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Development of pest management modules and their economic evaluation for legume pod borer, *Maruca vitrata* (Pyralidae: Lepidoptera) in cowpea (*Vigna unguiculata*)

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ABSTRACT

Legume pod borer, *Maruca vitrata* (Geyer) is a major constraint in production of cowpea [*Vigna unguiculata* (L.) Walp.] in India. A field experiment was conducted during rainy (*kharif*) season of 2021–22 and 2022–23 at ICAR-Indian Institute of Pulses Research, Regional Research Station, Dharwad, Karnataka to evaluate different pest management modules, viz. bio-intensive, integrated and chemical module including an untreated control against legume pod borer in cowpea. All the pest management modules were found to be significantly superior over control in terms of pest reduction. Based on pooled average data of two-year study, integrated module comprising sequential spray of chlorantraniliprole 18.5 SC @0.5 mL/L, followed by botanical insecticide, azadirachtin 0.15% @4 mL/L and biorational insecticide, emamectin benzoate 5 G @0.5 g/L at 50% flowering at 10 days interval, was found effective with lowest pod damage of 11.88% and gave 65.97% protection over untreated control. Highest grain yield (1191.73 kg/ha) with 83.19% increase over untreated control, high benefit:cost ratio (1:2.05) and incremental benefit:cost ratio (2.64) were obtained in integrated module. This module reduced the grain yield loss to the extent of 45.41% whereas, the bio-intensive module and chemical module reduced the loss of grain yield up to 28.25 and 27.45%, respectively from pod borer damage. Thus, integrated module developed may be adopted to reduce the damage by pod borer in cowpea.

Keywords: Cowpea, Economics, IPM, *Maruca vitrata*, Pod borer

Cowpea [*Vigna unguiculata* (L.) Walp.] is an important arid legume crop grown in Indian sub-continent and central Africa. It is cultivated as a mix or sole crop and in agroforestry combinations for diverse uses as pulse, vegetable and fodder. Due to high amount of protein in grains with better biological value on dry weight basis, cowpea is also called as vegetable meat for common man. Grains of cowpea contain 23.4% protein, 1.8% fat and 60.3% carbohydrates (Lamani 2013). Nitrogen-fixing ability, high protein content, drought tolerance and resilience to challenging environment makes cowpea, a promising climate resilient food legume crop of 21st century (Tripathi *et al.* 2019).

Cowpea is grown as a *kharif* crop but can also be cultivated as a *rabi*/summer crop. In India, it is cultivated in an area of 3.9 million ha with 2.21 mt production and 0.50 t/ha productivity (Anonymous 2022). In Karnataka, area under cowpea is 0.78 million ha with 0.34 million tonne production and 0.43 t/ha productivity (Annonymous 2024). The yield of cowpea is low due to various abiotic and biotic constraints. Insect-pests are one of the major biotic factors in reducing cowpea grain yield.

Among different insect-pests, legume pod borer, *Maruca vitrata* (Geyer), (Pyralidae: Lepidoptera) is the most destructive borer insect-pest that cause significant grain yield losses in cowpea (Singh and Jackai 1988, Sharma 1998). It is widely distributed in tropical Southeast Asia and sub-Saharan African countries. Due to its extensive host range, destructiveness, and wide distribution, this pest is considered as major borer pest of grain legumes. Damage to crop is caused by larval webbing of flowers, buds and pods. Later instar larvae are capable of boring into the pods and occasionally into the peduncle and stem. Varying grain yield loss of 20–60% by *M. vitrata* has been reported in cowpea (Singh and Alen 1980, Pandey *et al.* 1991). In Bangladesh, pod borer damage in cowpea was 54.4% during harvest, but yield loss was estimated to be 20% (Ohno and Alam 1989). Seasonal variation in cowpea yield losses up to 48–72% by the pod borer with a threshold of 40% larval infestation in flowers was observed in Nigeria (Ogunwolu 1999). Chemical insecticides are the only option available to farmers for quick suppression of the pod borer in cowpea. The frequent and heavy usage of chemical insecticides leads to the problem

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of resistance, residues and environmental pollution. There is lack of information and studies available on integrated pest management modules for control of legume pod borer in cowpea. Thus, there is a need to develop and evaluate an effective integrated pest management module for the control of *M. vitrata* in the cowpea under field conditions and work out the economics of these modules.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) season of 2021–22 and 2022–23 at ICAR-Indian Institute of Pulses Research, Regional Research Station, Dharwad (17.10ºN, 76.26ºE; at an elevation of 428 m amsl), Karnataka. The experimental location falls in the Northern Transition Agro-climatic Zone-8 of Karnataka with shallow black cotton soil. Cowpea cultivar, DC 15 was sown in a plot size, 10 m × 3 m with the spacing, 45 cm × 10 cm in randomised complete block design (RCBD) with five replications. The crop was grown following standard agronomic practices except crop protection measures. The following three pest management modules were developed and evaluated against legume pod borer *M. vitrata* in cowpea, M_1 (Bio-intensive module), Spraying of neem soap @10 g/L followed by *Beauveria bassiana* @5 g/L, pongamia soap @10 g/L; M_2 (Integrated module), Spraying of chlorantraniliprole 18.50 SC @0.30 mL/L, followed by Azadirachtin 0.15 EC @5 mL/L, Emamectin benzoate 05 SG @0.5 g/L; M_3 (Chemical module), Spraying of dimethoate 30 EC @2.5 mL/L, followed chloropyrifos 20 EC @2.5 mL/L, lamdacyhalothrin 2.5 EC 1 mL/L; and M_4, (Untreated control), Without any spray.

The first application of insecticide or biopesticides in each pest management module was sprayed at 50% flowering and subsequent sprays of other components was done at 10 days interval. Spraying of each treatment was carried out in warm, sunny weather with low to no wind at 500 L/ha using a high-volume knapsack sprayer fitted with a hollow cone nozzle. The five plant samples were taken from each plot at harvest and recorded total number of pods/plant, damaged pods and percentage pod damage was calculated as below:

$$\text{Percent pod damage} = \frac{\text{Number of damaged pod/plant}}{\text{Total number pods/plant}} \times 100$$

The matured cowpea pods were harvested manually and grain yield (kg/ha) was recorded per plot basis and converted per hectare basis for a standardised assessment of yield differences among treatments and for comparison of the effectiveness of different pest management modules. The Benefit-Cost Ratio (BCR) was calculated using the method described by Kodandaram *et al.* (2024). For the BCR study, the total costs associated with crop production from the preparation of the land to harvest including cost of treatment was calculated. The final BCR was estimated by using below formula.

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross Return (₹/ha)}}{\text{Total Cost of Cultivation (₹/ha)}}$$

Statistical analysis: Experimental data were transformed to angular transformation, then subjected to analysis of variance (ANOVA). The different treatments were compared by Duncan's Multiple Range Test (DMRT) when ANOVA (p=0.05) was significant. The statistical analysis was performed in OPSTAT software (Version-beta) developed by Sheoran *et al.* (1998).

RESULTS AND DISCUSSION

The results of the present study revealed that the average pod damage in year 2021–22 ranged from 12.56–36.10% in different pest management modules and untreated control. The integrated module (M_2) was found effective with lowest incidence of pod damage of 12.56% and highest reduction in pod damage of 65.22% by *M. vitrata* in comparison to untreated control. Bio-intensive module (M_1) and chemical module (M_3) were next best treatments with 16.29% and 17.28% pod damage and 54.89% and 52.13% reduction in pod damage, respectively. Similar results were also obtained in year 2022–23, where the integrated module (M_2) was found to be significantly superior in bringing down the pod damage (11.20%) over other modules and gave highest pest reduction of 66.78% as compared to untreated control. The bio-intensive module (M_1) and chemical module (M_3) gave 16.02% and 18.87% pod damage and 52.48% and 44.02% reduction in pod damage, respectively (Table 1).

It is evident from the pooled average data of two years (2021–22 and 2022–23) on efficacy of different pest management modules (Table 1) that among different modules, integrated module (M_2) was most effective. The lowest % pod damage of 11.88% with highest reduction of pod damage of 65.97% over control was observed in integrated module (M_2). The bio-intensive module (M_1) and chemical module (M_3) recorded 16.15 and 18.08% pod damage with 53.72 and 48.22% reduction of pod damage, respectively.

The present study clearly indicated that integrated module comprising of sequential sprays of novel molecule such as chlorantraniliprole, biorational insecticide, emamectin benzoate and botanical insecticide, azadirachtin was effective in control of legume pod borer *M. vitrata* in cowpea. The chlorantraniliprole is an anthranilic diamide insecticide having excellent field efficacy against lepidopteran insects (Kodandaram *et al.* 2010). This insecticide selectively binds to the ryanodine receptors in insect muscle cells, resulting in activation of RyRs and uncontrolled release of Ca^+ ions leading to paralysis and death of the target insect (Lahm *et al.* 2007). The other component of integrated module emamectin benzoate is a second generation avermectin derived insecticides (Kodandaram *et al.* 2010). The contact and stomach action of emamectin benzoate might help in control of *M. vitrata* larvae feeding on flowers, flower buds and pods. Recently, Patel *et al.* (2023) observed that chlorantraniliprole 18.5% SC and emamectin benzoate 5% SG were found to be most effective in reducing the incidence of *M. vitrata* in cowpea. Similarly, Pradeeprao and Kumar (2024) revealed lowest population of *M. vitrata* in emamectin benzoate 5% SG treated plots of cowpea.

Azadirachtin, a neem-based insecticide, another component in integrated module is known to have strong insecticidal action. The antifeedant and repellant action of azadirachtin might have helped in reducing the pest damage in cowpea. Spraying of neem-based insecticide, azadirachtin @0.005% or NSKE (Neem seed kernel extract) 4% is recommended for control of pod borer in cowpea (Rai *et al.* 2014). The sequential spray of chlorantraniliprole, azadirachtin and emamectin benzoate of integrated module having different mechanism of actions might have played a greater role in controlling the pod borer and minimising the pod damage in cowpea. The *M. vitrata* larvae which escaped or survived from the spraying of one insecticide might have been controlled in the subsequent spray of another insecticide having different mode of action.

Our results were similar to the findings of Maurya *et al.* (2017) who reported minimum pod borer damage (7.71%) in IPM plots and maximum pod borer damage (8.22%) in non-IPM plots by *M. vitrata* in pigeonpea. The percent insect control in IPM was 44.69% in comparison to non-IPM (farmer's practices). Similarly, Sasmal *et al.* (2018) also found IPM module performed better over other modules with respect to pod borer incidence in mung bean. The IPM module was found better over farmers practice in pigeonpea crop with 48.66% decrease in pod damage by legume pod borer, *M. vitrata* (Malathi *et al.* 2020). Halder *et al.* (2016) also revealed IPM module to be effective over bio-intensive module in managing sucking pests in chilli crop. Preethi *et al.* (2022) observed that IPM module was effective in supressing the larval population of *M. vitrata* significantly than the farmer's practices in garden bean.

Recently, Banerjee and Pal (2023) evaluated different pest management modules along with farmers practice and revealed that IPM modules to be significantly better than farmers practices in minimising *Helicoverpa armigera* population in field pea. Thus, results of present studies can be corroborated with above findings in the effectiveness of integrated module to be significantly better than other modules in minimising pod borer infestation in cowpea**.**

In different modules, significant variation in marketable grain yield of cowpea was observed in year 2021–22. The maximum grain yield was obtained in integrated module (1,473.47 kg/ha) in comparison to bio-intensive and chemical modules and untreated control. The cowpea grain yield in bio-intensive module was 1,059.58 kg/ha and in chemical module, it was 1,034.08 kg/ha and it was at par significantly with each other. Similar trend was recorded during the year 2022–23 with the maximum grain yield recorded in integrated module (910 kg/ha), followed by chemical module (759.38 kg/ha) and bio-intensive module (753.75 kg/ha). Lowest grain yield was recorded in untreated control in both the years of study (Table 2).

The pooled average of two years grain yield of cowpea showed similar results with maximum yield in integrated module (1191.73 kg/ha) followed by bio-intensive module (906.67 kg/ha) and chemical module (896.73 kg/ha) with 83.19, 39.37 and 37.84% yield increase over untreated control, respectively.

Percent avoidable yield loss was determined for different pest management modules based on average grain yield of cowpea. It was observed that the integrated module can reduce the loss of yield to the extent of 45.41% whereas the bio-intensive module and chemical module can reduce the loss of grain yield up to 28.25 and 27.45%, respectively from pod borer damage in cowpea.

The higher grain yield and reduction in yield loss of cowpea in the integrated module could be due to more effectiveness of chloranatraniliprole, emamectin benzoate and azadirachtin, sprayed sequentially in reducing the pod damage by pod borer, *M vitrata*. Our results on grain yield of cowpea are in tune with the findings of Malathi *et al.* (2020) who reported highest percent yield increase in IPM field of pigeonpea over farmer's practice. Similarly, Maurya *et al.* (2017) obtained maximum grain yield of pigeonpea

Table 1 Efficacy of pest management modules against legume pod borer *M. vitrata* in cowpea

Pest management modules	2021–22		2022–23		Pooled average	
	% pod damage	PROC*	% pod damage	PROC*	% pod damage	PROC*
M_1	16.29[b] (23.78)	54.88	16.02[b] (23.55)	52.48	16.15[b] (23.68)	53.72
M_2	12.56[c] (20.72)	65.22	11.20[c] (19.48)	66.78	11.88[c] (20.13)	65.97
M_3	17.28[b] (24.49)	52.13	18.87[b] (25.63)	44.02	18.08[b] (25.07)	48.22
M_4	36.10[a] (36.91)	-	33.71[a] (35.48)	-	34.91[a] (36.20)	-
CD	2.26		3.19		2.49	
SEM	0.73		1.03		0.80	
CV ($p \leq 0.05$)	6.14		8.80		6.81	

*PROC, Percent reduction over control. Values in the parentheses are angular transformed. Mean values of different modules followed by different letters differs significantly by DMRT ($p \leq 0.05$). Treatment details are given under Materials and Methods.

Table 2 Effect of pest management modules on grain yield of cowpea

Pest management modules	Yield (kg/ha)			PIOC*	PAYL**
	2021–22	2022–23	Pooled average		
M_1	1059.58^b	753.75^b	906.67^b	39.37	28.25
M_2	1473.47^a	910.00^a	1191.73^a	83.19	45.41
M_3	1034.08^b	759.38^b	896.73^b	37.84	27.45
M_4	715.47^c	585.63^c	650.55^c	-	
CD	159.34	112.19	77.00		
SEM	51.14	36.01	24.72		
CV ($p \leq 0.05$)	10.68	10.71	6.06		

Mean values of different modules followed by different letters differs significantly by DMRT test ($p \leq 0.05$). *PIOC, Per cent Increase Over Control; **PAYL, Per cent Avoidable Yield Loss [(Yield in Treatment Plot – Yield in UTC / Yield in Treatment Plot) ×100]. Treatment details are given under Materials and Methods.

in IPM plots (1286.5 kg/ha) against non-IPM plots (888 kg/ha) in both seasons. Sasmal *et al.* (2018) also observed highest average yield of mungbean (8.3 q/ha) in the IPM module when evaluated against pod borer.

The economic analysis in terms of benefit:cost ratio (BCR) for every module is greater than one, indicating that the benefit has been achieved. When the modules were compared, the integrated module was more economical followed by chemical module and bio-intensive module giving the highest BCR of 2.05, 1.68 and 1.63, respectively. Highest Incremental Cost Benefit Returns (ICBR) of 2.64 was obtained in integrated module, whereas, in bio-intensive and chemical module, ICBR was 1.09 and 1.17, respectively (Table 3).

The high BCR and ICBR in the integrated module might be due to higher grain yield of cowpea and higher net returns among the different pest management modules. Our findings concur with the results of Maurya *et al.* (2017), Sasmal *et al.* (2018) and Malathi *et al.* (2020) who reported highest benefit:cost ratio in IPM module in pigeonpea, mung bean for pod borer, *M. vitrata*, respectively. Preethi *et al.* (2022) also observed a higher benefit:cost ratio in IPM module for pod borers in garden bean. Recently, Banerjee and Pal (2023) obtained higher ICBR (1.78) in IPM module evaluated against *H. armigera* population in field pea than the farmer's practice.

Thus, it can be concluded from the present study that integrated module with sequential spray of chlorantraniliprole 18.5 SC @0.5 mL/L, followed by azadiractin 1500 ppm @4 mL/L and emamectin benzoate 5 G @0.5 g/L at 50% flowering at 10 days interval was most effective in minimising the pod damage by *M. vitrata* in cowpea. This module significantly enhanced the cowpea grain yield and gave high BCR and incremental returns with highest percent of avoidable yield losses. This integrated module can be adopted and taken advantage to minimise the pod damage and yield losses in cowpea by legume pod borer and avoids spraying of conventional insecticide and

Table 3 Economics of pest management modules evaluated against legume pod borer *M. vitrata* in cowpea

Modules	Cost of treatments (A)			B	C (A+B)	D	E= D × 66.12*	F=E-C	G=E/C	$H=(FT_1-FT_4)/FT_4 \times 100$	ICBR
	Cost of insecticides (₹/ha)	Labour** (₹/ha)	Total cost of treatment (₹/ha)	Cost of cultivation (₹/ha) ***	Total cost of cultivation (₹/ha)	Grain yield (kg/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	B:C ratio	Incremental returns over control (%)	
M_1	3,325	1,500	4,825	31,922.5	36,747.5	906.67	59,948.80	23,201.30	1.63	109.18	1.09
M_2	4,977.5	1,500	6,477.5	31,922.5	38,400	1,191.73	78,798.41	40,398.41	2.05	264.23	2.64
M_3	1,835	1,500	3,335	31,922.5	35,257.5	896.73	59,291.73	24,034.23	1.68	116.69	1.17
M_4	-	-	-	31,922.5	31,922.5	650.55	43,014.09	11,091.59	1.35	-	-

ICBR, Incremental Cost Benefit Returns. *MSP of cowpea, ₹66.12/kg (APMC market rate at Hubli, Karnataka); ** Cost of labour for spraying; *** Variable cost (per hectare basis) involved in cowpea cultivation except plant protection i.e. Cost of seed, fertilisers, irrigation, human labour, tractor hours/bullock pair and marketing charges. It varies from location to location. Treatment details are given under Materials and Methods.

reduce the load of harmful residues in environment and on cowpea crop.

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