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EVALUATION OF IPM MODULES AGAINST THE FALL ARMY WORM *SPODOPTERA FRUGIPERDA* (J E SMITH) ON MAIZE

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ABSTRACT

Fall armyworm *Spodoptera frugiperda* (J E Smith) has become a devastating pest in maize. Field experiments were carried out to assess the efficacy of various IPM modules against this pest. Amongst these, biointensive module recorded highest number of coccinellids (1.27/ plant) and ants (0.42/ plant), while chemical control module led to highest larval reduction over control (86.04%) and being superior with significantly higher grain yield (53.45 q/ ha). This also gave a 1.86 B:C ratio followed by the IPM module (48.06 q/ ha) with 1.85 B:C ratio.

Key words: *Spodoptera frugiperda*, modules, chemical control, biointensive, IPM, insecticides, coccinellids, ants, maize, yield, benefit cost ratio

Fall armyworm (FAW) *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae) is an invasive and a polyphagous pest of many crops causing significant damage to maize (CABI, 2019). More than 350 plant species have been reported as host plants, causing significant damage to economically valuable crops (Montezano et al., 2018). In India, maize is cultivated in an area of 9.86 million ha with a production of 31.51 mt and productivity of 31.95 q/ ha (FAO, 2021). Among the major maize-growing states, Karnataka stands first with an area of 1.68 million hectares and a production of 5.18 million tonnes with a productivity of 30.92 q/ha (FAO, 2021). In 2016, the FAW invaded the African continent, and then spread rapidly to >28 countries of southern and eastern Africa (Goergen et al., 2016). From India it was reported in 2018 (Sharanabasappa et al., 2018), and it has been appearing in severe form, especially during rainy and post-rainy seasons, causing heavy yield losses throughout the country (Deshmukh et al., 2020). FAW has the potential to destroy up to 80 mt of maize worth USD 18 billion/ year, affecting about 600 million people in Africa, Asia-Pacific and the Near East (FAO, 2020). A recent study from India, the pesticide expenditure to produce 100 kg of maize grains has increased from US$ 0.124 in 2017 to US$ 1.39 in 2020 (Deshmukh et al., 2021). The increasing problems due to continued usage of pesticides and failure of control strategies to check the pests, necessitates the development of IPM strategies (Pretty and Bharucha, 2015). From India, good number of natural enemies have been reported (Shylesha et al., 2018; Sharanabasappa et al., 2019; Navik, 2020; Firake and Behere, 2020). It is essential to explore these natural enemies as a component in IPM and the present study attempts this.

MATERIALS AND METHODS

Field experiments were carried out during rabi 2019 and 2020 at the experimental sites located at the Agricultural and Horticultural Research Station (14.2959° N, 75.8323°E), Kathalagere, Davanagere and the farmer's field (14.1435° N, 75.5539° E), Surahonne village of Honnali taluka of Davanagere district of Karnataka, The maize hybrid, CP-818 was sown at a spacing of 60x 30 cm with plot size of 125 m^2 for each module. The experiments were laid in randomized block design (RBD) with five replications. The sprays were prepared by mixing the required quantity of insecticides or biorationals at required dosages in normal water at 500 l/ ha. The treatments include- biointensive module [Installation of pheromone traps (10/ ha) at the time of sowing, removal of egg masses and neonates (at fortnightly interval from 15- 49 DAS), spraying of sugar solution 10% (two sprays at fortnightly interval, 1^{st} at 15 and 2^{nd} at 30 DAS, spraying of *Metarrhizium rileyi* @ 3 g/ l (two sprays at 21 and 35 DAS)], IPM module [installation of pheromone traps (10/ ha) at the time of sowing, removal of egg masses and neonates (at fortnightly interval from 15 DAS), spraying of *Metarrhizium rileyi* @ 3g/ l (single spray at 15 DAS), spraying of emamectin benzoate @ 0.5g/ l (single spray at 21 DAS)], chemical control module [(seed treatment with cyantraniliprole 19.8 % + thiamethoxam 19.8 % @6 ml/ kg of seed, spraying of emamectin benzoate 5SG @ 0.5 g/ l (at 15 DAS), spraying of chlorantraniliprole18.5SC @ 0.4ml/ l (28 DAS)] and control [no plant protection measures were applied, served as an untreated control]. Observations on the fall army worm were made on 20 plants/ replications at weekly intervals from 15 to 50 DAS. The effect of modules was determined by observing the larval incidence and plant damage (Davis and Williams, 1992); and yield along with the cost-benefit ratio. The grain yields obtained were converted into q ha[1] and subjected to one-way ANOVA with SPSS software for each year as well as pooled (p = 0.05).

RESULTS AND DISCUSSION

During 2019-20, larval density of fall army worm was significantly higher in the untreated control (1.19/ plant), and reduction over control was significantly less in the chemical control module (92.0%), followed by the IPM module (67.22%) and biointensive module (52.10%). In 2020-21, the chemical control module led to maximum reduction (79.55%) over control, followed by the IPM module (75.55%) and the biointensive module (61.77%). Pooled data revealed that the reduction over control was maximum in chemical control module (0.24/ plant) followed by IPM module (0.44/ plant). During 2020-21, significantly lowest mean leaf damage was observed with chemical control module (1.44) followed by the IPM module (1.53) and biointensive module (2.75); maximum decrease in the leaf damage was in IPM module (64.48) followed by chemical control (66.58) and biointensive module (36.23). The chemical control module gave significantly higher grain yield (53.45 q /ha; maximum cost of cultivation was in the chemical control module (Rs. 43115); and this gave maximum gross returns (Rs.80175) and net profit (Rs. 37060), with a cost-benefit ratio of 1.86. Also, the maximum yield loss (avoidable) was compensated in the chemical control module (47.91%) with yield increment upto 91.98% (Table 2). The difference in larval load was due to the seed treatment in chemical intensive module; incidence was only 0.10 and 0.28/ plant at 14 and 21 DAS, respectively during 2019-20; in 2020-21, it was 0.13 and 0.24/ plant at 14 and 21 DAS, respectively (Table 1, 2).

The presented results are consistent with those of Babu et al. (2021), who found that seed treatment with thiomethoxam 19.8+ cyantraniliprole 19.8%t @ 4 ml/ kg resulted in a lower incidence. Suganthi et al. (2022) found that cyantraniliprole+ thiamethoxam 19.8FS seed treatment provided effective protection. Two sprays of *Metarrhizium rileyi* @ 3 g/ l at 21 and 35 DAS in biointensive module and one spray of *M. rileyi* @ 3 g/ l at 15 DAS, IPM module led to less number of larvae/ plant. *M. rileyi* was found to reduce infestation by 58.91-62.87% (Mallapur et al., 2018). Two sprays of sugar solution (10%) at 15 and 30 DAS resulted in increase in ant density in bi intensive module. Canas and O’Neil (1998) reported an increase in ant population in sugar-treated maize. The application of sugar in maize fields enhanced the number of individual natural enemies, linked to lower leaf area damage and whorl infestations. Sugar could play a vital role by preserving the natural enemies (Canas and O’Neil, 1998). Different IPM methods should be utilized in a coordinated manner (Bista et al., 2020). Due to the broad spectrum and high insecticidal activity, new pesticide compounds demonstrate better efficacy in suppressing FAW in maize. Despite the fact that the chemical control module produced the highest yield (53.45 q/ ha), it is recommended to include/ follow the IPM module because its benefit-cost ratio (1.85), that is nearly identical to that of chemical control module.

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AUTHOR CONTRIBUTION STATEMENT

SSD, KCM and KBA planned and designed this experiment. KBA analyzed the data and SSD, KCM and SS assisted in developing the manuscript.

FINANCIAL SUPPORT

No financial support in executing the experiment.

CONFLICT OF INTEREST

No conflict of interest.

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Table 1. Incidence of *S. frugiperda* in maize (rabi 2019-20, 2020-21)

Incidence

	Mean number of larvae/ plant* in 2019-20								Mean number of larvae/plant* 2020-21								
Modules	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	Overall larval mean	% RoC**	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	Overall larval mean	% RoC**	Pooled mean
Bio intensive module	1.08± 0.19 (1.25)^{b}	0.77± 0.17 (1.12)^{bc}	0.48± 0.06 (0.99)^{b}	0.40± 0.02 (0.95)^{b}	0.42± 0.09 (0.95)^{b}	0.25± 0.05 (0.87)^{b}	0.57^{b}	52.10^{c}	1.56± 0.21 (1.43)^{b}	1.62± 0.17 (1.45)^{b}	0.62± 0.25 (1.03)^{b}	0.40± 0.05 (0.95)^{a}	0.69± 0.19 (0.08)^{b}	0.30± 0.06	0.86^{c}	61.77^{b}	0.71
IPM module	1.20± 0.08 (1.30)^{b}	0.58± 0.20 (1.03)^{ab}	0.12± 0.03 (0.79)^{a}	0.12± 0.00 (0.79)^{a}	0.14± 0.06 (0.80)^{a}	0.18± 0.05 (0.82)^{a}	0.39^{ab}	67.22^{b}	1.73± 0.08 (1.49)^{b}	0.25± 0.06 (0.86)^{a}	0.28± 0.07 (0.89)^{a}	0.48± 0.25 (0.96)^{a}	0.10± 0.03 (0.77)^{a}	0.12± 0.03 (0.80)^{a}	0.55^{ab}	75.55^{a}	0.44
Chemical control module	0.10± 0.04 (0.77)^{a}	0.28± 0.08 (0.88)^{a}	0.31± 0.05 (0.90)^{ab}	0.42± 0.04 (0.96)^{b}	0.35± 0.07 (0.92)^{b}	0.16± 0.05 (0.81)^{a}	0.27^{a}	92.0^{a}	0.13± 0.21 (0.79)^{a}	0.24± 0.05 (0.86)^{a}	0.30± 0.07 (0.89)^{a}	0.25± 0.04 (0.86)^{a}	0.23± 0.03 (0.85)^{a}	0.16± 0.04 (0.81)^{a}	0.46^{a}	79.55^{a}	0.24
Control	1.16± 0.08 (1.28)^{b}	1.30± 0.30 (1.32)^{c}	1.02± 0.09 (1.23)^{c}	1.08± 0.03 (1.26)^{c}	1.30± 0.11 (1.34)^{b}	1.29± 0.37 (1.31)^{b}	1.19^{c}	-	2.07± 0.26 (1.59)^{b}	2.93± 0.25 (1.85)^{c}	2.28± 0.26 (1.66)^{b}	2.26± 0.14 (1.66)^{b}	2.65± 0.14 (1.77)^{c}	1.29± 0.35 (1.31)^{b}	2.25	-	1.72
SEm±	0.054	0.051	0.040	0.026	0.050	0.057	-	-	0.051	0.049	0.075	0.064	0.051	0.065	-	-	
CD (p=0.05)	0.12	0.22	0.095	0.08	0.12	0.19	-	-	0.16	0.15	0.231	0.20	0.15	0.20	-	-	
CV (%)	7.26	14.39	7.09	5.98	8.70	14.34	-	-	7.66	8.76	15.02	13.00	9.93	15.44			

Leaf damage

	Mean leaf damage /plant* (1-9 scale) in 2019-20								Mean leaf damage /plant* (1-9 scale) in 2020-21								
Modules	14 DAS**	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	Mean leaf damage (1-9 scale)	% RoC**	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	Mean leaf damage (1-9 scale)	% RoC**	Pooled mean
Bio intensive module	2.28^{b}	2.72^{c}	2.64^{b}	3.21^{b}	2.87^{b}	4.18^{c}	2.98^{b}	33.59	2.31^{b}	2.16^{b}	2.22^{b}	2.86^{b}	3.45^{b}	3.52^{b}	2.75	36.23	2.87
IPM module	2.19^{b}	2.02^{b}	1.57^{a}	2.18^{a}	2.30^{a}	2.27^{a}	2.09^{a}	53.50	2.12^{b}	1.38^{a}	1.19^{a}	1.60^{a}	1.49^{a}	1.418^{a}	1.53	64.48	1.81
Chemical control module	1.22^{a}	1.67^{a}	1.85^{a}	2.19^{a}	2.31^{a}	3.29^{b}	2.08^{a}	53.52	1.31^{a}	1.16^{a}	1.22^{a}	1.90^{a}	1.65^{a}	1.42^{a}	1.44	66.58	1.77
Control	2.26^{b}	3.14^{d}	5.10^{c}	5.22^{c}	5.46^{c}	5.79^{d}	4.49^{c}	-	2.21^{b}	3.48^{c}	4.00^{c}	5.30^{c}	5.54^{c}	5.39^{c}	4.32	-	4.41
SEm±	0.09	0.07	0.10	0.22	0.08	0.13	-	-	0.18	0.12	0.08	0.10	0.19	0.18	-	-	
CD (p=0.05)	0.26	0.22	0.31	0.67	0.24	0.40	-	-	0.54	0.36	0.24	0.30	0.60	0.56	-	-	
CV (%)	9.68	6.67	8.12	15.29	5.48	7.49	-	--	19.67	13.00	7.90	7.54	14.34	14.04	-	-	

Values in parentheses √x+0.5 transformed values; *Mean number of 100 plants; **RoC - Reduction over control. Means sharing similar letters in the same column not significantly different by Tukey's HSD test, p= 0.05 at p< 0.01. NS= Non-Significant at p>0.05

Table 2. Cost economics for the management of *S. frugiperda* (pooled)

Treatments	Yield q/ha	Cost of production (Rs/ha)	Cost of Protection (Rs/ha)	Total cost of cultivation (Rs/ha)	Gross Income (Rs/ha)	Net Income (Rs/ha)	B:C ratio	Avoidable yield loss (%)	Yield increment over control (%)
Bio-intensive module	36.56[c]	33856	4425	38281	54840	15559	1.43	23.85	31.32
IPM module	48.06[b]	33856	5050	38906	72090	32184	1.85	42.07	72.62
Chemical control module	53.45[a]	33856	9259	43115	80175	37060	1.86	47.91	91.98
Control	27.84[d]	33856	0	33856	41760	7904	1.23	-	-
SEm±	1.15	-	-	-	-	-	-	-	-
CD (p=0.05)	3.54	-	-	-	-	-	-	-	-
CV (%)	6.19	-	-	-	-	-	-	-	-

Note: Cost of maize = Rs 1500/q. Cost of insecticides:Sugar = Rs.32 (1 kg), Rs 1600 (50kg); *Metarrhizium rileyi,*(1500g) = Rs.150; Emamectin benzoate 5 SG (250g) = Rs.550; Cyantraniliprole+Thiamethoxam (Fortanza duo for seed treatment) (80ml) = Rs.1600; Chlorantraniliprole 18.5 SC (200ml) = Rs. 2,475; Pheromone traps = Rs. 150 (No.= 1), Rs.1500 (No.= 10); Cost of labour : a. Men = Rs. 400/day, b. Women = Rs. 300/day; Standard spray volume = 500 lit/ha. Means sharing similar letters in same column not significantly different by Tukey's HSD test at p= 0.05

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