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Impact of Intercropping Soybean on Natural Enemy Guilds in Cotton and Suitability of Trapping Methods for Various Insects

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Abstract: Field studies were carried out in cotton in the experimental fields of College Farm, Rajendranagar, Hyderabad during *kharif* 2019-20 to determine the impact of soybean as an intercrop and study its role in mitigating pests and enhancing the diversity of natural enemies. The study also estimated the efficiency of various sampling methods for insects of various orders. Insect pests of 18 families of 6 orders from intercropped cotton and 13 families of 5 orders from sole cotton were collected while predators of 22 families and 9 orders from intercropped cotton and of 22 families and 8 orders were collected from sole cotton. Diversity indices revealed a strong and robust natural enemy assemblage in the intercropped and sole cropped cotton ecosystems. However, intercropped cotton recorded lesser pest density (9.68/m^2), higher predator (1.06/m^2) and parasitoid density (0.31/m^2) than sole cotton (11.21, 0.75 and 0.14/m^2, respectively).Yellow sticky traps were most effective for sampling major pests namely leaf hoppers, whiteflies and thrips at 66.02, 87.89 and 85.32 per cent of their total numbers, respectively. Coccinellids and hymenopterans could be effectively sampled from sticky traps (85.95 and 75.50-93.42 per cent, respectively).

Keywords: Cotton, Intercrop, Soybean, Parasitoids, Predators

Cotton occupy about 2.4 per cent of the world's arable land. It supports the global textile mills market and the global apparel manufacturing market that produce garments for wide use valued at USD 748 billion and 786 billion, respectively, in 2016 (Lu 2018). Yield loss due to sucking pests in *Bt* cotton was 35.61 per cent in 2016-17 (Makwana et al 2018) and 33.02 per cent in *Bt* seed cotton in 2016 (Tukaram et al 2017). Globally, cotton 10 per cent of insecticide in 2019 according to International Cotton Advisory Committee. Cotton forms 6.5 per cent of the gross cropped area in India while consuming 50% of the total pesticides (Department of Agriculture, Cooperation & Farmers' Welfare, Annual Report 2020-21, Nayak and Solanki 2021).

An over reliance on synthetic insecticides and its associated environmental impact have resulted in the evolution of resistance in insects, secondary pest outbreaks, and resurgences (Razaq et al 2019). The introduction of *Bt* cotton has helped minimise pesticidal sprays to some extent, however, an integrated approach is required to gain control of the devastating pests attacking the crop. Out of the many pest management practices feasible at the farmers' level, increasing plant diversity in the field can achieve increased population of various natural enemies, which subsequently enhance natural pest control. For many pest species, natural enemies are the primary regulating force in the dynamics of their populations (Pedigo and Rice 2009). Deterrence of colonisation is probably one of the most promising means of controlling insect pests through intra-field diversity, because only a little additional diversity in the crop field may have a profound effect on colonization by insects (Cromartrie Jr 1993).

In cotton, intercropping can provide resources such as food and shelter and enhance the abundance and effectiveness of natural enemies (Mensah 1999). Growing short duration intercrops like soybean in cotton helps to safeguard the economy of the farmer through extra yields of intercrop and protects from adverse climatic risk and improves soil fertility through biological nitrogen fixation. Much work has been done on agronomic and soil aspects of cotton-soybean intercropping methods but little is known about the composition and nature of predatory and parasitic guilds and the impact they create on pest abundance and diversity.

Sampling is an essential and fundamental component of any experimental based research in entomology, whether conducted in laboratory, greenhouse or field. When selecting an appropriate sampling method, one should closely consider the design of the respective sampling tools and their costs, as well as the ecological traits and habitat conditions of the target taxa (Gullan and Cranston 2010). Various sampling methods have been used to sample and monitor cotton insect pests. Sticky traps have been widely used to sample harmful and beneficial insects. Preference of insects towards specific colour is a much-known phenomenon. Most often yellow coloured sticky traps are used to trap aphids and whiteflies (Devi and Roy 2017). Sweep net (SN) is considered to be a simple and cost-effective method to collect parasitic Hymenoptera from vegetation (Narendran 2001, Yi et al 2012). Five methods were evaluated and their suitability in sampling various groups of insects in the cotton ecosystem.

MATERIAL AND METHODS

The experiment was laid out in a plot of 1200 m^2 in College Farm, Rajendranagar during *kharif* 2019-20. The plot was divided into two modules *viz*., module M-I and module M-II of 600 m^2 each. Module M-I was raised as sole cotton while in Module M-II cotton was intercropped with soybean in 1:2 ratio. Spacing adopted was 90 X 60 cm for cotton and 30 X 10 cm for soybean. Bt cotton variety Jadoo was sown in the second week of July and soybean variety, JS 335 was sown ten days after germination of cotton to allow it to establish. Observations on insect fauna were recorded 10 days after germination to the second harvest of crop i.e. from the last week of August to the second week of December using yellow pan traps (YPT), pitfall traps (PFT), yellow sticky traps (ST), sweep nets (SN) and visual observations (VC). Five yellow pan traps and four pitfall traps were placed in each module and water mixed with little soap and salt was poured into them. One sticky trap was placed in each module. Twenty-four hours after placing traps in the field, insects trapped were collected, separated into respected families under each order and their abundance was worked out. A sweep net was used to collect insects in the modules once every fortnight by moving in a diagonal path across each module. At each point, five sweeps were taken up and a total of five points were considered. Twenty randomly selected plants were examined in visual counts. After compiling data on insect abundance, it was analyzed using OPSTAT software (Sheoran et al 1998). Diversity indices were calibrated to study the diversity parameters of pests, natural enemies, and neutral insects in the modules using the following formulae:

a) Species diversity (H) was calculated using formula Shannon-Weaver index (1949).

$$\text{Species diversity (H)} = \sum_{i=1}^{s} (pi)(\ln pi)$$

where pi = Proportion of ith species in the total sample

pi = fi/n

n = Total number of specimens in the sample

fi = Number of specimens of the ith species

s = Total number of species

ln = Natural logarithm (loge)

b) Margelef diversity index (Margalef 1958): This was calculated using the formula

$$= (S-1)/Ln(N)$$

Where,

S = Total number of species

N = Total number of individuals in the sample

Ln = Natural logarithm

c) Pielou's Evenness Index (E) (Pielou, 1966) was calculated using the formula.

$$E = H' / Ln\ S$$

where,

H' = Shannon – Wiener diversity index

S = Total number of species in the sample

Ln = Natural logarithm

d) Simpson's Index of Diversity (D) (Simpson 1949)

$$D= \Sigma\ ((n_i-1) /N * (N-1))$$

where: n_i- Number of individuals in the *i*-th species;

N -Total number of individuals in the community

e) Total predator density was calculated using the formula

$$\frac{\text{Total no. of predators collected}}{\text{Total area (sq.m.) sampled}}$$

RESULTS AND DISCUSSION

Insect pests: Insect pests of 18 families belonging to six orders from intercropped cotton and 13 families belonging to five orders from sole cotton were collected. A total of 5,843 insects were collected from intercropped cotton and 6,732 individuals from sole cotton. Abundance of major pest families of cotton was significantly greater in sole cotton crop than intercropped cotton. Abundance values of *Amrasca biguttula, A. devastans* (Cicadellidae), *Aphis gossypii* Glover (Aphididae), *Bemisia tabaci* Gennadius (Aleyrodidae) and *Thrips tabaci* Lindeman (Thripidae) were 784, 935, 781 and 2709, respectively in intercropped cotton and 925, 1112, 1154 and 3437, respectively in sole cotton (Table 1). Studies on pest density revealed that soybean had considerable negative impact on pest density and hence qualifies for a very effective candidate crop to be considered as an intercrop in cotton ecosystem. Total pest density was 9.68 per sq.m. and 11.21 per sq.m. in intercropped cotton and sole cotton, respectively highlighting the role of soybean as an intercrop in suppressing pest populations by boosting natural enemy population.

Predators: Arthropod predators of 22 families and 9 orders from intercropped cotton and those of 22 families and 8 orders were collected from sole cotton during the period. A total of 636 predator individuals were collected in intercropped cotton and 454 individuals from sole cotton plots. Family Coccinellidae of Coleoptera was represented by eight genera *Cheilomenes sexmaculata* (Fabricius), *Coccinella transversalis* Fabricius, *Propyleadis secta*(Mulsant), *Harmonia octomaculata* (Fabricius), *Hippodamia variegata* (Goeze), *Brumoidessuturalis* (Fabricius), *Scymnus nubilus* Mulsat and *Illeiscincta* (Fabricius). *H. octomaculata*, *H. variegata* and *C. transversalis* were recorded during the first one month, while remaining species till harvest. *C. sexmaculata* was most abundant species. Intercropped cotton recorded higher population (132 beetles) of Coccinellids than sole cotton (82 beetles). Carabidae and Staphylinidae (*Paederus fuscipes* Curtis) were the other two families and their total population was 22 and 53, respectively in intercropped module and 21 and 28, respectively in sole cotton (Table 1). Predatory hemiptera was another major order represented by four families *viz*, Anthocoridae [(*Orius tantillus* (*Motschulsky*)], Lygaeidae (*Geocoris* sp.), Nabidae (*Nabis* sp. commonly called as damsel bugs) and Reduviidae (*Rhynocoris* sp). Their population was 13, 16, 4 and 3, respectively in intercropped module while it was 6, 11, 4 and 2, respectively in sole cotton. Order Diptera included predatory insects from two families *viz*., *Ischiodan scutellaris* (Fabricius) and *Paragus* sp. from Syrphidae and long-legged flies from Dolichopodidae. Population of Syrphidae and Dolichopodidae was 13 and 56, respectively in intercropped module, while it was 6 and 40, respectively in sole cotton. Predators of other families were observed in very low numbers and were of less importance. Order Araneae was represented by nine families of spiders, among which Lycosidae and Araneidae were the most abundant. Their total population was 85 and 78, respectively in intercropped module while it was 73 and 46, respectively in sole cotton.

Table 1. Abundance of insect families in intercropped and sole cotton modules

Insect family	Population in module		p value
	Intercropped	Sole	
Cicadellidae	784	925	0.014*
Aphididae	935	1112	0.029*
Aleyrodidae	781	1154	0.001*
Thripidae	2709	3437	0.017*
Coccinellidae	132	82	0.283
Staphylinidae	53	28	0.251
Araneidae	78	46	0.073
Platygasteridae	52	21	0.015*
Diapriidae	32	18	0.025*
Eupelmidae	23	7	0.021*
Braconidae	21	11	0.033*

*Significant at 5% level

Shannon-Wiener index (H') was 2.47 and 2.46, respectively in intercropped and sole cotton, while Margelef's index of diversity was 3.25 and 3.43 in intercropped cotton and sole cotton modules, respectively indicating a very stable predator community. Pielou's evenness index (E) was 0.79 in both modules implying uniform numbers of the various families which is indicative of higher biodiversity ensuring good natural control in the field. Simpson's Diversity index (D) was 0.11 and 0.12 in intercropped cotton and sole cotton, respectively which again revealed a very strong and balanced predator community in both the modules. In general, predator community at Rajendranagar was reliable and long lasting, safe guarding the crop against pests and maintaining their levels much below the ETL for most part of the crop season. However, though diversity indices did not differ much between the intercropped and sole cotton, predator density was 1.4 times higher in intercropped module compared to sole cotton module (1.06 and 0.75 no./sq.m., respectively) underlining the role of intercropping on predator population enhancement (Table 2).

Parasitoids: Parasitoids of 14 families and 2 orders were collected from each module. A total of 185 individuals were collected in intercropped cotton and 90 individuals from sole cotton. Hymenoptera and Diptera were the two orders observed. The five most abundant families were of Platygastridae, Diapriidae, Mymaridae (*Mymar sp*., *Anagrus sp*.and *Gonatocerus sp.*), Braconidae and Eupelmidae with total population of 52, 32, 25, 21 and 23, respectively in intercropped module which was far higher than that in sole cotton module *i.e*, 21, 18, 15, 11 and 7, respectively. Platygastridae and Mymaridae were effective egg parasitoids of Hemipterans, Mymarids specially parasitize eggs of leaf hoppers. Other families of Hymenoptera were recorded in very low numbers in both the modules (Table 1).

Studies on diversity indices of parasitoids revealed that Shannon-Wiener index (H') was 2.04 and 2.13, respectively in intercropped and sole cotton; Margelef's diversity index was 2.29 and 2.67 in intercropped cotton and sole cotton, respectively implying very stable population of parasitoids. Higher values of diversity index and Margelef's diversity index in both modules indicated a balanced population which rendered natural control so successfully in the field that for most of the crop growth period the pests were found to be below ETL. Pielou's evenness index (E) was 0.80 and 0.83 for intercropped cotton and sole cotton, respectively showing almost uniform numbers of parasitoids of each family. Simpson's Diversity Index (D) was 0.15 and 0.13 in both modules, respectively revealing the rich diversity of parasitoids. Higher diversity indices implied lesser competition between the genera for various resources since parasitoids of different families vary in terms of food preferences and this helps to keep up chances of enhanced natural control. Though diversity indices did not differ between the modules, total parasitoid density in intercropped module was more than twice that in sole cropped one underlining yet again how intercropping favoured build-up of natural enemies (0.31 and 0.14/sq.m. respectively) (Table 2).

Neutral insects: Neutral insects of 14 families belonging to 7 orders were collected from each module during the study. A total of 495 neutral insect individuals were collected in intercropped cotton while 358 were collected from sole cotton. Flower beetles of Nitidulidae (Coleoptera) (200) and Entomobryidae (Collembola) (178) were the most abundant insects in both the modules. Population of other families *i.e*. Muscidae, Phoridae, Caliphoridae, Forficulidae, Apidae, Tipulidae, Stratiomyidae, Baetidae, Tephritidae, Scarabaeidae and Sarcophagidae was very low (Table 6). Total numbers were higher in intercropped module compared to sole cotton. *Apis dorsata Fabricius* and *Apis florae Fabricius* (Apidae; Hymenoptera) were found foraging actively throughout the flowering period. Forficulidae (Dermaptera) and Epispadias (Zygentoma) were scavenger insects collected in the study. Baetidae of Ephemeroptera (Mayflies) can be categorized as occasional visitors to the field. Each trophic level of the food pyramid plays an important role in the maintenance of the ecological balance. Maintenance of vegetation adjacent to or in crop fields provides alternative food, refuge and sometimes oviposition substrate for predators and parasitoids thereby increasing natural enemy abundance and colonization of neighbouring crops. Neutral insects are the key factors for flow of energy in a food web and hence their numbers were also documented in the present study.

The diversity indices of neutral insects in predators and parasitoids, the modules did not differ with each other with respect to diversity indices. Shannon-Wiener index (H') and Margelef's diversity index were 1.56 and 1.68 and 2.09 and 2.18 in intercropped cotton and sole cotton, respectively indicating a stable population in the modules. Pielou's evenness index (E) was 0.59 and 0.63 in intercropped cotton and sole cotton, respectively indicating that they contained almost unvarying numbers of insects in the families (Table 2). However, density of neutral insects was quite different between the modules (0.82 and 0.64 in intercropped cotton and sole cotton, respectively) exhibiting positive effects of intercropping on the population of neutral insects.

Suitability of trapping methods to insects of various families: Analysis of results on insect catches in various methods of trapping revealed the suitability of sampling methods. Insects of 8 families belonging to 4 orders were recorded in the study.

Insect pests: Among various sampling methods for pests of various families, sticky traps collected significantly greatest number of pests *viz*., leaf hoppers (66.02% of total catch), thrips (65.94%), whiteflies (87.89%) and Mirids (85.32%), while visual counts were good enough to sample aphids (41.53%) and Pyrrhocorids (55.75 %) and yellow pan traps collected fairly good number of leafhoppers (19.74%), whiteflies (17.01%), lesser numbers of Mirids (3.66%) and Pyrrhocorids (1.76%). Sweep nets were useful in sampling Pyrrhocorids (42.47%), while pitfall traps trapped all of the Acridids (100%) (Table 3).

Predators: Three predator families of Coleoptera were among which Coccinellids were more abundant and significantly in higher numbers (85.95%) were collected mostly from sticky traps than other methods. Visual counts, sweep nets and yellow pan traps were less effective since they collected 7.53, 3.68 and 2.84 per cent of Coccinellids, respectively. Carabids being mostly groundwellers, were collected only in Pit fall traps (100%). Yellow pan traps were more effective to trap rove beetles (Staphylinidae) (61.43%) than other methods. Sweep nets and pit fall traps recorded very few numbers of the beetles (22.86 and 11.43% respectively). All the Dolichopodids were trapped in yellow pan traps. Nabid bugs were observed in significantly higher numbers in sticky traps (91.21%), folllowed by Sweep nets (6.51%) and Visual counts (2.28%) (Table 4).

Table 2. Diversity indices and density of predators and parasitoids in intercropped and sole cotton

Diversity indices	Predators		Parasitoids		Neutral insects	
	IC	SC	IC	SC	IC	SC
Shannon Wiener (H')	2.47	2.46	2.04	2.13	1.56	1.68
Margelef's diversity index	3.25	3.43	2.29	2.67	2.09	2.18
Pielou's evenness (E)	0.79	0.79	0.80	0.83	0.59	0.63
Simpson diversity (D)	0.11	0.12	0.15	0.13	0.30	0.26
Total density (no./sq.m)	1.06	0.75	0.31	0.14	0.82	0.64

IC = Intercropped cotton, SC = Sole cotton

Spiders belonging to four families were observed during the study. All Lycosid and Theridiid spiders which live close to the ground were trapped in pit fall traps. Sweep nets and visual counts were significantly effective to record Araneid spiders (45.45%) than yellow pan traps (9.09%). Thomisid spiders which usually stay near the flowers and wait for the prey were best sampled in Visual counts (100%).

Parasitoids: Sticky traps displayed significant attraction for almost all of the Hymenopteran families namely Platygastridae, Diapriidae, Mymaridae, Braconidae and Eupelmidae (75.50, 80.28, 93.42, 85.07 and 85.80% respectively of total population). Yellow pan traps were second most effective trapping 24.50 per cent of Platygastrids, 19.72 per cent of Diapriids, 6.58 per cent of Eupelmids, 14.93 per cent of Mymarids and 14.14 per cent of Braconids, while Cynipid wasps were collected only in yellow pan traps (Table 5).

Neutral insects: Those insects which form a part of the ecosystem but were neither pests nor natural enemies were considered as neutral insects. Ten families of neutral insects belonging to five orders were recorded in various sampling methods. Springtails of family Entomobryidae live in debris on the ground and hence were collected in significantly higher numbers from pit fall traps (72.41% of total population) followed by yellow pan traps (27.59%). Yellow pan traps can capture the entire population of four Dipteran families *viz*, Sarcophagidae, Calliphoridae, Muscidae and Phoridae, while insects of Tipulidae, another Dipteran family was observed only in sticky traps. Earwigs of Forficulidae were trapped only in pit fall traps (100%) as they move close to the ground. Flower beetles in the family Nitidulidae were trapped in significantly higher numbers in sticky traps (64.31%), while17.36 and 12.86 per cent were sampled using sweep nets and yellow pan traps. Scarabaeids were trapped only in pit fall traps (Table 5).

The present study threw light on abundance and diversity of predator, parasitoid and neutral insect assemblages in cotton ecosystem and compared them in the presence and absence of an intercrop (soybean). Though diversity of natural enemies and neutral insects was more or less similar

Table 3. Insect pest abundance in different collection methods

Pest family	Trap catch (% of total catch)				
	Visual	Yellow pan trap	Sticky trap	Sweep net	Pitfall trap
Cicadellidae	14.23^{c}	19.74^{b}	66.02^{a}	0.00^{d}	0.00^{d}
Aphididae	41.53^{a}	23.93^{c}	34.53^{b}	0.00^{d}	0.00^{d}
Aleyrodidae	3.54^{c}	8.56^{b}	87.89^{a}	0.00^{d}	0.00^{d}
Miridae	9.17^{b}	3.66^{c}	85.32^{a}	1.83^{d}	0.00^{e}
Pyrrhocoridae	55.75^{a}	1.76^{c}	0.00^{d}	42.47^{b}	0.00^{d}
Thripidae	22.12^{b}	11.92^{c}	65.94^{a}	0.00^{d}	0.00^{d}
Gelechiidae	66.43^{a}	13.98^{b}	19.58^{b}	0.00^{c}	0.00^{c}
Acrididae	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	100^{a}

Values in a row with the same alphabet are not statistically different

Table 4. Predator abundance in different collection methods

Family	Trap catch (% of total catch)				
	Visual	Yellow pan trap	Sticky trap	Sweep net	Pitfall trap
Coccinellidae	7.53^{b}	2.84^{d}	85.95^{a}	3.68^{c}	0.00^{e}
Carabidae	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	100.00^{a}
Staphylinidae	4.29^{d}	61.43^{a}	0.00^{e}	22.86^{b}	11.43^{c}
Dolichopodidae	0.00^{b}	100.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}
Nabidae	2.28^{b}	0.00^{c}	91.21^{a}	6.51^{b}	0.00^{c}
Lycosidae	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	100.00^{a}
Araneidae	45.45^{a}	9.09^{b}	0.00^{c}	45.45^{a}	0.00^{c}
Thomisidae	100.00^{a}	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}
Theridiidae	0.00^{b}	0.00^{b}	0.00^{b}	0.00^{b}	100.00^{a}

Values in a row with the same alphabet are not statistically different

Table 5. Parasitoids and neutral insect abundance in different collection methods

Family	Trap catch (% of total catch)				
	Visual	Yellow pan trap	Sticky trap	Sweep net	Pitfall trap
Parasitoids					
Platygastridae	0.00[c]	24.50[b]	75.50[a]	0.00[c]	0.00[c]
Diapriidae	0.00[c]	19.72[b]	80.28[a]	0.00[c]	0.00[c]
Eupelmidae	0.00[c]	6.58[b]	93.42[a]	0.00[c]	0.00[c]
Mymaridae	0.00[c]	14.93[b]	85.07[a]	0.00[c]	0.00[c]
Braconidae	0.00[c]	14.14[b]	85.80[a]	0.00[c]	0.00[c]
Cynipidae	0.00[c]	100.00[a]	0.00[b]	0.00[c]	0.00[c]
Neutral Insects					
Entomobryidae	0.00[c]	27.59[b]	0.00[c]	0.00[c]	72.41[a]
Sarcophagidae	0.00[b]	100.00[a]	0.00[b]	0.00[b]	0.00[b]
Calliphoridae	0.00[b]	100.00[a]	0.00[b]	0.00[b]	0.00[b]
Muscidae	0.00[b]	100.00[a]	0.00[b]	0.00[b]	0.00[b]
Phoridae	0.00[b]	100.00[a]	0.00[b]	0.00[b]	0.00[b]
Tipulidae	0.00[b]	0.00[b]	100.00[a]	0.00[b]	0.00[b]
Apidae	0.00[b]	100.00[a]	0.00[b]	0.00[b]	0.00[b]
Forficulidae	0.00[b]	0.00[b]	0.00[b]	0.00[b]	100.00[a]
Scarabaeidae	0.00[b]	0.00[b]	0.00[b]	0.00[b]	100.00[a]
Nitidulidae	5.47[d]	12.86[c]	64.31[a]	17.36[b]	0.00[e]

Values in a row with the same alphabet are not statistically different

between the modules, their increased abundance in the intercropped module ensured continues flow of energy from one trophic level to another leading to a complex interwoven food web. Such web rarely allowed pest levels to rise above the ETL due to enhanced natural control. An intercrop, if correctly assembled in time and space, can lead to agroecosystems capable of maintaining their own soil fertility, regulating natural protection against pests and sustaining productivity (Thrupp 2002, Scherr and McNeely 2008). Intercropping of compatible plants promotes biodiversity by providing a habitat for a variety of insects and soil organisms that would not be present in a single crop environment. The most common advantage of intercropping is the production of greater yield from the same field making more efficient use of the available growth resources using a mixture of crops of different nutrient requirements based on the complementary utilization of growth resources by the component crops (Lithourgidis et al 2011). Moreover, intercropping cotton with soybean improves soil fertility through biological nitrogen fixation, increases soil conservation through greater ground cover than sole cropping. Intercropping provides insurance against crop failure or against unstable market prices for cotton, especially in areas subject to extreme weather conditions such as frost, drought, and floods (Lithourgidis et al 2011). Rao (2011) also recorded significantly lowest infestation of whitefly in cotton + soybean (1.07 whiteflies/leaf), compared to other intercropped treatments and lowest population of thrips was in cotton + soybean, but aphids was lowest in cotton + green gram. Godhani (2006) quantified low population of aphids in cotton intercropped with maize, sesamum, soybean than pure cotton plots, respectively. Kadam et al (2014) observed that, cotton + soybean was superior treatment recording highest count of chrysopids followed by, cotton + green gram), cotton + sesamum (leaves) and least in sole cotton.

Khuhro et al (2020) found that yellow sticky traps collected overall highest number of whiteflies followed by green colour sticky traps, pink colour sticky traps and light green colour sticky traps. Sweep net and yellow pan traps were suitable for quantitative estimation of parasitoids whereas malaise trap was more suitable for qualitative estimates (Shweta and Rajmohana 2018). Mellet et al (2006) observed that ground dwellers comprised 21 families, 49 genera and 54 species, of which Lycosidae represented 62.5 per cent followed by Theridiidae comprising 20.0 per cent and Linyphiidae (9.1 per cent).

CONCLUSIONS

The higher diversity of natural enemies in the intercropped plot kept the pest under check from time to time and the need for pest management practices was low, leading to lesser input costs and a safer environment. The intercropping cotton with soybean is suitable for many areas of the state, where both cotton and soybean are grown but mostly as sole crops. Intercropping offers greater financial stability than sole cropping, which makes the system particularly suitable for labour-intensive small farms to reap good harvests and keep their ecosystems safe for generations to come. Findings on suitable trap types for various insects benefits biodiversity studies. Yellow sticky traps could attract majority of herbivorous hemipterans, predaceous coccinellids, parasitoids of hymenoptera, crane flies and flower beetles and can be preferably be used for sampling and studying them. Pitfall traps are highly useful to trap both adults and immature stages of epigeal insects and spiders.

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