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Flower strip farmscaping to promote natural enemies diversity and eco-friendly pest suppression in okra (*Abelmoschus esculentus*)

ANIL MEENA[1], R K SHARMA[2], S CHANDER[3], D K SHARMA[4] and S R SINHA[5]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012 India

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ABSTRACT

Investigations were conducted on flower strip farmscaping along with intercropping to promote natural enemy diversity and eco-friendly pest suppression in okra during *kharif* 2016 and 2017. Pooled data of both the years revealed that whitefly was lowest (7.66 /15 leaves) in biopesticides treated okra having baby-corn as an intercrop with flower plants strip. Likewise, a minimum population of leafhoppers (39.89/15 leaves), red spider mites (99.16/cm^2/15 leaves) and lowest fruit infestation by fruit borer (9.60%) were observed on treated okra having cowpea as an intercrop with flower strip farmscaping. Maximum population of natural enemies, viz. coccinellids (5.40), spiders (6.38), *Geocoris* bug (2.47), rove beetles (1.99/5 plants) and carabid beetles (1.32/2 pitfall traps) were recorded on untreated okra with cowpea intercropping having flower strip farmscaping. Shannon-wiener index value was found lower for pests on okra treatments having flower strips, while index value was higher for natural enemies on same treatments.

Key words: Farmscaping, Flower strip, Habitat manipulation, IPM, Natural enemies, Okra

Okra is an important vegetable crop grown extensively throughout the year all over India and tropical and subtropical parts of the world. The insect pests creating a bottleneck in higher production of okra are leafhopper (*Amrasca* (*Sundapteryx*) *biguttula* (Ishida)), whitefly (*Bemisia tabaci* (Gennadius)), shoot and fruit borer (*Earias vittella* (Fabricius)) and fruit borer. Kanwar and Ameta (2007) recorded 48.97% reduction in okra fruit yield due to attack by the insect pests. Indiscriminate use of insecticides in vegetable production is resulting in various health hazards. Moreover, disturbances in the pest-natural enemy balance may be caused either by the direct application of insecticides or by the drift of the chemicals in the nearby untreated areas that serve as a reservoir of natural enemies. Modern agriculture has greatly altered and fragmented natural habitats that lead to loss of biodiversity and ecosystem services such as biological control (Geslin *et al.* 2016). Ecological engineering or habitat management can be an important strategy that can partly restore these services. Generally in the agroecosystem natural enemies not only consume herbivore but also depend on plant material like pollen nectars and extra flower nectars. Floral nectar is often scarce in agricultural ecosystems (Heimpel and Jervis 2005). The ecological services could be maximised to conserve and augment natural enemies population by provisioning of alternative food sources. Habitat management involving manipulation of agro-ecosystem can exert direct detrimental effects on pests and promote natural enemies by providing suitable floral vegetation thereby supporting natural enemies with shelter, nectar, honeydew, alternative prey/hosts, and pollen (Gurr *et al.* 2017).

Farmscaping refers to intentionally introducing flowering plants into agricultural ecosystems with a view to increase pollen and nectar resources required by most natural enemies of insect pests (Sreedhar 2012, Philips *et al.* 2014). Various forms of farmscaping have been used to increase the activity of beneficial insects in the form of permanent hedgerows or temporary insectary strips in the vegetable fields (Tschumi *et al.* 2016). Moreover**,** the efficiency of farmscaping could be increased with combinations of other eco-friendly IPM strategies like the inclusion of biopesticides (Meena *et al.* 2017b).

MATERIALS AND METHODS

The experiment was conducted at the research farm of Division of Entomology, IARI, New Delhi, located at 28º38'23''N latitude; 77º09'27''E longitude; 228.61m altitude during *kharif* 2016 as well as 2017. The trials were laid out in two sets, one set without flower strips whereas, other had flower strip with uniformly sized plots measuring 5 m × 4 m (20 m^2) in Factorial Randomized Block Design containing six treatments, viz. T_1-untreated sole okra, T_2-treated sole okra, T_3-untreated okra + baby

Present address: [1]Ph D Scholar (anilbatawada03@gmail.com), [2]Head and Principal Scientist (rksharma57@gmail.com), [3]Professor and Principal Scientist (schanderthakur@gmail.com), [5]Chief Technical Officer (srsinha62@gmail.com), Division of Entomology. [4]Principal Scientist (dks_env@rediffmail.com), CESCRA.

corn (2:1), T_4-treated okra + baby corn (2:1), T_5-untreated okra + cowpea (2:1) and T_6–treated okra + cowpea (2:1) with four replications of each; thus in all there were 24 plots in each experimental set. Treated means two sprays of each biopesticide, viz. Azadirachtin (0.03% E.C.) @ 3 ml/l of water and *Beauveria bassiana* (1.15% S.C containing 1×10^8 spores per ml) @ 2.5 ml/l of water, were made alternatively at 15 days interval on initiation of pest infestation after germination and afterward different crop growth stages.The row-to-row distance and plant-to-plant spacing for okra and intercrops were 60 cm and 45 cm respectively. Sowing of the recommended variety of okra (*Arka Anamika*) and intercrops such as baby corn (*Zea mays* L.) variety (G-5414) and cowpea (*Vigna unguiculata* (L.) variety (*Kashi Kanchan*) was done in July 2016 and 2017 as a sole crop and farmscaping crop combination as detailed out in the treatments. On the other hand, mature seedlings of marigold and vincia were transplanted in strips adjacent to each replication of okra at a distance of 60 cm.

Floral plants strip: For evaluating the performance of flower strips specifically designed to promote natural enemies and their pest suppression potential, were kept adjacent to each replication of set-II. All flower strips consisted of mixture of 5 plant species, viz. marigold (*Tagetes erecta* L.), sesame (*Sesamum indicum* L.), zinnia (*Zinnia elegans* L.), vincia (*Catharanthus roseus* (L.) and cosmos (*Cosmos sulphurous* Cav.) for providing abundant floral and extra-floral resources and each strip was 0.5 m wide. The planting of sesame, zinnia, and cosmos was done along with okra while marigold and vincia were transplanted in each strip.

Data collection: The population of leaf hoppers, whiteflies and mites on 3 leaves (upper, middle and lower) was recorded through visual count technique during early hours of the day on randomly selected and tagged 5 plants per replication. The fruits infested with shoot and fruit borer were observed at each picking and their weight was recorded. The weight of healthy and infested fruits was taken separately and per cent infestation was computed for each treatment. The population of red spider mites on the selected leaves was recorded by placing a cardboard sheet that had a window of 1 cm^2 on the ventral surface of the leaf, using a hand lens (10×).The associated natural enemies such as spiders, big-eyed bug, rove beetles and coccinellids were also recorded by the visual count technique on the same 5 plants during early hours of the day. For the estimation of the population of soil-dwelling predators, especially carabids, 2 pitfall traps were randomly placed in each plot of 20 m^2.

The following analyses were done to estimate the species richness and abundance:

$$\text{Relative density (RD\%)} = \frac{\text{Number of individual of one species}}{\text{Total number of individual of all species}} \times 100$$

Shannon-Weiner diversity index (H') = $- \sum pi\ ln\ pi$ where p*i,* decimal fraction of individuals belonging to i^{th} species.

RESULTS AND DISCUSSION

Pooled data of *kharif* 2016 and 2017 (Table 1) showed that enhanced crop diversity with intercrops and farmscaping had a conspicuous negative influence on the pest population build-up due to habitat manipulation. Consequently, lowest mean population of whiteflies, *B. tabaci* (7.66/15 leaves) was recorded on treated okra having baby corn intercropping with flower strip, while minimum populations of leaf hoppers, *A.* (*Sundapteryx*) *biguttula* (39.89/15 leaves) and red spider mites, *T. cinnabarinus* (99.16/cm^2/15 leaves) were observed on treated okra

Table 1 Comparative impact of farmscaping without and with flower plants strip on the mean population of major insect pest of okra (pooled analysis of two *kharif* seasons data)

Treatments*	Sucking pests (Mean population /15 leaves)#								
	White fly			Leaf hopper			Red spider mite		
	NFS	WFS	Mean A	NFS	WFS	Mean A	NFS	WFS	Mean A
T1	17.20	14.28	15.74	90.11	75.61	82.86	171.09	157.04	164.06
T2	12.43	10.62	11.52	63.28	52.05	57.67	146.78	138.45	142.62
T3	13.00	10.62	11.81	81.75	68.76	75.26	144.36	132.55	138.46
T4	8.76	7.66	8.21	56.74	46.98	51.86	124.94	109.07	117.00
T5	14.03	12.38	13.21	73.42	57.56	65.49	135.64	120.72	128.18
T6	10.24	8.86	9.55	47.00	39.89	43.44	109.89	99.16	104.52
Mean B	12.61	10.74		68.72	56.81		138.78	126.16	
	A	B	A x B	A	B	A x B	A	B	A x B
SEm. ±	0.046	0.027	0.065	0.26	0.15	0.37	0.80	0.46	1.14
CD (P=0.05)	0.016	0.009	0.023	0.09	0.05	0.13	0.28	0.16	0.39

*T1, Untreated okra sole, T2, Treated okra sole, T3, Untreated okra+ baby corn, T4, Treated okra + baby corn, T5, Untreated okra + cowpea, T6, Treated okra + cowpea; Four spray of Azadirachtin 0.03% E.C. and *Beauveria bassiana* 1.15% S.C were made alternatively at 15 days interval. #Means of four replications; NFS, No Flower strip; WFS, With Flower strip farmscaping.

with cowpea intercropping having flower strip. On the other hand, maximum population of whiteflies (17.20), leafhoppers (90.11) and red spider mite (171.09) were observed in untreated sole okra without flower strip. Year wise data revealed that Shannon-Weiner Diversity index value for pests was lower (0.763 and 0.823) in the treatments having flower strip farmscaping as compared to those without farmscaping (0.780 and 0.842) during *kharif,* 2016 and 2017, respectively. In case of fruit borer, pooled data of two years (Table 2) revealed that on number and weight basis highest marketable yield (350.90 × 10^3/ha and 4.99 ton/ha) was recorded in the treatment (T_6) with flower strip farmscaping, while it was minimum (164.65 × 10^3/ha and 2.32 ton/ha) in the (T_1) having sole okra without farmscaping. All the treatments were significantly effective in reducing fruit infestation as compared to the sole okra (T_1) without flower strip which recorded maximum (40.38%) infestation. Treated okra having cowpea intercropping (T_6) with flower strips farmscaping was found to be most effective (9.60% infestation) treatment whereas, T_6 (11.46% infestation) without farmscaping was second effective treatment. Moreover, a similar trend was followed in case of fruit infestation on a weight basis. It was evinced that all the treatments significantly differed in regards to the population of pestiferous species between flower strips farmscaping and without farmscaping in okra, indicating a negative influence of flowers on the pest population, possibly due to the creation of physical barrier that hindered the movement of the pest (Risch 1981). Moahansundaram *et al.* (2012) and Sujayanand *et al.* (2016) also observed that okra insect pests could be effectively managed by the inclusion of baby corn, cluster bean and marigold. Beneficial fauna harboured by maize composed primarily of ants, spiders, rove beetles, predaceous mites and ground beetles (Rose and Dively 2007). Similar findings were also observed in different crops, *viz.* tomato crop farmscaped with marigold, cowpea farmscaped with marigold and niger, maize farmscaped with marigold (Kpassawah *et al.* 2013, Meena *et al.* 2017a, Lal *et al.* 2017). Although inclusion of biopesticides and intercropping with farmscaping in the present investigation had a cumulative impact on reducing the pests that also observed earlier by Meena *et al.* (2017b).

As Pooled data of two years (Table 3) revealed significantly higher populations of coccinellids (5.40), spiders (6.38), big-eyed bug (2.47), rove beetles (1.99/5 plants) and carabid beetles (1.32/ 2 pitfall traps) on untreated okra with cowpea intercropping pattern having farmscaping. On the other hand, the lower population of these natural enemies, viz. coccinellids (3.37), spiders (3.08), *Geocoris* bug (0.80) and rove beetles (0.63/5 plants) and carabid beetles (0.43/2 traps) were observed on treated sole okra crop without farmscaping. The values of Shannon-Weiner Diversity Index were relatively higher in okra with flower strips farmscaping (1.447 and 1.431) as compared to that

Table 2 Comparative impact of farmscaping without and with flower strip on the okra fruit and shoot borer infestation (pooled analysis of two *kharif* seasons data)

Treatments*	Marketable fruit yield/ha						Fruit infestation (%)					
	No.(103) basis			Wt.(t) basis			No. basis			Wt. basis		
	NFS	WFS	Mean A	NFS	WFS	Mean A	NFS#	WFS$	Mean A	NFS#	WFS$	Mean A
T1	164.65	187.68	176.16	2.32	2.68	2.50	40.38 (39.47)	32.90 (35.02)	36.64 (37.24)	41.20 (39.95)	33.17 (35.18)	37.18 (37.65)
T2	229.80	249.63	239.72	3.31	3.58	3.45	20.57 (26.88)	16.69 (24.12)	18.63 (25.35)	19.97 (26.55)	16.36 (23.86)	18.17 (25.20)
T3	283.83	297.73	290.78	4.09	4.28	4.19	16.24 (23.77)	14.26 (22.19)	15.25 (22.98)	15.61 (23.28)	13.82 (21.83)	14.71 (22.55)
T4	307.48	314.03	310.75	4.40	4.52	4.46	12.89 (21.04)	12.48 (20.69)	12.68 (20.86)	12.79 (20.96)	11.91 (20.19)	12.35 (20.57)
T5	309.73	316.75	313.24	4.44	4.52	4.48	13.84 (21.85)	13.40 (21.48)	13.62 (21.66)	13.73 (21.76)	13.50 (21.56)	13.61 (21.66)
T6	341.98	350.90	346.44	4.89	4.99	4.94	11.46 (19.79)	9.60 (18.04)	10.53 (18.91)	11.51 (19.84)	10.01 (18.45)	10.76 (19.14)
Mean B	272.91	286.12		3.91	4.09		19.23 (25.48)	16.55 (23.59)		19.13 (25.39)	16.46 (23.51)	
Factor	A	B	A x B	A	B	A x B	A	B	A x B	A	B	A x B
S. Em. ±	6.73	3.89	NS	0.114	0.066	NS	0.35	0.20	0.49	0.38	0.22	0.54
CD (P=0.05)	2.33	1.35	3.29	0.040	0.023	0.056	0.12	0.07	0.17	0.13	0.08	0.19

*T1, Untreated okra solel; T2 - Treated okra sole; T3, Untreated okra + baby corn; T4, Treated okra + baby corn; T5, Untreated okra + cowpea; T6, Treated okra + cowpea; Four spray of Azadirachtin 0.03% E.C. and *Beauveria bassiana* 1.15% S.C were made alternatively at 15 days interval; #Means of four replications; NFS, No Flower strip; WFS, With Flower strip farmscaping; Figures in parenthesis are angular transformed values.

Table 3 Comparative impact of farmscaping without and with flower plants strip on the mean natural enemies occurrence (pooled analysis of two *kharif* seasons data)

Treatments*	Natural enemies (Mean population/5 plants)#														
	Coccinellids			Spiders			*Geocoris* sp.			Rove beetles			Carabid beetles$		
	NFS	WFS	Mean A	NFS	WFS	Mean A	NFS	WFS	Mean A	NFS	WFS	Mean A	NFS	WFS	Mean A
T1	3.45	3.84	3.64	3.43	4.48	3.95	0.95	1.66	1.31	0.72	1.23	0.97	0.36	0.77	0.57
T2	3.37	3.70	3.54	3.08	4.15	3.62	0.80	1.48	1.14	0.63	1.07	0.85	0.43	0.75	0.59
T3	4.00	4.50	4.25	4.05	5.38	4.71	1.52	2.00	1.76	1.17	2.03	1.60	0.75	1.13	0.94
T4	3.94	4.39	4.17	3.80	5.11	4.46	1.38	1.82	1.60	0.93	1.64	1.28	0.76	1.04	0.90
T5	4.56	5.40	4.98	5.05	6.38	5.72	1.91	2.47	2.19	1.40	1.99	1.69	0.94	1.32	1.13
T6	4.51	5.34	4.93	4.72	6.12	5.42	1.73	2.33	2.03	1.14	1.81	1.48	0.93	1.28	1.11
Mean B	3.97	4.53		4.02	5.27		1.38	1.96		1.00	1.63		0.70	1.05	
	A	B	A × B	A	B	A × B	A	B	A × B	A	B	A × B	A	B	A × B
S. Em. ±	0.014	0.008	0.020	0.018	0.010	0.025	0.009	0.005	0.013	0.010	0.006	0.014	0.023	0.013	0.033
CD at 5%	0.005	0.003	0.007	0.006	0.004	0.009	0.003	0.002	0.004	0.003	0.002	0.005	0.008	0.005	0.011

*T1, Untreated okra solel; T2 - Treated okra sole; T3, Untreated okra + baby corn; T4, Treated okra + baby corn; T5, Untreated okra + cowpea; T6, Treated okra + cowpea; Four spray of Azadirachtin 0.03% E.C. and *Beauveria bassiana* 1.15% S.C were made alternatively at 15 days interval; #Means of four replications; NFS, No Flower strip; WFS, With Flower strip farmscaping; Figures in parenthesis are angular transformed values

in okra without flower plants strip (1.392 and 1.381) during *kharif*, 2016 and 2017 respectively. It was evinced from the study that the treatments with farmscaping harboured higher populations of natural enemies as compared to that without farmscaping thereby significantly reducing the pest load on okra. Moreover, the present investigation indicated that treatments that harboured a higher population of natural enemies, had significantly lower pest population and thus performed their ecological service in reducing pest population build up on okra. Tschumi *et al.* (2016) found that abundance of key natural enemies of aphids (hoverflies, lacewings and ladybirds) was greatly enhanced in tailored flower strips compared with potato control strips and caused 75% reduction in aphid population on potato. Likewise, similar results have also been observed in different crops like broccoli with alyssum strip (Brennan 2016) and onion with marigold strip (Silveira *et al.* 2009). The natural enemies' population showed a density-dependent relationship with the population of their prey, that was more evident under flower farmscaping. Present findings can be further explained by the resource concentration hypothesis (Root1973) that states, specialist herbivorous insects are more abundant in the less diverse ecosystem as it is easier to host find, stay in, and reproduce. Moreover, according to enemy's hypothesis (Russell 1989) the predatory insects and parasitoids are more effective to control populations of herbivores in diverse systems of vegetation. Therefore, conservation of beneficial insects is paramount importance in biological pest suppression and harnessing the natural control for better pest regulation.

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