Research Article

Development and Field Evaluation of a Biorational IPM Module against Okra Shoot and Fruit Borers, *Earias vittella* and *Helicoverpa armigera* (Lepidoptera: Noctuidae)

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Abstract | Okra (*Abelmoschus esculentus* L.) is an important tropical vegetable of many African and Asian countries including Pakistan. Infestation of okra crop by lepidopterous borers, *Earias vittella* and *Helicoverpa armigera* (Noctuidae: Lepidoptera), has been one of the contemporary issues of the farmers in Afro-Asian regions. This two-year field study was carried out to evaluate an IPM (bio-intensive) module developed by selecting through *in-situ* evaluation and incorporating the most effective pest control options along with the biological (parasitoid *Trichogramma chilonis* egg cards) and cultural techniques against okra lepidopterous borers. According to results, maximum shoot and fruit infestations (*i.e.* 19.86 and 15.63%, respectively) by okra borers were recorded in control (unsprayed) module, while minimum (*i.e.* 6.76 and 2.89%, respectively) were found in IPM module. Mean shoot and fruit infestations in farmers' routine module were 13.91 and 10.83%, respectively during 2016. Similarly, in 2017, mean shoot and fruit infestations in IPM module, farmers' routine module and control module were 7.62, 14.19 and 19.52%, and 4.58, 11.07 and 18.16%, respectively. Likewise, 1.33 and 2.75 fold higher yields of marketable okra fruits were recorded for IPM module respectively than farmer's routine module and control module. Based on the overall study findings, we recommend IPM module to the indigenous okra growers to combat infestations of *E. vittella* and *H. armigera* and other lepidopterous borers.

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Introduction

Okra (*Abelmoschus esculentus*) belongs to family Malvaceae and is one of the major summer vegetables being cultivated in many Afro-Asian countries including Pakistan (Iqbal et al., 2014). Okra fruits have a great nutritional and medicinal importance and have been an essential part of human diet (Gemede et al., 2015). Okra crop is originated from the tropical Africa and is widely grown throughout tropical and subtropical countries (Sinnadurai, 1992; Aladele et al., 2008). In Pakistan, this vegetable crop is cultivated on a wide area with an increasing trend. Owing to its high yield output and income over the investment, farmers usually prefer okra crop over other summer vegetables (Aziz et al., 2011).

In Indo-Pak regions, okra crop is infested by a number of insect pests and diseases from sowing to harvest rendering its production and quality lower than other okra producing countries (Kanwar and Ameta, 2007; Munthali and Tshegofatso, 2014). Under the agro-

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climatic conditions of Punjab (Pakistan), okra crop is hampered by different insect and mite pests including shoot and fruit lepidopterous borers, whiteflies, jassids, mites, flea beetles, bugs and leaf-rollers (Aziz et al., 2012; Nawaz et al., 2019). Particularly, okra shoot and fruit borers (*Earias vittella* Fabricius and *Helicoverpa armigera* Hübner, Noctuidae: Lepidoptera) are the most damaging pests which cause considerable loss to okra yield (Aziz et al., 2012; Kassi et al., 2018). Caterpillars of these lepidopterous borers chew into terminal shoots and stems causing dead-hearts and infest young okra fruits rendering them inedible and unfit for human consumption (Wajid and Ansari, 2009). These borers cause considerable damage to okra crop and can cause 30 to 80% yield loss and 10 to 60% okra fruit infestations (Kanwar and Ameta, 2007; Wajid and Ansari, 2009; Aziz et al., 2011).

Indigenous okra growers exclusively rely on different conventional synthetic insecticides for the control of okra shoot and fruit borers (Iqbal et al., 2014). Most of these insecticides are hazardous and highly persistent causing several problems of environmental contamination and health hazards (Edwards, 2013). Moreover, field populations of *E. vittella* and *H. armigera* have been demonstrated to get resistance to most of the recurrent conventional insecticides (Ahmad and Arif, 2009; Qayyum et al., 2015). Apart from the conventional synthetic insecticides, there are many other biorational pest control strategies which are less toxic and more environment-friendly such as resistant or tolerant plant material, novel-chemistry synthetic pesticides, botanical and microbial pesticides and insect predators and parasitoids (Rosell et al., 2008).

Although some studies have demonstrated *in-situ* effectiveness of different control strategies for the management of okra shoot and fruit borers, particularly in Indo-Pak regions. However, most of these studies were partial and isolated without any integration of different control tactics together. Therefore, keeping in view the ecological consequences of extensive use of persistent synthetic conventional insecticides in fruit and vegetable production and the importance of biorational pest management strategies, this filed study was aimed to develop and evaluate a bio-intensive IPM module by wisely integrating different cultural, botanical, biological and chemical control methods against the infestations of okra shoot and fruit borers (*E. vittella* and *H. armigera*). The findings of study would be helpful to the indigenous okra growing community for combating lepidopterous borers in okra and other vegetable crops.

Materials and Methods

Study site and experimental layout

The study was performed in two consecutive crop seasons *i.e.* in April 2016 and April 2017 under the agro-climatic conditions of Sargodha region. The experiments were conducted at two different localities (32°07'49"N; 72°41'43'E and 32°07'59"N; 72°41'25"E) situated in the research area of the College of Agriculture, University of Sargodha (Punjab, Pakistan).

Modules development

Treatments included three different pest control modules including control. For the development of IPM (bio-intensive) module, most effective treatments were selected from the preliminary screening trials. Okra cultivar 'Sabzpari' was the most tolerant genotype screened out against shoot and fruit borers of okra (*E. vittella* and *H. armigera*) in the first set of screening trials (Javed et al. unpublished data). It exhibited more comparative tolerance against the infestations by okra borers as compared to other okra genotypes. From the 2nd set of field evaluation trials (Javed et al., 2018), two most effective insecticides, *i.e.* emamectin benzoate and indoxacarb, and the two most effective botanicals, *i.e.* aqueous extracts of neem (*Azadirachta indica*) and bitter apple (*Citrullus colocynthis*), were selected and incorporated in the development of IPM module against okra borers. All these treatments significantly reduced the larval population and infestations of okra lepidopterous borers (*E. vittella* and *H. armigera*) and were incorporated in the IPM module along with the release of an egg parasitoid of *E. vittella* and *H. armigera i.e. Trichogramma chilonis* (@ one egg card per plot or treatment containing approximately 500 parasitized eggs). Finally, this biorational IPM module was compared with the routine plant protection module adopted and being practiced by the indigenous okra growers against the infestations of okra shoot and fruit borers and with a control module. The detail of modules is given below;

Pest management modules

M-I: Farmers' routine module:

- Seed treatment with imidacloprid @5g kg^{-1} of seed.
- Manual hoeing at 30, 50 and 70 DAS (days after

sowing).
- Three foliar applications of chlorpyrifos with 10 days interval.
- Two foliar applications of deltamethrin with 10 days interval.

M-II: IPM module:
- Seed treatment with 5% neem (*A. indica*) seed extract.
- Manual hoeing at 30, 50 and 70 DAS.
- Two weekly foliar application of neem (*A. indica*) seed extract.
- One subsequent foliar applications of 5% bitter apple extract.
- Two foliar applications of emamectin benzoate with 10 days interval.
- One subsequent foliar application of indoxacarb.
- Five releases of *T. chilonis* cards with 10 days interval from 40 DAS.

M-III: Unsprayed or control module: ***Experimental layout:*** Row-to-row and plant-to-plant distances were maintained as 75 and 15 cm, respectively. Insecticides and botanicals were applied upon attainment of ETL of *E. vittella* and *H. armigera* (*i.e.* 5% infestation) using knapsack sprayer fitted with a hollow-cone nozzle. Experimental layout was according to Randomized Complete Block Design (RCBD) along with three replications for each treatment or module. Other agronomic practices *i.e.* irrigation, fertilization and herbicide (Dual-Gold 960 EC; S-metolachlor) applications were carried out in all experimental plots as per routine recommendations for okra crop. Data regarding fruit and shoot infestation and yield were recorded for all treatments as described previously (Javed et al., 2018). Comparative evaluation of these three modules (as described below) was carried out for two consecutive years.

Statistical analysis

Statistical interpretation of the data was done using Statistix 8.1 V (Tallahassee, FL, USA). One-way ANOVA was used to find out the effect of treatments (pest control modules) on okra shoot and fruit infestation and crop yield. Treatment means were compared by using Least Significant Difference (LSD) test at 0.05 level of significance.

Results and Discussion

The preset study was conducted to perform a comparative evaluation of different pest management modules for the control of okra shoot and fruit borers (*E. vittella* and *H. armigera*). Mean percent infestation of okra shoots and fruits by lepidopterous borers was statistically different from each other (paired t-test; t = 2.69; df = 62; p = 0.01) and, hence was analyzed separately for both year trials.

Trend of okra shoot and fruit infestation by lepidopterous borers in 2016

Analysis of variance (Table 1) clearly showed that three modules were significantly different from each other regarding percent shoot ($F_{2, 58}$ = 238.67, p < 0.001) and fruit damage ($F_{2, 58}$ = 136.70, p < 0.001) by *E. vittella* and *H. armigera* during 2016. Maximum mean shoot and fruit infestations (*i.e.* 19.86 and 15.63%, respectively) by okra borers were recorded in control (unsprayed) module (M-III), while minimum (*i.e.* 6.76 and 2.89%, respectively) were found in IPM module (M-II) (Table 2). Mean percent shoot and fruit infestations in farmers' routine module (M-I) were 13.91 and 10.83%, respectively during 2016. According to picking-wise comparison (Table 3), maximum shoot and fruit infestations were recorded at 4th picking which were 18.33, 11.67 and 24.33% and 16.30, 5.51 and 18.35% respectively for farmers' routine module (MI), IPM module (M-II) and control module. Minimum borers' infestations were recorded at 2nd and 7th pickings for all the three modules (Table 3).

Trend of okra shoot and fruit infestation by lepidopterous borers in 2017

Analysis of variance showed similar trend of okra shoot and fruit infestations by lepidopterous borers during 2017 trial. All three modules were again statistically different from each other for their mean percent shoot ($F_{2, 58}$ = 247.43, p < 0.001) and fruit ($F_{2, 58}$ = 122.85, p < 0.001) infestations caused by okra fruit and shoot borers (Table 4). Mean okra shoot infestations in farmers' routine module (M-I), IPM module (M-II) and control module (M-III) were 14.19, 7.62 and 19.52%, respectively (Table 5). Similarly, IPM module (M-II) was most effective exhibiting minimum mean percent fruit infestation (4.58%) followed by farmers' routine module (M-I). According to picking-wise comparison (Table 6), maximum shoot and fruit infestations were found at 4th picking *i.e.* 19.67, 13.17 and 25.04% and 13.86, 7.19 and 20.83%, respectively for farmers' module (M-I), IPM module (M-II) and control module (M-III),

Table 1: *Analysis of variance of the okra shoot infestation (%) caused by lepidopterous borers (Earias vittella and Helicoverpa armigera) in different pest control modules during 2016.*

		Shoot infestation				Fruit infestation			
Source of Variance	DF	SS	MSS	F-Value	P-Value	SS	MSS	F-Value	P-Value
Replication	2	238.9	119.44			21.11	10.55		
Module	2	9326.9	4663.44	238.67	0.000	3537.26	1768.63	136.70	0.000
Error	58	1133.3	19.54			750.38	12.94		
Total	62	10699.1				4308.75			

Table 2: *Overall comparison of means of the okra shoot infestation (%) caused by lepidopterous borers (Earias vittella and Helicoverpa armigera) in different pest control modules during 2016.*

Treatments	Shoot infestation means	Fruit infestation means
Module-I	13.91 B	10.83 B
Module-II	6.76 C	2.89 C
Module-III	19.86 A	15.63 A

Means in a column sharing similar letters are not significantly different (LSD Test at α = 0.05).

Table 3: *Comparison of means of the okra shoot infestation (%) caused by lepidopterous borers (Earias vittella and Helicoverpa armigera) in different pest control modules for each picking during 2016.*

Modules	1st Picking		2nd Picking		3rd Picking		4th Picking		5th Picking		6th Picking		7th Picking	
	Shoot infestation													
Module-I	14.33	± 2.40	12.00	± 4.93	16.33	± 1.86	18.33	± 0.88	14.00	± 3.61	16.33	± 4.10	10.00	± 5.51
Module-II	7.33	± 2.60	4.67	± 2.03	9.33	± 2.03	11.67	± 1.20	7.00	± 1.73	4.67	± 1.45	2.67	± 1.76
Module-III	20.33	± 1.45	16.67	± 2.96	22.33	± 2.03	24.33	± 2.03	20.20	± 2.31	18.33	± 1.45	16.00	± 2.65
	Fruit infestation													
Module-I	11.13	± 1.81	9.77	± 2.06	12.26	± 0.75	16.30	± 1.46	7.57	± 1.30	9.97	± 0.76	8.84	± 2.85
Module-II	3.08	± 1.22	1.90	± 0.06	4.10	± 1.03	5.51	± 1.50	3.04	± 0.65	2.08	± 1.23	0.90	± 0.31
Module-III	16.32	± 1.48	14.94	± 2.64	17.28	± 3.14	18.35	± 2.96	15.99	± 2.96	15.04	± 0.87	11.41	± 2.83

Table 4: *Analysis of variance of the okra shoot infestation (%) caused by lepidopterous borers (Earias vittella and Helicoverpa armigera) in different pest control modules during 2017.*

		Shoot infestation				Fruit infestation			
Source of Variance	DF	SS	MSS	F-Value	P-Value	SS	MSS	F-Value	P-Value
Replication	2	9.3	4.63			1.54	0.77		
Module	2	10464.2	5232.11	247.43	0.000	2886.80	1443.40	122.85	0.000
Error	58	1226.4	21.15			681.48		11.75	
Total	62	11699.9				3569.81			

Table 5: *Overall comparison of means of the okra shoot infestation (%) caused by lepidopterous borers (Earias vittella and Helicoverpa armigera) in different pest control modules during 2017.*

Treatments	Shoot infestation means	Fruit infestation means
Module-I	14.19 B	11.07 B
Module-II	7.62 C	4.58 C
Module-III	19.52 A	18.16 A

Means in a column sharing similar letters are not significantly different (LSD Test at α = 0.05).

Table 6: *Comparison of means of the okra shoot infestation (%) caused by lepidopterous borers (Earias vittella and Helicoverpa armigera) in different pest control modules for each picking during 2017.*

Modules	1st Picking		2nd Picking		3rd Picking		4th Picking		5th Picking		6th Picking		7th Picking	
	Shoot infestation													
Module-I	8.33	± 1.76	15.67	± 2.33	17.67	± 1.86	19.67	± 0.67	12.67	± 1.45	14.67	± 0.88	10.67	± 1.76
Module-II	2.11	± 0.58	9.20	± 2.15	11.00	± 2.73	13.17	± 3.46	6.04	± 2.08	7.67	± 2.03	4.21	± 0.58
Module-III	14.00	± 2.08	21.10	± 1.53	23.00	± 1.53	25.04	± 2.52	18.67	± 2.31	20.71	± 1.73	15.67	± 0.88
	Fruit infestation													
Module-I	8.10	± 2.27	12.81	± 3.08	12.33	± 1.40	13.86	± 1.29	10.16	± 3.23	11.27	± 0.77	8.99	± 1.35
Module-II	1.74	± 1.04	6.25	± 2.15	5.71	± 1.91	7.19	± 2.03	3.80	± 1.04	4.77	± 1.46	24.62	± 1.05
Module-III	15.27	± 2.85	19.87	± 1.31	19.34	± 1.31	20.83	± 2.65	17.33	± 1.40	18.34	± 2.34	16.16	± 1.34

Table 7: *Analysis of variance of the mean okra fruit yield under different pest control modules.*

		2016				2017			
Source of Variance	DF	SS	MSS	F-Value	P-Value	SS	MSS	F-Value	P-Value
Replication	2	92.5	46.27			28.4	14.19		
Module	2	11798.9	5899.46	73.32	0.001	14142.6	7071.28	86.63	0.001
Error	58	321.8	80.46			326.5	81.63		
Total	62	12213.3				14497.5			

while minimum shoot and fruit infestations were observed at 1st and 7th pickings for all three modules (Table 6).

Effect of different pest control modules on okra fruit yield

Results revealed a significant impact of different pest control modules evaluated against okra shoot and fruit bores on the okra marketable fruit yield for both years ($F_{2, 58}$ = 73.32, p = 0.001 for 2016 and $F_{2, 58}$ = 86.63, p = 0.001 for 2017) (Table 7). Maximum okra fruit yield (10,435 kg ha^{-1}) was recorded in the IPM module (M-II), whereas minimum okra fruit yield was recorded as 3,602 kg ha^{-1} in control module (M-III) during 2016. Farmers' routine module (M-I) gave 7,327 kg ha^{-1} okra fruit yield during 2016 under the agro climatic conditions of Sargodha (Punjab, Pakistan) (Table 8). A similar trend of fruit yield was recorded for 2017 trial. Maximum and minimum mean yields of marketable okra fruits were exhibited for IPM (10,793 kg ha^{-1}) and control (4,095 kg ha^{-1}) modules, respectively (Table 8).

Table 8: *Comparison of means of the average okra fruit yield (kg ha^{-1}) under different pest control modules.*

Treatments	2016	2017
Module-I	7,327 B	8,551 B
Module-II	10,435 A	10,793 A
Module-III	3,602 C	4,095 C

Means in a column sharing similar letters are not significantly different (LSD Test at α = 0.05).

Bio-intensive pest management has been gained key importance for the fruit and vegetable production in the modern era. However, in the field conditions biorational pest control strategies could be effective only when these are combined along with synthetic insecticidal options (Aziz et al., 2012; Rajashekhar et al., 2016). This two year field study was conducted to evaluate an IPM module against shoot and fruit borers of okra (*E. vittella* and *H. armigera*) developed by selecting most effective pest control tactics screened out from preliminary *in-situ* evaluation. These screening trials showed that okra genotype Sabzpari was comparatively the most resistant or tolerant among tested available okra germplasm and, hence was chosen as the first important component of IPM strategies. Similarly, novel chemistry insecticides emamectin benzoate and indoxacarb, and botanical extracts of neem (*A. indica*) and bitter apple (*C. colocynthis)* were selected as most effective insecticidal treatments. An IPM module was developed by incorporating these best treatments with biological (*Trichogramma* egg cards) and cultural (manual hoeing) control techniques against shoot and fruit borers of okra and this pest management module was compared with farmers' adopted routine pest control module and a control module.

Results of the study demonstrated that IPM module exhibited minimum shoot and fruit infestation by lepidopterous borers simultaneously with maximum marketable okra fruit yield. These findings are in agreement with the results of Ajanta et al. (2010) who revealed that IPM module consisting of thiamethoxam and spinosad and neem extract exhibited maximum okra yield and minimum *E. vittella* infestations. Similarly, Birah et al. (2012) showed that bio-intensive module, including imidacloprid, spinosad, maize as barrier crop, clipping of dead-hearts and foliar sprays of NSKE and *Pongamia pinnata* essential oil, was the most effective module against okra shoot and fruit borers.

Similar results have been described by Singh et al. (2012) who concluded that judicious use of insecticides (imidacloprid, indoxacarb, thiamethoxam) and acaricide (hexythiazox) and biological control agent (*T. chilonis*) used in module (M-I) along with seed treatment (with imidacloprid) had kept the pest population below economic threshold level. Another similar study was conducted by Kumawat et al. (2014) on the bioefficacy of 9 different pest management modules against okra shoot and fruit borers and demonstrated that module M3 (*Beauveria bassiana* + NSKE + Spinosad + *T. chilonis*) and M8 (*Metarhizium anisopliae* + NSKE + Spinosad + *Bacillus thuringiensis* Kurstaki) were the most effective against these okra borers as compared to the other modules.

Conclusions and Recommendations

Conclusively, this study revealed *in-situ* effectiveness of IPM module against okra lepidopterous borers as compared to the conventional approach solely based on persistent synthetic insecticides. IPM module exhibited maximum okra fruit yield and minimum pest infestations. Therefore, based on these findings, IPM module is recommended to the indigenous okra growers to combat infestations of *E. vittella* and *H. armigera* and other lepidopterous borers.

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Author's Contribution

MZM and MJ conceived and designed the experimental protocols. MJ performed experiments. MJ and ML performed statistical analyses. MZM and MJ prepared the manuscript. MA provided technical assistance in experimentation.

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