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Eco-friendly management of sucking insect pests in okra with homemade and commercial neem formulations under Punjab conditions

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Sucking insect pests like leaf hopper, *Amrasca bigutulla bigutulla* (Ishida) and whitefly, *Bemisia tabaci* (Gennadius) pose a great threat to the high production of okra fruit. Being vegetable crop, it is eaten as raw and cooked, but due to attack of pest numbers of sprays were done at weekly interval to manage this pest. To reduce the pesticides load on crop and human body the botanical based biorational were in use. So there is need for eco-friendly management of these sucking pests so as to reduce the pesticide load in the okra crop. Neem and its formulations as botanical insecticides can play an important role against sucking insect pests and as an alternative to chemical insecticides. Experiments were conducted at Punjab Agricultural University, Ludhiana during 2018 and 2019. Neem formulations Ecotin 5% @ 200 mL and PAU homemade neem extract @ 3000 mL per hectare were found effective for the management of leaf hopper and whitefly in okra. The present finding will help in reducing the pesticide load on vegetable crops and enhance natural enemy biodiversity.

Keywords: Leaf hopper, Management, Neem formulation, Okra, Whitefly

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Vegetable farming has an important place in Indian agriculture due to their nutritional, medicinal and commercial value[1]. Okra belongs to family Malvaceae and is grown in warm and tropical regions like Africa and South Asia. It is generally utilized as a green vegetable with lots of nutrition. It is an excellent source of vitamins C, K, protein and low in calories that keep our body healthy and fit. Production wise, India ranks first in okra cultivation with 6,466,000 tonnes production per year[2]. Under Punjab, it is grown over an area of 5.30 thousand hectares with an overall production of 55.39 thousand tones and average productivity of 104.46 q/ha[3].

Leaf hopper, *Amrasca bigutulla bigutulla* (Ishida) and whitefly, *Bemisia tabaci* (Gennadius) are the key sucking pests which cause damage to okra crop right from sowing to harvesting. Mostly, these sucking insect pests are controlled by chemical insecticides as they provide quick knock down effect[4]. However, studies have shown that injudicious use of these insecticides has led to the development of resistance/pest resurgence[5] which further increase the input cost of plant protection thus causing huge monetary loss to the farmers. Careless and indiscriminate use of these insecticides led to many new problems like contamination of soil, ground water, food and air with insecticide residues which carry side effects on useful insects and other organisms. Additionally non-lethal and lethal accidents occur among human beings due to mishandling of highly toxic synthetic insecticides. These serious concerns led the scientists to think about alternatives to these insecticides.

Different plants with bioactive metabolites have been used to manage different insect pests in various crops. Application of botanicals helps to reduce the number of problems that emerge from uses of pesticides like resistance, resurgence, secondary pest outbreak, environment pollution etc. Botanicals have varied mode of action like repellent, anti-feedant, low persistency, naturally available, ecofriendly and easily biodegradable. These can be easily incorporated in the integrated pest management module. Neem as an anti-feedant was found effective against different sucking insect pests[4]. These botanicals enhance the diversity of natural enemies and help to save our environment. Biopesticides based on plants or pathogenic microorganisms offer an eco-friendly and effective

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solution to pest problems and are safe to the humans and environment[5]. The plant extracts act as repellent, anti-feedant and its seed contains certain chemicals, which inhibits the population of insect pests. Therefore, in recent years, focus has been shifted towards the use of potential plant extracts to manage the pest populations below the threshold levels[6].

Neem being used for various purposes likes medicinal, cosmetics, insecticidal etc. Azadirachtin present in neem have anti-feedant, repellent, ovicidal effect plays many roles against insect feeding on our crops. Leaf hopper and whitefly are a big menace to vegetable growers especially okra crop where these insects cause damage both by feeding and indirectly by transmitting viral diseases. Neem products are extracted from the *Azadirachta indica*[7] and the main active ingredients of the neem are azadirachtin, salannin, meliantriol, nimbin, desacetylnimbin, desacetylsalannin, and nimbidin[8]. Azadirachtin has repellent, anti-feedant, insect growth regulatory and anti-ovipositional properties[9,10] and is effective against nearly 550 insect species belonging to different orders[10,11]. Neem extract was found to be highly effective insecticide against various sucking insect pests like whitefly, leaf hopper and mites[12]. These unique characteristics attract the researchers and farmers for commercialisation of novel botanicals in India. In India, only neem based botanical pesticides have been registered and allowed to use commercially for various purposes. Therefore, many studies have been conducted for the use of neem for management of sucking insect pest[13-15]. Natural enemies play a great role in maintaining insect pest population under field conditions. Initially population of insect pest is managed by the natural enemies (spiders and coccinellids). As the population of insect pest increases under favourable climate conditions where insect life duration reduces and reproduction increases. To manage the pests at this stage we need to apply botanicals or biorationals in the field. These chemicals are ecofriendly and less persistent in nature. Eco-friendly alternative approach is the need of the hour, so, keeping this in view the present investigation was envisaged to study the effect of different neem formulations against leaf hopper and whitefly in okra under field conditions.

Materials and Methods

The experiments to test the efficacy of neem formulations against sucking insect pests of okra were conducted on variety Punjab 8 during *kharif* season of 2018 and 2019 at the Entomological Research Farm, Punjab Agricultural University, Ludhiana. Neem based formulations, Ecotin (azadirachtin 5%) was evaluated @ 150 (T1), 177 (T2) and 200 mL/ha (T3) and PAU homemade neem extract @ 2000 (T4), 2500 (T5) and 3000 mL/ha (T6) against leaf hopper and whitefly. These neem based formulations were compared with imidacloprid 17.8 SL (confidor) @ 100 mL/ha (T7), water spray (T8) and untreated control (T9). PAU homemade neem extract was prepared by boiling 4.0 kg terminal parts of the shoots of neem trees including leaves, green branches and fruits in 10 litres of water for 30 min. This material was filtered through muslin cloth and used for spraying. After boiling, half the material is left as neem concentrate solution[3]. Neem formulations were also observed for any phytotoxicity symptoms. All the treatments including control were in randomized block design with three replications with plot size of 50 sq. m. All the agronomic practices recommended by Punjab Agricultural University were followed for raising the okra crop. The chemicals were applied as foliar application using knapsack sprayer initiating at appearance of the pest. Two sprays were given at an interval of 10 days. Yield was recorded on whole plot basis and converted to q/ha. The observations on number of leaf hopper (nymph and adult) and whitefly adults from top three leaves were recorded at 3, 7 and 10 days after spray (DAS) from ten randomly selected plants from each replication. Per cent reduction over control was also calculated. The corrected density index (CDI), or equivalent index was calculated from pre- and post-treatment counts as per the formula given below and was used to evaluate pesticide efficacy[16].

$$CDI = (N_{T2}/N_{T1}) / (N_{C2}/N_{C1})$$

Where, N_{T1} and N_{T2} are the pre- and post-treatment pest population in treated plots, respectively, and N_{C1} and N_{C2} are the pest population in control plot at pre- and post-treatment, respectively. The data were analyzed using CPCS program as per the method given by[17] after transformation of the data. Yield of okra was also recorded and the data collected were subjected to analysis of variance (ANOVA) after applying appropriate transformations.

Results

The results revealed that different kinds of management practices significantly reduced leaf

hopper and whitefly population than untreated control in okra.

Leaf hopper

Pooled data of leaf hopper on okra observed for consecutive two years (2018 and 2019), showed that Ecotin (azadirachtin 5%) @ 200 mL/ha was at par with insecticide imidacloprid 17.8 SL @ 100 mL/ha. After 3 days of first spray, Ecotin (azadirachtin 5%) @ 175 mL/ha, population of leaf hopper per three leaves was 8.51 and found superior over the lower dose of Ecotin (azadirachtin 5%) @ 150 mL and PAU homemade neem extract @ 3000 mL/ha. Ecotin (azadirachtin 5%) @ 200 mL/ha and imidacloprid 17.8 SL @ 100 mL/ha were at par with each other even after 7 days of sprays (Table 1). Other treatments showed lower efficacy against leaf hopper in okra. Ecotin (azadirachtin 5%) @ 200 mL/ha and imidacloprid 17.8 SL were significantly at par and superior than other treatments after 3 days of second spray. Ecotin (azadirachtin 5%) @ 175 mL was better than its lower dose. PAU homemade neem extract @ 3000 mL/ha decreased the leaf hopper population in okra crop. After 7 days of spray, imidacloprid 17.8 SL @ 100 mL/ha was significantly superior than Ecotin (azadirachtin 5%) @ 200 mL/ha followed by Ecotin (azadirachtin 5%) @ 150 and 175 mL/ha and PAU homemade neem extract @ 3000 mL/ha.

The per cent reduction over the control in leaf hopper population at different time interval after first and second spray of different treatments is presented in Table 2. After three days of spray, Ecotin (azadirachtin 5%) @ 200 mL/ha and imidacloprid 17.8 SL @ 100 mL/ha recorded more than 50% reduction in population over control followed by Ecotin (azadirachtin 5%) @ 150 and 175 mL/ha. All the other treatments gave less than 30% reduction over control. Similarly, after second spray, imidacloprid 17.8 SL @ 100 mL/ha gave 84.95% reduction in leaf hopper population followed by Ecotin (azadirachtin 5%) @ 200 mL/ha with 70.65% reduction over control after 3 days of spray. PAU homemade neem extract @ 3000 mL/ha showed 49.78% reduction over control.

Whitefly

From the two year pooled data it has been concluded that the whitefly population varied from 2.75 to 3.08 before spray and was non-significant among the treatments (Table 1). After 3 days of spray, Ecotin (azadirachtin 5%) @ 200 mL/ha was at par with Ecotin (azadirachtin 5%) @ 175 mL/ha and imidacloprid 17.8 SL @ 100 mL/ha. Ecotin (azadirachtin 5%) @ 150 and 175 mL/ha and imidacloprid @ 100 mL/ha were at par with each other and significantly better than their lower doses. Similarly, Ecotin (azadirachtin 5%) @ 150 mL/ha and PAU homemade neem extract @ 3000 mL/ha were at par and superior than the lower doses of PAU homemade neem extract. After 7 days of spray, all

Table 1 — Efficacy of neem formulations against leaf hopper and whitefly in okra (pooled 2018 and 2019)

Treatments	Dose (g or mL/ha)	Number of leaf hopper/ 3 leaves							Number of whitefly/ 3 leaves						
		Before spray	First spray			Second spray			Before spray	First spray			Second spray		
			3DAS	7DAS	10DAS	3DAS	7DAS	10DAS		3DAS	7DAS	10DAS	3DAS	7DAS	10DAS
Ecotin (azadirachtin 5%)	150	14.73	9.48 (3.23)	10.20 (3.43)	11.00 (3.45)	8.53 (3.08)	9.31 (3.20)	9.88 (3.29)	3.05	1.65 (1.62)	1.55 (1.59)	1.60 (1.61)	1.15 (1.46)	1.13 (1.45)	1.15 (1.46)
	175	14.60	8.51 (3.08)	9.15 (3.18)	9.81 (3.28)	7.18 (2.85)	7.96 (2.99)	8.49 (3.07)	2.98	1.48 (1.57)	1.36 (1.53)	1.38 (1.53)	0.98 (1.40)	0.95 (1.39)	0.95 (1.39)
	200	15.43	7.17 (2.85)	7.81 (2.96)	8.31 (3.05)	5.46 (2.54)	5.93 (2.62)	6.41 (2.71)	3.01	1.31 (1.52)	1.23 (1.49)	1.26 (1.50)	0.88 (1.36)	0.83 (1.35)	0.81 (1.34)
PAU homemade neem extract	2000	14.58	12.91 (3.72)	13.91 (3.86)	14.68 (3.95)	12.68 (3.69)	13.90 (3.85)	14.83 (3.97)	2.75	2.36 (1.83)	2.41 (1.84)	2.46 (1.85)	2.05 (1.73)	2.10 (1.75)	2.26 (1.80)
	2500	14.98	12.20 (3.63)	13.30 (3.78)	13.95 (3.86)	11.00 (3.46)	12.03 (3.60)	12.83 (3.71)	3.08	2.15 (1.77)	2.26 (1.80)	2.31 (2.00)	1.78 (1.66)	1.85 (1.68)	1.98 (1.72)
	3000	15.15	11.08 (3.47)	12.10 (3.61)	12.78 (3.71)	9.34 (3.21)	10.16 (3.33)	10.91 (3.45)	2.78	1.91 (1.70)	1.98 (1.72)	2.00 (1.72)	1.48 (1.57)	1.51 (1.58)	1.60 (1.61)
Imidacloprid 17.8 SL	100	14.83	6.73 (2.77)	5.08 (2.46)	5.18 (2.48)	2.80 (1.94)	2.38 (1.82)	2.70 (1.91)	3.01	1.41 (1.55)	1.33 (1.52)	1.36 (1.53)	0.88 (1.36)	0.85 (1.35)	0.80 (1.33)
Water spray	-	14.73	14.71 (3.96)	15.66 (4.08)	16.58 (4.19)	16.00 (4.12)	17.05 (4.24)	17.85 (4.34)	2.76	2.68 (1.91)	2.80 (1.94)	2.90 (1.97)	2.71 (1.92)	2.75 (1.93)	2.82 (1.95)
Control	-	14.78	15.63 (4.07)	16.88 (4.22)	17.76 (4.33)	18.60 (4.42)	19.76 (4.55)	20.41 (4.62)	2.91	2.95 (1.98)	3.03 (2.00)	3.08 (2.01)	3.13 (2.02)	3.18 (2.04)	3.21 (2.05)
CD (p=0.05)	-	NS	(0.08)	(0.08)	(0.09)	(0.09)	(0.13)	(0.11)	NS	(0.09)	(0.10)	(0.10)	(0.11)	(0.09)	(0.08)

Figures in parenthesis are square root transformed values

doses of Ecotin (azadirachtin 5%) and imidacloprid 17.8 SL @ 100 mL/ha were found significantly better than other treatments. After 3 days of spray, Ecotin (azadirachtin 5%) @ 200 mL/ha and imidacloprid @ 100 mL/ha gave more than 70% reduction over control followed by Ecotin (azadirachtin 5%) @ 150 and 175 mL/ha and PAU homemade neem extract @ 3000 mL/ha that recorded more than 50% reduction in whitefly population (Table 2). Population of leaf hopper and whitefly gradually increased after 7 days of spray so there is need to apply the botanicals at 7 days interval.

Corrected density indices (CDI) were calculated to measure reductions in pest population in different treatments of neem based formulations and the standard checks. Being synthetic in nature imidaclorprid showed highest efficacy against these sucking pests but Ecotin and PAU Homemade neem extract also showed better efficacy against leaf hopper and whitefly at all the sampling intervals (Table 2).

In all the treatments, the populations of natural enemies were at par except in imidacloprid 17.8 SL treatment where the population was comparatively low (Table 3).

Yield

In pooled analysis (Table 4), Ecotin (azadirachtin 5%) @ 200 mL/ha recorded higher yield (86.41 q/ha) and statistically significant among botanicals followed by its lower doses when compared with control (71.66 q/ha) and water spray (72.58 q/ha). Considering chemical insecticide, imidacloprid 17.8 SL

Table 2 — Per cent reduction over control and efficacy index of different neem formulations against leaf hopper and whitefly

Treatments	Dose (g or mL/ha)	Per cent reduction in the population over the control											
		Leaf hopper						Whitefly					
		First spray			Second spray			First spray			Second spray		
		3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	3DAS	7DAS	10DAS	3DAS	7DAS	10DAS
Ecotin	150	39.35	39.57	38.06	54.14	52.88	51.59	44.07	48.84	48.05	63.26	64.47	64.17
(azadirachtin 5%)	175	45.55	45.79	44.76	61.40	59.72	58.40	49.83	55.12	55.19	68.69	70.13	70.40
	200	54.13	53.73	53.21	70.65	69.99	68.59	55.59	59.41	59.09	71.88	73.90	74.77
PAU homemade neem	2000	17.40	17.59	17.34	31.83	29.66	27.34	20.00	20.46	20.13	34.50	33.96	29.60
extract	2500	21.94	21.21	21.45	40.86	39.12	37.14	27.12	25.41	25.00	43.13	41.82	38.32
	3000	29.11	28.32	28.04	49.78	48.58	46.55	35.25	34.65	35.06	52.72	52.52	50.16
Imidacloprid 17.8 SL	100	56.94	69.91	70.83	84.95	87.96	86.77	52.20	56.11	55.84	71.88	73.27	75.08
Water spray	-	5.89	7.23	6.64	13.98	13.71	12.54	9.15	7.59	5.84	13.42	13.52	12.15
		Corrected density index											
Ecotin	150	2.02	2.14	3.07	3.94	3.68	1.42	1.15	1.15	1.16	1.29	1.31	1.42
(azadirachtin 5%)	175	1.83	1.92	2.60	3.40	3.19	1.28	1.06	1.03	1.02	1.12	1.13	1.20
	200	1.48	1.54	1.87	2.39	2.28	1.02	0.93	0.92	0.93	1.00	0.98	1.01
PAU homemade neem	2000	2.79	2.88	4.61	5.94	5.59	1.95	1.83	1.98	1.98	2.55	2.70	3.09
extract	2500	2.59	2.67	3.89	5.00	4.70	1.79	1.49	1.66	1.66	1.98	2.13	2.42
	3000	2.33	2.42	3.27	4.18	3.96	1.61	1.47	1.61	1.59	1.82	1.92	2.17
Imidacloprid 17.8 SL	100	0.32	0.31	0.17	0.14	0.15	0.45	0.48	0.44	0.43	0.30	0.28	0.26
Water spray	-	0.93	0.94	0.86	0.87	0.88	0.94	0.96	0.97	0.99	0.91	0.91	0.93

Figures in parenthesis are square root transformed values

Table 3 — Effect of treatments on natural enemies population per plant after two sprays

Treatments	Dose (g or mL/ha)	Natural enemies per plant						
		Before spray	First spray			Second spray		
			3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS
Ecotin (azadirachtin 5%)	150	0.47	0.30	0.23	0.27	0.20	0.20	0.27
	175	0.40	0.27	0.27	0.23	0.20	0.17	0.23
	200	0.57	0.20	0.20	0.23	0.17	0.20	0.23
PAU homemade neem extract	2000	0.43	0.36	0.30	0.33	0.26	0.30	0.33
	2500	0.50	0.33	0.23	0.26	0.23	0.20	0.23
	3000	0.40	0.33	0.33	0.33	0.26	0.23	0.26
Imidacloprid 17.8 SL	100	0.43	0.16	0.13	0.13	0.06	0.06	0.06
Water spray	-	0.46	0.46	0.50	0.56	0.63	0.66	0.66
Control	-	0.36	0.50	0.53	0.53	0.60	0.60	0.63
CD (p=0.05)	-	NS	0.11	0.14	0.10	0.11	0.10	0.11

Table 4 — Effect of different treatments on okra yield

Treatments	Dose (mL/ha)	Yield (q/ha)		
		2018	2019	Pooled mean
Ecotin (azadirachtin 5%)	150	82.36	79.00	80.68
Ecotin (azadirachtin 5%)	175	85.66	81.63	83.65
Ecotin (azadirachtin 5%)	200	88.83	84.00	86.41
PAU homemade neem extract	2000	77.00	74.33	75.67
PAU homemade neem extract	2500	78.73	76.50	77.61
PAU homemade neem extract	3000	80.40	77.33	78.86
Imidacloprid 17.8 SL	100	92.43	87.80	90.11
Water spray	-	74.90	70.26	72.58
Untreated control	-	74.13	69.20	71.66
CD (p=0.05)	-	2.19	2.12	1.46

Table 5 — Economics of effective neem formulations in okra

Treatments	Dose (mL/ ha)	Yield (q/ha)	Cost of two sprays (Rs/ha)	Additional yield over control (q/ha)	Income from additional yield (Rs/ha)	Net returns over control (Rs/ha)
Ecotin (azadirachtin 5%)	200	86.41	3540	14.75	23231.25	19691.25
PAU homemade neem extract	3000	78.86	600	7.20	11340.00	10740.00
Imidacloprid 17.8 SL	100	90.11	1110	18.45	29058.75	27948.75
Untreated control	-	71.66	-	-	-	-

Cost of Ecotin: Rs. 7600/litre, Cost of PAU homemade neem extract: Rs. 50/ha
Cost of imidacloprid 17.8SL: Rs. 3050/litre, Cost of spray: Rs. 250/ha, Rate of okra: Rs. 1575/q

@ 100 mL/ha recorded highest yield of 90.11 q/ha followed by Ecotin (azadirachtin 5%) @ 200 mL/ha. Ecotin (azadirachtin 5%) @ 200 mL/ha resulted in net profit of Rs 19691.25 per ha followed by PAU homemade neem extract @ 3000 mL/ha with Rs 10740.00 per ha (Table 5).

Discussion

Leaf hopper and whitefly can be managed by botanicals like Ecotin (azadirachtin 5%) @ 200 mL per ha and PAU homemade neem extract @ 3000 mL per ha and can be easily incorporated in management modules. The present studies are in agreement with the finding of[18], who reported that neem derived products play essential role in pest management of agricultural field crops and stored grains. Some scientists have reported that neem extract show high mortality rate, decreasing fertility, growth inhibitory activity on insect species from different orders like Hymenoptera, Diptera, Coleopteran, Lepidoptera, Orthoptera, Hemiptera etc.[19,20]. Present study was also supported by scientist and co worker who reported continuous application of synthetic chemicals now has been restricted due to its ill effects on environment that create pesticides persistency and affect the balance of nature through natural enemies, pollinators and other wild life disruption[21]. On the other hand botanicals derived from different plants like neem, custard apple, tobacco, pyrethrum etc found to be safer insecticides as they are environment friendly against predators, parasitoids and pollinators[22] Our results are also supported by[23] who reported that whitefly and leaf hopper can be controlled by spraying azadirachtin 1% on okra crop. Neem leaves, fruits, stem etc. are used from ancient time for the management of insect pests and human welfare. The net return over control was high in imidacloprid treatment as compared to botanicals. Comparing botanical with insecticide application farmers will prefer the insecticide as it give immediate result but application of botanical reduce the pesticides load on food and environment. Application of botanicals at initial stages of pest appearance will reduce two to three insecticidal sprays.

Conclusion

In old golden era, different plants with bioactive metabolites have been used to manage different insect pests in various crops. Crude extract of these botanicals was directly used against biotic factors that play major role in reducing the crop yield. Now in present scenario farmers use chemical insecticides to kill the pest immediately without noticing its side effects. So, application of botanicals, having varied mode of action like repellent, anti-feedant, low persistency, naturally available, ecofriendly and easily biodegradable, may play a key role in managing insect pests and making the environment green and clean. So, it can be concluded that in present scenario

where non-judicious and indiscriminate uses of pesticides on the vegetable cause great harm to the human and environment, can be curtailed by the introduction of old management strategies like use of botanicals, its metabolites and other traditional methods like use of cow dung ash. Neem formulation Ecotin (azadirachtin 5%) and PAU homemade neem extract proved effective in maintaining the sucking insect pest populations at lower level and can be incorporated in IPM schedule.

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Conflict of Interest

There is no conflict of interest regarding the manuscript

Author Contributions

Conceptualization and designing of the research work (AK, RSC, PSS); Execution of the field experiments and data collection (AK, RSC, PSS, SS); Analysis of data and interpretation (AK, RSC); Preparation of original draft manuscript (AK); Reviewing and editing of manuscript (AK, RSC, PSS, SS).

Data Availability

The authors approved that the data supporting the result and finding of this experiment are available from the corresponding author upon request.

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