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RESEARCH PAPER

Evaluation of different management modules against fall armyworm, *Spodoptera frugiperda* (J. E. Smith) on fodder maize

B. S. SAHANA[1], NARENDRA S. KULKARNI[1], JAYANT S. BHAT[2], UMESH V. MUMMIGATTI[3] AND H. M. SHAILA[1]

[1]Department of Entomology, [2]Department of Genetics and Plant Breeding, [3]Department of Crop Physiology
College of Agriculture, Dharwad, University of Agricultural Sciences, Dharwad - 580 005, India
*E-mail: Sahanabs8989@gmail.com

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Abstract: The present study was conducted at the Indian Grassland and Fodder Research Institute (IGFRI), Southern Regional Research Station (SRRS), Dharwad, Karnataka, during the *kharif* season of 2023 to evaluate various management modules against fall armyworm.The findings indicated that all tested modules significantly out performed the untreated check, demonstrating lower larval counts, reduced leaf damage and increased yields of both green and dry fodder. Among the modules, the Integrated Pest Management (IPM) approach was found to be more effective than the bio-intensive module but less effective than the sole chemical control module. However, due to the potential risks associated with pesticide residues from the chemical module, which can adversely impact both animal and human health, its use is discouraged. The study recommends the adoption of the IPM module as a beneficial and environmentally safe alternative for farmers managing fall armyworm in fodder crops.

Key words: Fall armyworm, Fodder maize, Management, Modules

Introduction

India's agricultural system, characterized by mixed farming, relies heavily on livestock, with 20.5 million people depending on it for their livelihoods. The availability of high-quality fodder is crucial for milk production, which constitutes over 60% of production costs (Chaudhary *et al*., 2012; Anon, 2013). Maize is a vital fodder crop due to its nutritional value, yielding 40-50 tonnes of green fodder per hectare, rich in carbohydrates and essential nutrients. However, maize production faces significant challenges from insect pests, including the fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera : Noctuidae) first reported in India in May 2018 (Sharanabasappa *et al*., 2018) which has caused severe yield losses, impacting 6% to 100% of maize maize plants infested in different parts northern Karnataka (Mallapur *et al*., 2018). This pest noticed on sugarcane (Chormule *et al*., 2019) and listed different hosts of FAW (Deshmukh *et al*., 2021a) and on maize its high level of infestation was recorded in both the seasons (Pradeep *et al*., 2022). A recent study from Karnataka, the pesticide usage has increased after the invasion of fall armyworm and two rounds of insecticides (Deshmukh *et al*., 2021b). Eventhough new generation insecticide molecules are available for the management of fall armyworm, there usage is limited because of high cost and it necessitates forage growers to choose safe and low-cost alternative methods. Therefore, there is a need to evaluate eco-friendly approaches for the management of fall armyworm in fodder maize.

Material and methods

Fodder maize crop was raised during *kharif,* 2023 by following recommended package of practices (Anon) . There were four treatments in the experiment and each treatment was replicated five times. Each cropped area was divided into 20 plots of 4 × 5 m. Bioagents like bacteria, entomopathogenic fungi and other safe molecules were evaluated against fall armyworm at ICAR- Indian Grassland and Fodder Research Institute (IGFRI), Southern Regional Research Station (SRRS), Dharwad, Karnataka.

African tall variety of fodder maize was selected for the studies on evaluation of entomopathogenic fungi and other safe molecules for the management of fall armyworm in fodder maize. The seeds were obtained from Indian Grassland and Fodder Research Institute (IGFRI), Southern Regional Research Station (SRRS), Dharwad.

Ready formulations of bioagents were purchased from Institute of Organic Farming, University of Agricultural Sciences, Dharwad. Appliance used for spraying of insecticides was Knapsack sprayer and 200 litre of spray solution was used for the spray. All the recommended package of practices was used for raising the crop. Total of five replications randomised four times were taken in a 4 × 5 m^2 plot using African tall variety at the rate of 20 kg/ha with spacing of 45 × 15 cm during *kharif* 2023 at IGFRI, Dharwad.

Different management modules include

I. Bio-intensive module (*Beauveria bassiana* 2 g/l - *Metarhiziumrileyi* 2 g/l - Azadirachtin 3000 ppm 5 ml/l)

II. Chemical intensive module (Emamectin benzoate .4 g/l -Chlorantraniliprole18.5 SC at0.2 ml/l –Spinetoram 11.7 SC at 0.5 ml/l)

III. IPM Module (*Metarhiziumrileyi* 2 g/l - Azadirachtin 3000 ppm at 5 ml/l - Emamectin benzoate 5 SG at 0.4 g/l)

IV. Control

Imposition of treatments: Treatments were imposed as soon as infestation of fall armyworm was observed on fodder maize

Table 1. Effect of different management modules on number of larvae in fodder maize during *kharif* 2023

Treatments	Number of fall armyworm larvae per plant											
	14 DAS	18 DAS	22 DAS	29 DAS	33 DAS	37 DAS	44 DAS	48 DAS	52 DAS	59 DAS	Mean	ROC (%)
Bio-intensive module	4.52 (2.43)	4.52 (2.43)^{b}	2.68 (1.98)^{b}	2.85 (1.97)^{b}	2.79 (1.97)^{b}	1.72 (1.68)^{b}	1.76 (1.67)^{b}	0.76 (1.32)^{b}	1.29 (1.51)^{b}	1.31 (1.53)^{b}	2.02	50.61
Chemical intensive module	4.32 (2.30)	1.42 (1.54)^{a}	1.48 (1.56)^{a}	1.58 (1.61)^{a}	0.92 (1.38)^{a}	1.04 (1.42)^{a}	1.22 (1.44)^{a}	0.32 (1.05)^{a}	0.44 (1.15)^{a}	0.51 (1.22)^{a}	1.03	74.48
IPM Module	4.29 (2.28)	4.15 (2.21)^{b}	2.37 (1.80)^{a}	2.43 (1.81)^{ab}	1.38 (1.54)^{ab}	1.62 (1.58)^{b}	1.63 (1.59)^{a}	0.55 (1.23)^{ab}	0.62 (1.25)^{ab}	0.69 (1.29)^{a}	1.35	70.00
Control	4.24 (2.19)	4.15 (2.08)^{b}	4.38 (2.31)^{c}	4.19 (2.25)^{c}	3.89 (2.01)^{c}	4.22 (2.19)^{c}	4.54 (2.54)^{c}	3.92 (2.02)^{c}	3.76 (1.98)^{c}	3.79 (1.97)^{c}	4.09	-
S.Em. (±)	NS	0.10	0.08	0.09	0.05	0.08	0.06	0.08	0.06	0.06		-
C.V. (%)		10.43	8.74	11.26	9.67	8.89	8.42	9.23	9.24	10.44	8.62	-

DAS - Days after sowing, NS- Non-Significant, ROC= Reduction Over Control, Figures in parenthesis are square root transformed values, means in the columns followed by same alphabet do not differ significantly by DMRT(p=0.05)

crop. Pre count of number of larval population and per cent leaf damage was recorded one day before the initiation of the treatments and post count of number of larval population and per cent leaf damage was taken at 3, 7 and 14 days after spraying on 5 randomly selected plants. Subsequently, first spray was taken after 15 days after sowing and second day spray after 30 days and third spray was taken after 45 days after sowing specifically at whole region. Need based treatments were imposed and three rounds of sprays were taken.

The treatments were applied with the help of a knapsack sprayer in the morning. All the plots were treated at a time avoiding the drifts of spray fluid on neighboring plots. Care was taken to wash the spray pump with water thoroughly well before use.

Observations recorded

Observations on the number of larvae per plant and per cent Leaf damage assessment was made on randomly selected 5 plants per plot at 1 day before, 3, 7 and 14 days after treatment imposition and the green fodder yield (GFY) and dry fodder yield (DFY) was recorded in t/ha. The coccinellids count and Cost: Benefit ratio was also recorded on fodder maize.

Results and discussion

The experimental results regarding the evaluation of different management modules against fall armyworm larvae, leaf damage of FAW per cent, green fodder yield and dry fodder yield, natural enemies and B:C ratio on fodder maize are explained below:

At 14 days after sowing, counts ranged from 4.24 to 4.52 larvae per plant, but by 22 days, the chemical control dropped to 1.48 larvae/plant, while the untreated check had 4.38. This trend continued, with the chemical control achieving the lowest counts of 0.32 and 0.51 larvae/plant at 48 and 59 days, respectively. Overall, the chemical module achieved a 74.48% reduction in larval populations compared to the untreated check, followed by the IPM module with a 70.00% reduction and the biointensive module at 50.61% (Table 1).This was similar with findings of Deshmukh *et al*. (2020) who found that the chlorantraniliprole, emamectin benzoate were effective in reducing the FAW larval population.The study on fall armyworm larvae counts showed that the chemical control module was the most effective treatment, consistently recording the lowest larval counts across various time points (Fig.1).

Per cent leaf damage

The evaluation of leaf damage caused by the fall armyworm (FAW) revealed that, before treatment, leaf damage was uniform across all plots, ranging from 57.26% to 60.28%. At 22 days after sowing, the chemical control module showed the least leaf damage at 37.49%, followed by the IPM module at 57.04%, while the biointensive and untreated checks had 62.08% and 64.79%, respectively. By 48 days, the chemical control recorded only 14.35% damage, with the IPM module at 18.87%, contrasting sharply with the untreated control at 76.27%. At 52 and 59 days after sowing, the chemical control continued to perform best, with damage levels of 15.08% and 15.78%, respectively, while the untreated control reached up to 72.87% (Table 2). This was in accordance with findings of Omprakash *et al*. (2020) noticed spraying of two novel insecticides, chlorantraniliprole and spinetoram, recorded 95.45 per cent reduction in the plant infestation over control). The evaluation of different management modules against FAW in fodder maize showed that all methods significantly recorded lowest per cent leaf damage compared to the untreated control (Fig.2)

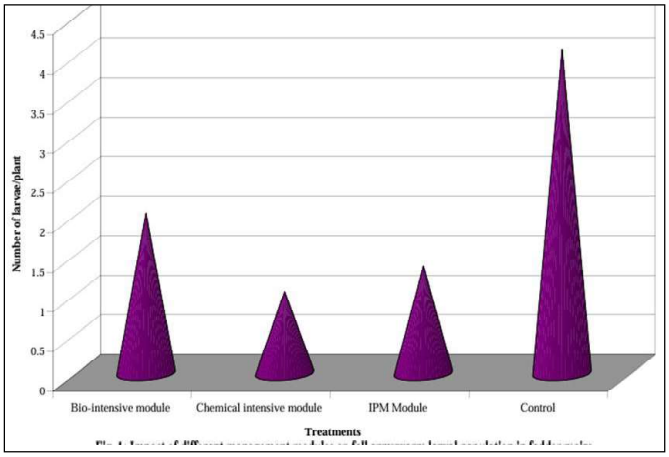

Fig 1. Impact of different mangement modules on fall armyworm larval population in fodder maize

Table 2. Effect of different management modules on per cent leaf damage by fall armyworm in fodder maize during *kharif* 2023

Treatments	Per cent leaf damage per plant										
	14 DAS	18 DAS	22 DAS	28 DAS	33 DAS	37 DAS	44 DAS	48 DAS	52 DAS	59 DAS	Mean
Bio-intensive module	60.28 (50.93)	62.08 (51.99)^{bc}	41.88 (40.33)^{b}	43.28 (41.14)^{b}	42.22 (40.52)^{c}	33.78 (35.54)^{ab}	33.92 (35.62)^{b}	27.88 (31.87)^{b}	28.29 (32.13)^{b}	28.38 (32.19)^{b}	40.20
Chemical intensive module	58.28 (49.77)	37.49 (37.76)^{a}	37.98 (38.04)^{a}	38.33 (38.25)^{a}	20.29 (26.77)^{a}	28.89 (32.51)^{a}	29.77 (33.07)^{a}	14.35 (22.26)^{a}	15.08 (22.85)^{a}	15.78 (23.41)^{a}	29.65
IPM Module	57.26 (49.17)	57.04 (49.05)^{b}	35.88 (36.79)^{a}	39.24 (38.78)^{a}	30.98 (33.82)^{b}	32.26 (34.61)^{a}	33.29 (35.24)^{b}	18.87 (25.75)^{a}	19.31 (26.07)^{a}	20.08 (26.62)^{a}	34.42
Control	57.78 (49.48)	64.79 (53.60)^{c}	64.68 (53.54)^{c}	69.92 (56.74)^{c}	74.79 (59.86)^{d}	79.13 (62.82)^{c}	80.29 (63.64)^{c}	76.27 (60.85)^{c}	72.19 (58.17)^{c}	72.87 (58.61)^{c}	71.27
S.Em. (±)	NS	2.66	1.19	0.96	2.15	0.7	0.41	1.21	2.01	1.82	-
C.V. (%)	12.22	10.03	9.23	8.46	8.35	10.62	12.09	8.99	10.89	12.24	-

DAS = Days after sowing, Figures in parenthesis are arcsine transformed values, means in the columns followed by same alphabet do not differ significantly by DMRT (p=0.05)

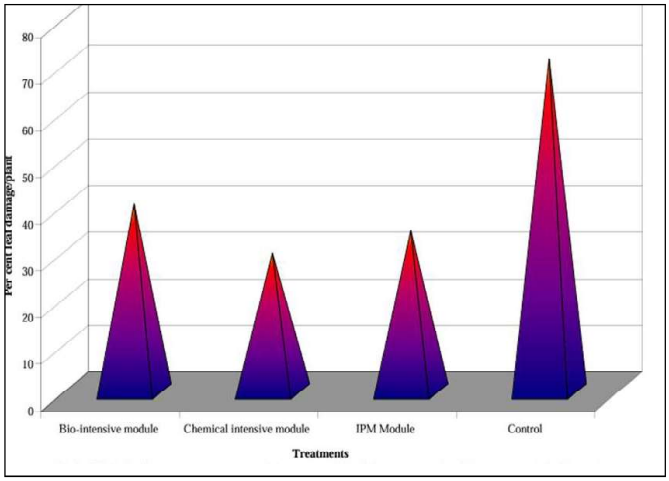

Fig 2. Effect of different management modules on percent leaf damage caused by fall armyworm in fodder maize

Fodder maize yield

The chemical control module recorded the highest green fodder yield at 41.00 t/ha, followed by the IPM module at 38.50 t/ha and the biointensive module at 34.50 t/ha, while the untreated check yielded only 22.00 t/ha. For dry fodder yield, both the chemical control and IPM modules tied at 8.26 t/ha, with the biointensive module producing 6.95 t/ha and the untreated control at 4.43 t/ha (Table 3). The results were in support with findings of Kavyashree *et al*. (2023) observed that chemical control module led to highest larval reduction over control (86.04%) and being superior with significantly higher grain yield (53.45 q/ha) than bio-intensive module that recorded highest number of coccinellids (1.27 / plant). The evaluation of different management modules against FAW in fodder maize showed that all methods significantly improved green and dry fodder yields compared to the untreated control (Fig.3)

Natural enemies

The coccinellid populations were highest in the untreated control (0.41), followed by biointensive (0.37) and IPM modules (0.29), with the chemical control recording the lowest (0.17) throughout the evaluation period (Table 4). The present results were in support with findings of Islam and Das (2017) who observed that the mortality of coccinellids (15.66%) was more inemamectin benzoate (1 g/l) treated plots.

B:C ratio

In terms of economic viability, the chemical control module also had the highest benefit-cost ratio (B:C) of 1.78, closely followed by the IPM module at 1.76 and the biointensive module at 1.60, while the untreated control had a B:C ratio of 1.19 (Table 5). Similarly, Kavitha *et al*. (2020) observed in TNAU the higher cob yield in IPM module of 4800 kg/ha and having cost benefit

Table 3. Impact of different management modules on yield of fodder maize

Treatments		GFY (t/ha)	DFY (t/ha)
I.	Bio-intensive module (*Beauveria bassiana* 2 g/l - *Metarhiziumrileyi*2 g/l - Azadirachtin 3000 ppm @ 5 ml/l)	34.50^{b}	6.95^{b}
II.	Chemical intensive module (Emamectin benzoate 0.4 g/l – Chlorantraniliprole 0.2 ml/l –Spinetoram 0.5 ml/l)	41.00^{a}	8.26^{a}
III.	IPM Module (*Metarhiziumrileyi* 2 g/l 3000 - Azadirachtinppm @ 5 ml/l - Emamectin benzoate 0.4 g/l)	38.50^{a}	7.76^{a}
IV.	Control	22.00^{c}	4.43^{c}
S.Em. (±)		1.10	0.37
C.V. (%)		12.50	11.90

GFY- Green fodder yield, DFY- Dry fodder yield

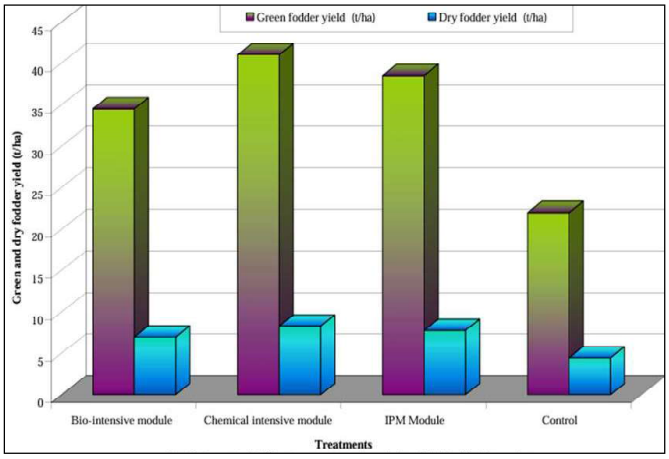

Fig 3. Impact of different management modules of yield of fodder maize

Table 4. Evaluation of different management modules on number of coccinellids in fodder maize during *kharif* 2023

Treatments	No. of coccinellids/ plant										
	14 DAS	18 DAS	22 DAS	28 DAS	33 DAS	37 DAS	44 DAS	48 DAS	52 DAS	59 DAS	Mean
Bio-intensive module	0.32	0.32	0.34	0.36	0.36	0.38	0.36	0.39	0.4	0.43	0.37
	(1.14)	(1.14)^{a}	(1.16)^{a}	(1.17)^{a}	(1.17)^{a}	(1.18)^{a}	(1.18)^{ab}	(1.19)^{ab}	(1.19)^{ab}	(1.20)^{ab}	
Chemical intensive module	0.30	0.21	0.22	0.19	0.19	0.17	0.13	0.13	0.12	0.07	0.17
	(1.13)	(1.09)^{c}	(1.09)^{b}	(1.07)^{c}	(1.07)^{c}	(1.06)^{c}	(1.04)^{c}	(1.04)^{c}	(1.02)^{c}	(1.01)^{c}	
IPM Module	0.22	0.23	0.23	0.24	0.26	0.28	0.33	0.34	0.34	0.38	0.29
	(1.09)	(1.11)^{b}	(1.11)^{b}	(1.12)^{b}	(1.12)^{b}	(1.12)^{b}	(1.15)^{b}	(1.16)^{b}	(1.16)^{b}	(1.18)^{b}	
Control	0.33	0.33	0.36	0.38	0.4	0.41	0.44	0.45	0.48	0.53	0.41
	(1.14)	(1.14)^{a}	(1.17)^{a}	(1.18)^{a}	(1.18)^{a}	(1.18)^{a}	(1.19)^{a}	(1.19)^{ab}	(1.20)^{a}	(1.23)^{a}	
S.Em.(±)	NS	0.003	0.013	0.013	0.01	0.016	0.013	0.01	0.01	0.013	-
C.V.(%)	9.16	11.24	9.47	10.66	10.46	11.48	11.69	12.29	10.2	9.26	-

DAS – Days after sowing, NS- Non-Significant, Figures in parenthesis are square root transformed values, means in the columns followed by same alphabet do not differ significantly by DMRT (p=0.05)

Table 5. Impact of different management modules on B:C ratio of fodder maize

Treatments	Yield (t/ha)	Cost of crop protection (₹ /ha)	Total cost of cultivation (₹ /ha)	Gross returns (₹ /ha)	Net returns (₹ /ha)	B:C ratio
Bio-intensive module	34.50	2955	53630	86280	32650	1:1.60
Chemical intensive module	41.00	6775	57450	102500	45050	1:1.78
IPM Module	38.50	3741	54416	96250	41834	1:1.76
Control	22.00	0	45875	55000	9125	1:1.19

Market price of green fodder maize: ₹ 2500 per tonne
Cost of crop production: ₹ 45875/ha

ratio of 1.6 and is followed by the farmers practice module of 3840 kg/ha that had cost benefit ratio of 1.4.

Conclusion

In the 2023 *kharif* season, a study assessed various management modules against fall armyworm (FAW) and found that all were more effective than the untreated check, resulting in fewer larvae, reduced leaf damage, and higher fodder yields. The Integrated Pest Management (IPM) module was superior to the bio-intensive approach but less effective than the sole chemical module. However, due to the health risks associated with pesticide residues from chemical treatments, its use is discouraged. The study recommends the IPM module as a beneficial and environmentally safe strategy for managing FAW in fodder crops.

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