II			OS			F		
55.	**Caesalpiniaceae**	*Bauhinia purpurea* L.	Butterfly plant, Pink butterfly plant	Tree		I	I		OS	OS		R	R
56.		*Cassia fistula* L.	Amaltas, Golden shower plant, Indian Laburnum	Tree	I	I	I	OS	OS	OS	R	R	R
57.		*Senna tora* L.	Coffee weed/ sickle pod Stinking Cassia, Chinese senna, sickle senna	Weed		I	I		S	S		F,B,R,W	R
58.	**Capparidaceae**	*Cleome viscosa* L.	Yellow spider flower, Cleome, Tickweed, Nai kadugu,	Weed		II	III		OS	OS, S		F,R	F,B,R
59.	**Caricaceae**	*Carica papaya* L.	Papaya, Melon plant, Pawpaw,	Fruit plant	IV	IV	IV	OS, S	OS, S	OS, S	F	F	F
60.	**Chenopodiaceae**	*Beta vulgaris* L.	Beetroot, Sugarbeet	Vegetable		II			S			F	
61.		*Chenopodium albam* L.	Pigweed, Bathua	Weed		II	II		S	S		F,R	F,R
62.		*Spinacea oleracea* L.	Spinach, Palak	Vegetable		II			OS,S			F,B	
63.	**Commelinaceae**	*Commelina benghalensis* L.	Whiskered Commelina	Weed		III	III		OS	OS		R	R
64.	**Convolvulaceae**	*Argyreia hookeri* C.B.Clarke	Hooker's Wood rose, Hooker's Morning Glory ,Gayri	Weed		I			S			B	
65.		*Convolvulus arvensis* L.	Field Bind weed, Hiranpug, Hiran khuri	Weed	I	III	III	OS	OS	OS	F, R	F,B,R,W	F,B,R,W
66.		*Ipomoea indica* L.	Bush Morning Glory, Morning Glory Plant	Weed		II	II		OS	OS		W	W
67.	**Cucurbitaceae**	*Citrullus lanatus* (Thumb) Mansf.	Watermelon	Vegetable	I	II	II	OS	OS	OS	F	F	F

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
68.		*Citrullus vulgaris* Sch.	Round melon	Vegetable	I			S			F		
69.		*Cucumis melo* L.	Muskmelon, Sugar melon	Vegetable	I			OS			F		
70.		*Lagenaria siceraria* L.	Bottle Gourd, Bitter calbash gourd, Kaippan chura	Vegetable	I		I	S		OS	F		F
71.		*Luffa aegyptiaca* Mill.	Sponge Gourd,	Vegetable	I	I	I	OS	OS	OS	F	F	F
72.		*Luffa acutangula* L.	Beera/Ridge gourd/ Ribbed gourd	Vegetable	I		II	S		S	F		F
73.		*Momordica charantia* L.	Bitter guard	Vegetable	I	I	I	S	OS	OS	F	F	F
74.	**Cyperaceae**	*Cyperus rotundus* L.	Nut grass, Common Nut Sedge, coco grass	Weed	I	I		S	S		F,B,R	F,B,R	
75.	**Euphorbiaceae**	*Acalypha indica*	Muripindi/Indian copper leaf	Weed		IV	II		OS	S		B	R
76.		*Acalypha lanceolata* L.	Indian Copperleaf	Ornamental		I	I		OS	OS		F,B,R	F,B,R
77.		*Codiaeum variegatum* (L.) A.Juss	Croton	Ornamental			I			OS, S			R
78.		*Croton petra*	Croton	Ornamental			I			OS, S			R
79.		*Croton sparciflorum* Morong	Croton	Ornamental		II	II		OS	OS		F	F
80.		*Euphorbia geniculata* L.	Pala aku/ Wild poinsettia	Weed		IV	III		OS	S		F,B,R,W	F,R
81.		*Euphorbia granulata* Forssk	Hazardani	Weed	III			OS			R		
82.		*Euphorbia heterophylla* L.	Wild Poinsettia, Wild spurge Spurge, Mothi doodhi	Weed		IV	IV		OS, S	OS		F,B,R,W	F,B,R,W
83.		*Euphorbia hirta* L.	Asthma Weed, Common spurge	Weed		IV	IV		OS	OS		F,B,R,W	F,B,R,W
84.		*Euphorbia pulcherrima* L.	Poinsettia	Ornamental		I	I		OS	OS		F	F
85.		*Jatropha curcas* L.	Jatropha, Barbados nut	Tree	I		I	OS		OS	R		F

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
86.		*Phyllanthus amarus* L.	Niruri /Otheite, Jangali amla, Jondhali	Weed		II	IV		S	OS, S		F,B	F,B,R
87.		*Phyllanthus niruri* L.	Hazardani/ Stonebreaker	Weed		IV			OS, S			F	
88.		*Ricinus communis* L.	Castor bean	Field crop		I	I		OS	OS		F	F
89.	**Fabaceae**	*Acacia* spp.	Acacia	Tree	III			OS, S			R		
90.		*Butea monosperma* Roxb.	Flame of forest	Tree		I	I		OS	OS		R	R
91.		*Cajanus cajan* (L.) Mill.	Arhar/ Pigeon Pea/ Red gram	Field crop		I	I		S	S		F	F
92.		*Cicer aritianum* L.	Chickpea/ Bengal gram	Field crop		I	I		OS	OS		F	F
93.		*Clitoria ternatea* L.	Butterfly Pea	Weed		IV	II		OS	OS		F,R	F,R
94.		*Crotalaria verrucosa* L.	Blue rattle weed	Field crop		I	I		OS	OS		R	R
95.		*Cyamopsis tetragonoloba* (L.) Taub.	Guar	Vegetable	IV	II	II	S	S	S	F	F	F
96.		*Dalbergia sissoo Roxb.*	Indian rosewood/ Shisham	Tree	I		I	OS		OS	R, W		R
97.		*Desmodium dichotomum* L.	Chikta	Weed		I			S			R	
98.		*Gliricidia sepium* (Jacq.) *Kunthex. Walp.*	Gliricidia	Tree			III			OS, S			F,R
99.		*Lablab purpureus* Isweet	Lablab Bean, Hyacinth bean	Field crop	I		I	S		S	F		F
100.		*Leucaena leucocephala* L.	Wild tamarind, White Babool,	Tree		I	II		OS	OS		R	R
101.		*Plumeria acutifolia* L.	The temple tree , Gorurchampa	Ornamental			I			OS			R
102.		*Prosopis juliflora* L.	Algaroba, Junglee kikar	Tree		II	II		S	S		R	R
103.		*Rhynchosia minima* DC	Burn-Mouth Vine, rhynchosia	Weed		I	I		OS	OS		R	R

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
104.		*Tephrosia purpurea* L.	Vempali/Wild indigo/ Purple tephrosia	weed			I			S			R
105.		*Vigna radiata* L.	Moong	Field crop	IV			S			F		
106.	**Lamiaceae**	*Anisomeles heyneana* Benth	Western Hill Catmint, Chandhara, Gopali	Weed		I			OS			B,R	
107.		*Hyptis sauveolens*	Ma bheera/ Sirna tulasi/ American mint	Weed			I			S			F
108.		*Leucas ciliata* L.	Tufted Leucas	Weed		I			OS			R	
109.		*Leucas urticaefolia* Br.	Dronpushpi/ White dead nettle	Weed		I			OS			F,B	
110.		*Mentha piperita* L.	Peppermint	Spice		I	I		OS, S	OS, S		F	F
111.		*Ocimum basilicum* L.	Basil, Ran Tulsi	Weed		I	I		OS	OS		R	R
112.		*Ocimum canum sims*	Pitchi tulasi/ Kukka tulasi/ Hoary basil	Weed			II			S			R
113.		*Ocimum sanctum* L.	Tulsi/ Indian Bassil	Weed		II			OS			F,R	
114.		*Ocimum tenuiflorum* L.	Holy basil, Tulsi	Weed		I	I		OS	OS		R	R
115.		*Salvia officinalis* L.	Salvia	Weed		I			OS			R	
116.	**Lythraceae**	*Lawsonia inermis* L.	Henna, Mehendi	Weed	I	I	I	OS	OS	OS	R	R	R
117.	**Malvaceae**	*Abelmoschus esculentus* L.	Okra, Bhindi, Ladies Finger,	Vegetable	IV	IV	II	OS	OS	OS	F	F	F
118.		*Abelmoschus ficulneus* (L.) Wight & Arn Ex.Wight	White Wild Musk Mallow, Native rosella Jangli bhindi, Ran bhendi	Weed		IV			OS, S			F,B	
119.		*Abelmoschus manihot* L.	Yellow Hibiscus	Weed		II	II		OS	OS		R	R
120.		*Abutilon hirtum* (Lam) Sweet var. *heterotrichum* (Hochst. Ex. Mattei)	Indian Mallow, Country Mallow, Abutilon, Indian abutilon, Petari	Weed		II			OS			R	

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
121.	**Malvaceae**	*Abutilon indicum* (L) Sweet	Indian Mallow, Kanghi Country Mallow	Weed	III	IV	IV	OS,S	OS,S	OS,S	B, R	F,B,R,W	F,B,R
122.		*Abutilon theophrasti* Sweet	Velvetleaf, China jute	Weed		II			OS			F,B	
123.		*Alcea rosea* L.	Hollyhock, Gulkhaira	Ornamental	III			OS			R		
124.		*Althaea* sp.	Hollyhock	Ornamental	III			OS			R		
125.		*Azanza lampas* (Cav.) Alef.	Jangli-bhendi	Weed		IV			S			B,R	
126.		*Gossypium arboreum* L.	Deshi cotton	Field crop	IV	IV	IV	S	S	S	F	F	F
127.		*Gossypium barbadense* L.	Egyptian cotton	Field crop			IV			S			F
128.		*Gossypium herbaceum* L.	Upland Cotton, Mexican Cotton,	Field crop	IV	IV		S	S		F	F	
129.		*Gossypium hirsutum* L.	American Cotton	Field crop	IV	IV	IV	S	S	S	F	F	F
130.		*Hibiscus cannabinus*	Gongura/Mesta/ Kenaf	Vegetable			I			S			F
131.		*Hibiscus micranthus*	Nitya malli/Tiny flower hibiscus	Ornamental			II			S			R
132.		*Hibiscus panduraeformis* Burm	Jangli Bhendi/ Wild Lady's Finger	Weed		II			OS			R	
133.		*Hibiscus rosa-sinensis* L.	China Rose, Chinese hibiscus	Ornamental	IV	IV	IV	OS,S	OS,S	OS,S	R	R	R
134.		*Hibiscus sabdariffa* L.	Roselle, Ambadi	Vegetable		IV			OS,S			F	
135.		*Malvastrum coramandelinum* Garcke	False Mallow, Broom weed	Weed		IV	III		OS,S	OS		F,B	F,B
136.		*Sida acuta* L.	Chilaka paraka/ /Common wire weed	Weed			IV			S			R
137.		*Sida cordifolia* L.	Country Mallow, Khareti	Weed	IV			OS,S			R		
138.		*Thespesia lampas* L.	Ban Kapas, Common Mallow	Weed		I			OS			R	
139.		*Urena sinuata* L.	Burr mallow/ Nalla benda/ Pedda benda	Weed			I			S			R

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
140.	**Meliaceae**	*Azadirachta indica* A. Juss.	Neem	Tree	I	I	I	OS	OS	OS	R	R	R
141.	**Menispermaceae**	*Cocculus hirsutus* L.	Broom Creeper, ink berry	Ornamental		I			OS			R	
142.		*Cochlospermum halicacabum*	Butter cup tree/ Chedu putnalu/ Konda buruga	Weed			II			S			R
143.	**Moraceae**	*Ficus indica* (L.) Mill.	Burgad	Tree	III			OS,S			R		
144.		*Ficus religiosa* L.	Peepal, bodhi plant, holy plant, scared fig	Tree	II	I	I	OS	OS	OS	R	R	R
145.		*Morus alba* L.	White Mulberry, Silkworm Mulberry, Russian Mulberry	Tree	I	I	I	OS	OS	OS	R	R	R
146.	**Moringaceae**	*Moringa oleifera* L.	Drumstick plant, Senjana	Tree		II	II		S	S		R	R
147.	**Myrtaceae**	*Eucalyptus* spp.	Eucalypts	Tree	I			OS			R		
148.		*Melaleuca leucadendron* L.	Bottle brush	Tree	I	I	II	OS, S	OS	OS	R	R	R
149.		*Psidium guajava* L.	Guava, Amrood	Fruit plant	I	I	I	OS	OS	OS	F	F	F
150.	**Nyctaginaceae**	*Boerhavia diffusa* Chois.	Red hogweed, Wineflower	Weed		IV			OS, S			F,B,R	
151.		*Boerhavia repens* Chois.	Punarnava/ Spreading hog weed	Weed		III			OS			F,R	
152.		*Bougainvillea glabra* L.	Bougainvillea	Ornamental	I	I	I	OS, S	OS	OS	R	R	R
153.	**Oxalidaceae**	*Oxalis corniculata* L.	Creeping Wood Sorrel, Creeping Oxalis	Weed		I			OS			F	
154.	**Papaveraceae**	*Argemone mexicana* L.	Mexican prickly poppy, Satyanashi	Weed		I	I		OS	OS		B,R	B,R
155.	**Papilionaceae**	*Psoralea corylifolia* L.	Babchi Seeds, Bavachi	Weed		I			OS			B,R	
156.	**Pedaliaceae**	*Sesamum indicum* L.	Sesame	Field crop		I	I		S	S		F	F

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
157.	**Phyllanthaceae**	*Phyllanthus fraternus* L.	Gulf Leaf-Flower	Weed		III			OS			B	
158.		*Phyllanthus reticulatus Poir*	Black honey shrub/ Pulicheru/ Nela purugudu	Weed			III			S			R
159.	**Poaceae**	*Acrachne racemosa* (B.Heyne ex.Roemer & Schult)	Makhra grass	Weed	II			S			F,B,R,W		
160.		*Cynodon dactylon* Pers.	Doob grass, Bermuda grass	Weed	I	I		OS	S		F,B,R	F,B,R	
161.		*Dinebra retroflexa* L.	Viper grass	Weed		I			S			F,R	
162.		*Eleusine indica* (L.) Gaertn.	Madhama, Indian Crowfoot Grass, Indian goosegrass	Weed	II			OS			F,B,R		
163.		*Eragrostis cilianensis* L.	Stink Grass, Candy grass	Weed		I			S			B,R	
164.		*Sorghum bicolor* (L.) Moench	Sorghum jwor	Field crop	I		I	S		OS	F		F
165.		*Urochloa panicoides* L.	Garden grass	Weed		I			S			B,R,W	
166.	**Portulacaceae**	*Portulaca grandiflora* Hook	Gule dupehri	Weed	III		I	S		OS, S	F, R		R
167.		*Portulaca oleracea* L.	Purslane	Weed		I	IV		S	S		B,R,W	B,R,W
168.		*Portulaca quadrifida* L.	Wild purslane	Weed		IV			S			B,R	
169.	**Punicaceae**	*Punica granatum* L.	Pomegranate, Anar	Fruit plant	II	I	I	OS, S	OS	OS	B	B	B
170.	**Rhamnaceae**	*Ziziphus mauritiana* Lamk.	Ber	Fruit plant	II	I	I	OS, S	OS	OS	F	B	B
171.	**Rosaceae**	*Rosa indica* L.	Ornamental	Ornamental	I	I	I	OS	OS	OS	R	F	F
172.	**Rutaceae**	*Murrya koenigii* Spreng	Curry leaf	Spice		IV	IV		OS, S	OS, S		B,R	B,R
173.	**Sapindaceae**	*Cardiospermum halicacabum* L.	Balloon vine	Weed		II	I		OS	OS, S		B,R	R
174.	**Sapotaceae**	*Achras zapota* L.	Sapota	Fruit plant		I	I		OS, S	OS, S		F	F
175.	**Solanaceae**	*Capsicum annum* L.	Chilly	Spice	II	IV	II	S	S	S	F	F	F
176.		*Datura fasturosa* L.	Dhatura	Weed	III			OS, S			R, W		
177.		*Datura metel* L.	devil's trumpet, metel	Weed	II	II	II	OS	OS	OS	B	B	B
178.		*Lycopersicon esculentum* Mill.	Tomato	Vegetable	IV	IV	IV	OS, S	OS, S	OS, S	F	F	F
179.		*Physalis minima* L.	Ground Cherry, Sun berry	Weed	I	I	I	OS, S	OS, S	OS, S	F,B,R	B,R	B,R

S. No.	Family	Botanical name	English/ Vernacular name	Plant category	Severity (Maximum grade)			Seasonality			Location of hosts		
					North	Central	South	North	Central	South	North	Central	South
180.		*Solanum melongena* L.	Brinjal, Egg plant	Vegetable	IV	IV	III	OS, S	S	S	F	F	F
181.		*Solanum nigrum* L.	Black nightshade, Black-berry night shade, Poisonberry	Weed	II	II	II	S	OS	OS	F,B,R	B,R	B,R
182.		*Solanum tuberosum* L.	Potato	Vegetable	III	IV	IV	OS, S	S	S	F	F	F
183.		*Solanum virginianum* L.	Thorny Nightshade, Yellow Berried, Thai eggplant	Weed	I	II	II	S	S	S	R	R	R
184.		*Withania somnifera* (L.) Dunal.	Askand, aksun Ashwagandha	Ornamental	IV			OS, S			R, W		
185.	**Tiliaceae**	*Corchorus olitorius* L.	Nalta jute/Janumu/ Parinta kura	Weed			II			S			R
186.		*Corchorus trilocularis* L.	Wild Jute, African jute	Weed		IV	IV		OS, S	S		F,B,R	F,B,R
187.		*Triumfetta rhomboidea* L.	Burr Bush, Chinese Burr	Weed		IV			S			R	
188.	**Verbenaceae**	*Duranta erecta* L.	Sky flower, Pigeon Berry	Weed		III	I		OS ,S	OS		R	R
189.		*Duranta repens* L.	Pivali Mendi/ Golden duranta	Weed		I			OS, S			R	
190.		*Lantana camara* L.	Lantana	Ornamental	II	IV	IV	S	OS	OS	R, W	B,R,W	B,R,W
191.		*Tectona grandis* L. F.	Teak, Sagun	Tree		II	III		OS	OS, S		R	R
192.		*Vitex negundo* L.	Quadrangular Chaste tree/Vavili/Nalla vavili	Weed			I			S			R
193.	**Vitaceae**	*Vitis vinifera* L.	Grape	Fruit plant	II			OS			F		
194.	**Zygophyllaceae**	*Tribulus terrestris* L.	Bhakari, Puncture Vine, Caltrop, Yellow Vine, Goathead, Gokharu	Weed	III			S			F,B,R		

#**Severity (Maximum grade) :** G 1: About 1-10 mealybugs scattered over the plant G 2: One branch infested heavily with mealybugs, G 3: Two or more branches infested heavily with mealybugs, up to 50% plant affected and G 4: Complete plant affected with mealybugs

Seasonality: S = Cotton season. OS= Off-season

Location of hosts: F: Within field; B: Field border; R: Roadside; W: Water channel

Annexure II: Frequency distribution of host plants of *P. solenopsis* by families

No. of families	Family Name	North	Central	South	All India
1.	Acanthaceae	0	3	3	5
2.	Aizoaceae	1	1	1	1
3.	Amaranthaceae	4	8	10	13
4.	Anacardiaceae	0	1	1	1
5.	Annonaceae	0	1	1	1
6.	Apiaceae	0	4	1	4
7.	Apocynaceae	0	1	1	1
8.	Asclepiadaceae	1	3	2	3
9.	Asteraceae	6	17	10	20
10.	Basellaceae	0	0	1	1
11.	Bombacaceae	0	0	1	1
12.	Boraginaceae	0	1	0	1
13.	Brassicaceae	2	0	0	2
14.	Caesalpiniaceae	1	3	3	3
15.	Capparidaceae	0	1	1	1
16.	Caricaceae	1	1	1	1
17.	Chenopodiaceae	0	3	1	3
18.	Commelinaceae	0	1	1	1
19.	Convolvulaceae	1	3	2	3
20.	Cucurbitaceae	7	3	5	7
21.	Cyperaceae	1	1	0	1
22.	Euphorbiaceae	2	10	12	14
23.	Fabaceae	5	10	14	17
24.	Lamiaceae	0	8	5	10
25.	Lythraceae	1	1	1	1
26.	Malvaceae	9	15	12	23
27.	Meliaceae	1	1	1	1
28.	Menispermaceae	0	1	1	2
29.	Moraceae	3	2	2	3
30.	Moringaceae	0	1	1	1
31.	Myrtaceae	3	2	2	3
32.	Nyctaginaceae	1	3	1	3
33.	Oxalidaceae	0	1	0	1
34.	Papaveraceae	0	1	1	1
35.	Papilionaceae	0	1	0	1
36.	Pedaliaceae	0	1	1	1
37.	Phyllanthaceae	0	1	1	2
38.	Poaceae	4	4	1	7
39.	Portulacaceae	1	2	2	3
40.	Punicaceae	1	1	1	1
41.	Rhamnaceae	1	1	1	1
42.	Rosaceae	1	1	1	1
43.	Rutaceae	0	1	1	1

No. of families	Family Name	North	Central	South	All India
44.	Sapindaceae	0	1	1	1
45.	Sapotaceae	0	1	1	1
46.	Solanaceae	10	8	8	10
47.	Tiliaceae	0	2	2	3
48.	Verbenaceae	1	4	4	5
49.	Vitaceae	1	0	0	1
50.	Zygophyllaceae	1	0	0	1
	Total number of hosts	**71**	**141**	**124**	**194**

Annexure III. Distribution of host plants of *P. solenopsis* exclusive and common among cotton growing zones grouped by families

S.No.	Family	North (N)	Central (C)	South (S)	NC	NS	CS	NCS	Total
1.	Acanthaceae		2	**2**			1		5
2.	Aizoaceae							1	1
3.	Amaranthaceae	2	1	3			5	2	13
4.	Anacardiaceae						1		1
5.	Annonaceae						1		1
6.	Apiaceae		3				1		4
7.	Apocynaceae						1		1
8.	Asclepiadaceae		1				1	1	3
9.	Asteraceae	2	8	1			5	4	20
10.	Basellaceae			1					1
11.	Bombacaceae			1					1
12.	Boraginaceae		1						1
13.	Brassicaceae	2							2
14.	Caesalpiniaceae						2	1	3
15.	Capparidaceae						1		1
16.	Caricaceae							1	1
17.	Chenopodiaceae		2				1		3
18.	Commelinaceae						1		1
19.	Convolvulaceae		1				1	1	3
20.	Cucurbitaceae	2				2		3	7
21.	Cyperaceae				1				1
22.	Euphorbiaceae	1	1	2		1	9		14
23.	Fabaceae	2	1	3		2	8	1	17
24.	Lamiaceae		5	2			3		10
25.	Lythraceae							1	1
26.	Malvaceae	3	7	5	1		2	5	23
27.	Meliaceae							1	1
28.	Menispermaceae		1	1					2
29.	Moraceae	1						2	3
30.	Moringaceae						1		1
31.	Myrtaceae	1						2	3
32.	Nyctaginaceae		2					1	3
33.	Oxalidaceae		1						1
34.	Papaveraceae						1		1
35.	Papilionaceae		1						1
36.	Pedaliaceae						1		1
37.	Phyllanthaceae		1	1					2
38.	Poaceae	2	3		1	1			7
39.	Portulacaceae		1			1	1		3
40.	Punicaceae							1	1
41.	Rhamnaceae							1	1
42.	Rosaceae							1	1

S.No.	Family	North (N)	Central (C)	South (S)	NC	NS	CS	NCS	Total
43.	Rutaceae						1		1
44.	Sapindaceae						1		1
45.	Sapotaceae						1		1
46.	Solanaceae	2						8	10
47.	Tiliaceae		1	1			1		3
48.	Verbenaceae		1	1			2	1	5
49.	Vitaceae	1							1
50.	Zygophyllaceae	1							1
	Total	**22**	**45**	**24**	**3**	**7**	**54**	**39**	**194**

Annexure IV: Common hosts across zones with dissimilar seasonality of *P. solenopsis*

S.No.	Code no.	Family	Botanical name	English/ Vernacular name	*P. solenopsis* seasonality		
					North	Central	South
1.	NC1	Poaceae	*Cynodon dactylon* Pers.	Doob grass, Bermuda grass	OS	S	
2.	NS1	Cucurbitaceae	*Lagenaria siceraria* L.	Bottle Gourd, Bitter calbash gourd, Kaippan chura	S		OS
3.	NS2	Poaceae	*Sorghum bicolor* (L.) Moench	Sorghum, Jowar	S		OS
4.	NS3	Portulacaceae	*Portulaca grandiflora* Hook	Gule dupehri	S		OS, S
5.	CS1	Acanthaceae	*Crossandra infundibuliformis Linn.*	Crossandra, Firecracker Flower		OS	OS, S
6.	CS2	Verbenaceae	*Tectona grandis* L. F.	Teak, Sagun		OS	OS, S
7.	CS3	Capparidaceae	*Cleome viscosa* L.	Yellow spider flower, Cleome, Tickweed, Nai kadugu,		OS	OS, S
8.	CS4	Sapindaceae	*Cardiospermum halicacabum* L.	Balloon vine		OS	OS, S
9.	CS5	Asteraceae	*Taraxacum officinale* Wigg.	Dandelion		OS	OS,S
10.	CS6	Asteraceae	*Sonchus arvensis* L.	Field Sow-Thistle,		OS	S
11.	CS7	Euphorbiaceae	*Euphorbia geniculata* L.	Pala aku/Wild poinsettia		OS	S
12.	CS8	Euphorbiaceae	*Acalypha indica* L.	Muripindi/Indian copper leaf		OS	S
13.	CS9	Verbenaceae	*Duranta erecta* L.	Sky flower, Pigeon Berry		OS ,S	OS
14.	CS10	Euphorbiaceae	*Euphorbia heterophylla* L.	Wild Poinsettia, Wild spurge Spurge, Mothi doodhi		OS, S	OS
15.	CS11	Tiliaceae	*Corchorus trilocularis* L.	Wild Jute, African jute		OS, S	S
16.	CS12	Malvaceae	*Malvastrum coramandelinum* Garcke	False Mallow, Broom weed		OS,S	OS
17.	CS13	Amaranthaceae	*Aerva lanata* (L.) Juss	Mountain Knot Grass, Chhaya, kapurmadhuri		S	OS, S
18.	CS14	Euphorbiaceae	*Phyllanthus amarus* L.	Niruri /Otheite, Jangali amla, Jondhali		S	OS, S
19.	NCS1	Aizoaceae	*Trianthema portulacastrum* L.	Itsit, Sanrai, Desert Horse Purslane, Giant pigweed	OS	OS	OS, S
20.	NCS2	Nyctaginaceae	*Bougainvillea glabra* L.	Bougainvillea	OS, S	OS	OS
21.	NCS3	Myrtaceae	*Melaleuca leucadendron* L.	Bottle brush	OS, S	OS	OS
22.	NCS4	Punicaceae	*Punica granatum* L.	Pomegranate, Anar	OS, S	OS	OS
23.	NCS5	Rhamnaceae	*Ziziphus mauritiana* Lamk.	Ber	OS, S	OS	OS
24.	NCS6	Solanaceae	*Solanum tuberosum* L.	Potato	OS, S	S	S
25.	NCS7	Asteraceae	*Chrysanthemum indicum* L.	Chrysanthemum, Shewanti.	OS, S	S	S
26.	NCS8	Solanaceae	*Solanum melongena* L.	Brinjal, Egg plant	OS, S	S	S
27.	NCS9	Cucurbitaceae	*Momordica charantia* L.	Bitter guard	S	OS	OS
28.	NCS10	Asclepiadaceae	*Calotropis procera* R. Br.	Rubber bush, apple of Sodom	S	OS	OS

S.No.	Code no.	Family	Botanical name	English/ Vernacular name	*P. solenopsis* seasonality		
					North	Central	South
29.	NCS11	Solanaceae	*Solanum nigrum* L.	Black nightshade, Black-berry night shade, Poisonberry	S	OS	OS
30.	NCS12	Verbenaceae	*Lantana camara* L.	Lantana	S	OS	OS
31.	NCS13	Amaranthaceae	*Achyranthes aspera* Linn.	Puthkanda, Crocus stuff, Devil's horsewhip	S	OS, S	OS, S
32.	NCS14	Asteraceae	*Tagetes erecta* L.	Marigold, Genda	S	S	OS,S

Annexure V: Common hosts across zones with dissimilar severity of *P. solenopsis*

S.No.	Code no.	Family	Botanical name	English/ Vernacular name	*P. solenopsis* severity		
					North	Central	South
1.	NS1	Cucurbitaceae	*Luffa acutangula*	Beera/Ridge gourd/ Ribbed gourd/	I		II
2.	NS2	Portulacaceae	*Portulaca grandiflora* Hook	Gule dupehri	III		I
3.	CS1	Fabaceae	*Leucaena leucocephala* L.	Wild tamarind, White Babool		I	II
4.	CS2	Portulacaceae	*Portulaca oleracea* L.	Purslane		I	IV
5.	CS3	Sapindaceae	*Cardiospermum halicacabum* L.	Balloon vine		II	I
6.	CS4	Verbenaceae	*Tectona grandis* L. F.	Teak, Sagun		II	III
7.	CS5	Capparidaceae	*Cleome viscosa* L.	Yellow spider flower, Cleome, Tickweed, Nai kadugu,		II	III
8.	CS6	Euphorbiaceae	*Phyllanthus amarus* L.	Niruri /Otheite, Jangali amla, Jondhali		II	IV
9.	CS7	Verbenaceae	*Duranta erecta* L.	Sky flower, Pigeon Berry		III	I
10.	CS8	Amaranthaceae	*Alternanthera paronychioides* A.St.Hil.	Smooth Chaff Flower, Reshimkata.		III	II
11.	CS9	Amaranthaceae	*Aerva lanata* (L.) Juss	Mountain Knot Grass, Chhaya, kapurmadhuri		III	IV
12.	CS10	Fabaceae	*Clitoria ternatea* L.	Butterfly Pea		IV	II
13.	CS11	Asteraceae	*Taraxacum officinale* Wigg.	Dandelion		IV	II
14.	CS12	Euphorbiaceae	*Acalypha indica*	Muripindi/Indian copper leaf		IV	II
15.	CS13	Euphorbiaceae	*Euphorbia geniculata*	Pala aku/Wild poinsettia		IV	III
16.	CS14	Malvaceae	*Malvastrum coramandelinum* Garcke	False Mallow, Broom weed		IV	III
17.	NCS1	Cucurbitaceae	*Citrullus lanatus* (Thumb) Mansf.	Watermelon	I	II	II
18.	NCS2	Convolvulaceae	*Convolvulus arvensis* L.	Field Bind weed, Hiranpug, Hiran khuri	I	III	III
19.	NCS3	Myrtaceae	*Melaleuca leucadendron* L.	Bottle brush	I	I	II
20.	NCS4	Solanaceae	*Solanum virginianum* L.	Thorny Nightshade, Yellow Berried, Thai eggplant	I	II	II
21.	NCS5	Punicaceae	*Punica granatum* L.	Pomegranate, Anar	II	I	I
22.	NCS6	Rhamnaceae	*Ziziphus mauritiana* Lamk.	Ber	II	I	I
23.	NCS7	Verbenaceae	*Lantana camara* L.	Lantana	II	IV	IV
24.	NCS8	Solanaceae	*Capsicum annum* L.	Chilly	II	IV	II
25.	NCS9	Amaranthaceae	*Digera muricata* (L.)	Tandla, False Amaranth	II	IV	I
26.	NCS10	Moraceae	*Ficus religiosa* L.	Peepal, bodhi plant, holy plant, scared fig	II	I	I
27.	NCS11	Solanaceae	Solanum tuberosum L.	Potato	III	IV	IV

S.No.	Code no.	Family	Botanical name	English/ Vernacular name	*P. solenopsis* severity		
					North	Central	South
28.	NCS12	Asteraceae	Chrysanthemum indicum L.	Chrysanthemum, Shewanti	III	II	II
29.	NCS13	Malvaceae	Abutilon indicum (L) Sweet	Indian Mallow, Country Mallow	III	IV	IV
30.	NCS14	Asteraceae	Tagetes erecta L.	Marigold, Genda	III	II	II
31.	NCS15	Malvaceae	Abelmoschus esculentus L.	Okra, Bhindi, Ladies Finger,	IV	IV	II
32.	NCS16	Solanaceae	Solanum melongena L.	Brinjal, Egg plant	IV	IV	III
33.	NCS17	Fabaceae	Cyamopsis tetragonoloba (L.) Taub.	Guar	IV	II	II
34.	NCS18	Asteraceae	Xanthium strumarium L.	Common Cocklebur, broad bur, burdock datura	IV	IV	II

Annexure VI: Common hosts of *P. solenopsis* across zones with different spatial distribution

S.No.	Code no.	Family	Botanical name	English/ Vernacular name	Location of *P. solenopsis* hosts		
					North	Central	South
1.	NS1	Euphorbiaceae	*Jatropha curcas* L.	Jatropha, Barbados nut	R		F
2.	NS2	Fabaceae	*Dalbergia sissoo* Roxb.	Indian rosewood, Shisham	R, W		R
3.	NS3	Portulacaceae	*Portulaca grandiflora* Hook	Gule dupehri	F, R		R
4.	CS1	Euphorbiaceae	*Acalypha indica* L.	Muripindi/Indian copper leaf		B	R
5.	CS2	Sapindaceae	*Cardiospermum halicacabum* L.	Balloon vine		B, R	R
6.	CS3	Capparidaceae	*Cleome viscosa* L.	Yellow spider flower, Cleome, Tickweed, Nai kadugu,		F, R	F,B,R
7.	CS4	Euphorbiaceae	*Phyllanthus amarus* L.	Niruri /Otheite, Jangali amla, Jondhali		F,B	F,B,R
8.	CS5	Amaranthaceae	*Aerva lanata* (L.) Juss	Mountain Knot Grass, Chhaya, kapurmadhuri		F,B,R	F, R
9.	CS6	Caesalpiniaceae	*Senna tora* L.	Coffee weed/ sickle pod Stinking Cassia, Chinese senna, sickle senna		F,B,R,W	R
10.	CS7	Euphorbiaceae	*Euphorbia geniculata* L.	Pala aku/Wild poinsettia		F,B,R,W	F, R
11.	CS8	Asteraceae	*Taraxacum officinale* Wigg.	Dandelion		R	F, R
12.	NCS1	Malvaceae	*Abutilon indicum* (L) Sweet	Indian Mallow, Country Mallow	B, R	F,B,R,W	F,B,R
13.	NCS2	Amaranthaceae	*Achyranthes aspera* Linn.	Puthkanda, Crocus stuff, Devil's horsewhip	B,R,W	F,B,R	F,B,R
14.	NCS3	Asteraceae	*Tagetes erecta* L.	Marigold, Genda	F	F,B	R
15.	NCS4	Rhamnaceae	*Ziziphus mauritiana* Lamk.	Ber	F	B	B
16.	NCS5	Aizoaceae	*Trianthema portulacastrum* L.	Itsit, Sanrai, Desert Horse Purslane, Giant pigweed	F,B,R	F, R	F, R
17.	NCS6	Solanaceae	*Physalis minima* L.	Ground Cherry, Sun berry	F,B,R	B, R	B, R
18.	NCS7	Solanaceae	*Solanum nigrum* L.	Black nightshade, Black-berry night shade, Poisonberry	F,B,R	B, R	B, R
19.	NCS8	Asteraceae	*Xanthium strumarium* L.	Common Cocklebur, broad bur, burdock datura,	F,R,W	F,B,R	R
20.	NCS9	Rosaceae	*Rosa indica* L.	Ornamental	R	F	F
21.	NCS10	Verbenaceae	*Lantana camara* L.	Lantana	R, W	B, R, W	B, R, W
22.	NCS11	Asteraceae	*Chrysanthemum indicum* L.	Chrysanthemum, Shewanti.		F	F

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