

INTEGRATED AGRONOMIC MANAGEMENT STRATEGIES FOR FALL ARMYWORM (*SPODOPTERA FRUGIPERDA*) IN MAIZE DURING THE KHARIF SEASON

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Abstract

Two experiments were carried out in this study. Experiment I has been conducted with Treatments: Factor A: Row arrangement *i.e.*, Regular (1 : 1) and Paired (2 : 2), Factor B: with intercrop *i.e.* Maize + Mungbean, Maize + Cowpea, Maize + Groundnut, Maize + Soybean, Sole maize. Experiment II: includes Push-pull strategy for Fall Army Warm (FAW) management during *Kharif* with treatments 1. Maize + Tephrosia, 2. Maize + Fenugreek, 3. Maize + Coriander, 4. Maize + Marigold (*A border row of hybrid napier to be planted for pulling FAW). Among the different intercropping based strategies in the row arrangement, significantly the highest maize grain yield was observed with regular row arrangement. Among the intercropping systems, maize + green gram and sole maize recorded significantly higher maize grain yields than the other treatments. However, FAW infestation and severity did not differ significantly between the different row arrangements.. But significantly lesser FAW infestation and severity observed from 50 DAS to harvest with maize + green gram intercropping when compare to the other intercropping's. Higher FAW infestation and severity was observed in all the Push-pull strategy treatments.

Introduction

Maize (*Zea mays* L.) is one of the most important cereal crops cultivated during the *kharif* and *Rabi* season in India and it serves as a major source for food, feed, and industrial raw material. However, maize productivity is severely threatened by the invasive pest fall armyworm (FAW). The fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), is a migratory and highly polyphagous pest native to the Americas. Due to the absence of a diapause trait, in the USA, it migrates northward annually in the fall season to infest temperate maize cropping areas (Westbrook *et al.* 2016). Fall Army Warm was officially reported outside the Americas for the first time in West Africa in January 2016 (Goergen *et al.* 2016), and by January 2018, the pest was reported in over 40 African countries (Prasanna *et al.* 2018). In Asia, FAW was first reported in the southern Indian state of Karnataka in May 2018 (Sharanabasappa *et al.* 2018, Shylesha *et al.* 2018), and subsequently in all the maize-growing states in the country (Suby *et al.* 2020, Deshmukh *et al.* 2021). Thus, FAW has now become a global problem, posing a serious threat to the food and nutritional security and livelihoods of hundreds of millions of farming households, especially those dependent on maize, in both Africa and Asia. Although FAW incidence has been reported on several crops, including maize (grain/sweet/waxy), sorghum, sugarcane, wheat, rice (very limited), millets, ginger, soybean, tomato, cotton, cabbage, groundnut, banana, pasture grasses and green amaranth, the pest has caused major economic damage mostly to maize across Africa and Asia, and secondarily to sorghum and sugarcane (to a limited extent). The economic impact of FAW is not only represented by the extensive yield losses caused by the pest to the affected crops like maize (Matova *et al.* 2020), but also additional management costs incurred by small holder farmers for example, the cost of managing the pest using various technologies,

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especially synthetic pesticides, besides increased labour. Current maize productivity is below its potential, although still higher than that of other major cereal crops which is attributed to a combination of several production constraints mainly lack of improved production technologies such as pest management practices, moisture stress, low fertility and poor cultural practices (Tufa and Ketema 2016). Arthropod pests are among the key factors contributing to low yields facing maize production today. In corn, they defoliate and kill young plants, result in huge loss of yield, and feeding of ears may cause depletion in grain quality and yield (Capinera 2017). Hence, this experiment has planned to study the effects of different agronomic management practices on FAW in maize crop.

Materials and Methods

The experiment was conducted in red sandy loam soil at the Agricultural Research Station, Karimnagar, Telangana, India, during the *kharif* season of 2020–21. The initial soil analysis indicated medium levels of available nitrogen, phosphorus, and potassium. Two experiments were conducted to evaluate intercropping and push–pull strategies for the management of fall armyworm (FAW) in maize. Experiment I: Intercropping-based strategy- The experiment was conducted in a Factorial randomized block design (FRBD) with three replications. Two factors were studied: Factor A – row arrangement, comprising regular (1:1) and paired (2:2) arrangements; and Factor B – intercropping system, comprising maize + mungbean, maize + cowpea, maize + groundnut, maize + soybean, and sole maize. Experiment II: Push–pull strategy for FAW management- The experiment was conducted in a randomized complete block design (RCBD) with four replications. The treatments consisted of maize + Tephrosia, maize + fenugreek, maize + coriander, and maize + marigold. A border row of hybrid Napier was planted around the experimental plots as a pull crop for FAW. FAW infestation was recorded as percentage plant infestation at 10-day intervals, starting from the date of first infestation until harvest. FAW damage severity was assessed using the Davis visual rating scale at the same intervals. At harvest, grain yield (kg ha^{-1}) and yield attributes were recorded for all treatments.

Results and Discussion

Grain yield was significantly higher under regular row arrangement (5,587 kg/ha) than paired-row arrangement (5,142 kg/ha). Stalk yield was statistically non-significant, although paired-row arrangement recorded a slightly higher stalk yield (6,626 kg/ha) than regular row arrangement (6,448 kg/ha). Regular row arrangement resulted in significantly higher net returns (₹40,115/ha) and B : C ratio (1.63) compared with paired-row arrangement (₹31,877/ha and 1.50, respectively). Maize + green gram recorded the highest grain yield (5,961 kg/ha), followed by sole maize (5,315 kg/ha), maize + soybean (5,243 kg/ha), maize + groundnut (5,161 kg/ha), and maize + cowpea (5,144 kg/ha). The grain yield differences were significant, as the highest yield in maize + green gram over the other intercropping treatments. Stalk yield was non-significant among the intercrop treatments, with the highest value recorded in maize + soybean (6,666 kg/ha). Maize + green gram recorded the highest net returns (₹47,031/ha) and B : C ratio (1.74), followed by sole maize (₹35,083/ha and 1.55), maize + soybean (₹33,738/ha and 1.53), maize + groundnut (₹32,221/ha and 1.51), and maize + cowpea (₹31,907/ha and 1.50). Thus, regular row arrangement combined with maize + green gram intercropping was the most profitable treatment, recording the highest grain yield, net returns and B : C ratio (Tables 1 and 2).

In-terms of % of FAW infestation and severity there was no difference was observed in between regular and paired row of sowing method. But significantly lesser percentage of FAW infestation at 50 DAS to harvest with maize + cowpea intercropping (24.9%) and it is onpar with maize + greengram intercropping (25.4%) and later stages it is decreasing. Severity of FAW

Table 1. Effects of Agro- ecological options for Fall Armyworm management with Intercropping based strategies on yield of maize.

	Grain yield (kg/ha)	Stalk yield (kg/ha)	Net returns (Rs./ha)	B : C Ratio
<i>Row arrangement</i>				
Regular	5587	6448	40115	1.63
Paired row	5142	6626	31877	1.50
CD at 5 %	361	NS	6689	0.11
SE(m) $\pm$	120	125	2234	0.04
<i>Intercrops</i>				
Maize + green gram	5961	6316	47031	1.74
Maize + cowpea	5144	6594	31907	1.50
Maize + groundnut	5161	6638	32221	1.51
Maize + Soybean	5243	6666	33738	1.53
Sole maize	5315	6472	35083	1.55
CD at 5 %	571	NS	10576	0.17
SE(m) $\pm$	190	198	3532	0.06

Table 2. Effects of Agro- ecological options for Fall Armyworm management with Intercropping based strategies on yield attributes of maize.

	Days to Tasseling stage	Days to Silking stage	Cob length (cm)	Cob diameter (mm)	Kernel rows (no.)	No. of kernels / row of cob	Shelling %
<i>Row arrangement</i>							
Regular	54.7	58.2	18.2	46.4	13.8	32.4	81.5
Paired row	54.8	58.1	17.4	46.4	14.0	30.4	81.2
CD at 5 %	NS	NS	0.62	NS	NS	1.64	NS
SE(m)	0.21	0.23	0.21	0.35	0.55	0.55	0.24
<i>Intercrops</i>							
Maize + green gram	54.7	58.3	19.5	47.6	14.4	34.0	81.6
Maize + cowpea	54.8	58.2	17.3	45.8	13.7	30.9	80.4
Maize + groundnut	54.2	57.7	17.4	46.2	13.9	30.9	81.2
Maize + Soybean	54.8	58.2	17.1	46.4	13.9	30.3	81.9
Sole maize	55.2	58.5	17.8	46.1	13.7	30.7	81.7
CD at 5 %	NS	NS	0.98	NS	NS	2.6	NS
SE(m)	0.33	0.36	0.33	0.55	0.37	0.87	0.38

Table 3. Effects of Agro- ecological options for Fall Armyworm management with Intercropping based strategies on % FAW infestation in maize.

	% FAW infestation								
	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS	100DAS
<i>Row arrangement</i>									
Regular	20.9	24.5	27.9	33.7	16.1	16.0	12.4	10.8	9.0
Paired row	20	23.8	27.3	33.1	13.6	13.6	10.4	9.6	8.3
CD at 5 %	NS	NS	NS	NS	NS	NS	1.9	NS	NS
SE(m)	1.5	1.2	1.5	1.7	1.0	0.9	0.06	0.5	0.4
<i>Intercrops</i>									
Maize + green gram	20.8	21.7	24.6	25.4	13.9	12.3	9.7	8.9	6.9
Maize + cowpea	16.7	21.8	24.6	24.9	13.7	11.3	9.4	8.6	7.4
Maize + groundnut	24.6	27.3	28.5	35.5	17.9	15.1	11.0	9.8	8.4
Maize + Soybean	20.7	24.4	29.9	35.0	16.7	14.3	11.5	9.6	8.5
Sole maize	19.7	25.5	30.5	46.3	24.4	21.1	15.3	14.0	12.3
CD at 5 %	NS	2.6	NS	7.9	4.6	4.5	2.9	2.61	2.11
SE(m)	2.4	1.9	2.4	2.6	1.7	1.5	0.9	0.8	0.7

Table 4. Effects of Agro- ecological options for Fall Armyworm management with Intercropping based strategies on severity of FAW infestation in maize.

	Severity of FAW infestation (as per Devis scale)								
	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS	100DAS
Row arrangement									
Regular	1.2	1.8	2.2	2.9	3.3	3.2	3.5	3.9	4.2
Paired row	1.2	1.9	2.3	2.7	3.16	3.4	3.5	4.1	4.3
CD at 5 %	NS	NS	0.01	0.02	0.02	NS	NS	0.02	0.06
SE(m)	0.02	0.02	0.04	0.06	0.05	0.14	0.03	0.05	0.02
Intercrops									
Maize + greengram	1.0	1.6	1.8	2.2	2.5	2.6	2.6	3.1	3.1
Maize + cowpea	1.2	1.7	2.2	2.5	2.9	3.1	3.3	4.0	3.8
Maize + groundnut	1.2	2	2.3	2.9	3.2	3.4	3.6	4.3	4.5
Maize + Soybean	1.1	1.1	2.4	3.1	3.6	3.7	3.7	4.3	4.6
Sole maize	1.4	2.0	2.5	3.3	3.9	3.5	4.3	4.5	5.1
CD at 5 %	0.03	0.09	0.07	0.09	0.08	0.55	0.12	0.09	0.09
SE(m)	0.1	0.03	0.02	0.03	0.03	0.22	0.04	0.03	0.03

infestation (as per Devis scale) recorded significantly less with maize + greengram intercropping (1.0) and later stages it was increasing slightly (Tables 3 and 4). Same trend was observed with findings of Pats *et al.* 1997 and Sivamurugan *et al.* 2024.

Among the treatments there was no significant difference was observed in-terms of maize grain yield, cob length (cm), net returns (Rs./ha) and B : C Ration, stalk yield, no. of kernels / row of cob, cob diameter (mm), kernel rows (no.) and shelling percentage, days to tasseling stage, days to silking stage. And recorded lesser maize grain yield when compared to the normal maize grain yield (Tables 5 and 6).

Table 5. Effects of Agro-ecological options for Fall Armyworm management with Push-pull strategy on yield of maize.

	Grain yield (kg/ha)	Stalk yield (kg/ha)	Net returns (Rs./ha)	B : C Ratio
Maize + fenugreek	4283	5674	16483	1.3
Maize + coriander	4162	5771	14255	1.2
Maize + marigold	4003	5681	11297	1.2
Maize + Tephrosia	4682	5556	23870	1.4
C.D.	NS	NS	NS	NS
SE(m)	221	170	4087	0.1
C.V.	8.0	6.0	49.6	10.7

Table 6. Effects of Agro-ecological options for Fall Armyworm management with Push-pull strategy on yield attributes of maize.

	Days to Tasseling stage	Days to Silking stage	Cob length (cm)	Cob diameter (mm)	Kernel rows (no.)	No. of kernels / row of cob	Shelling %
Maize + fenugreek	52.0	54.5	17.2	39.9	14.0	32.4	80.5
Maize + coriander	52.3	55.5	16.6	38.9	14.3	29.7	81.6
Maize + marigold	51.8	55.0	16.2	37.0	13.7	28.6	81.2
Maize + Tephrosia	52.3	55.5	17.3	39.6	14.3	30.5	81.8
C.D.	NS	NS	NS	NS	NS	NS	NS
SE(m)	0.4	0.4	0.5	1.0	0.3	1.1	0.7
SE(d)	0.5	0.6	0.7	1.5	0.4	1.6	1.0
C.V.	1.4	1.6	6.0	5.4	3.9	7.2	1.8

High percentage of FAW infestation and severity was observed in all the treatments and there was no significant difference was observed in-terms of FAW infestation and severity. But less incident and severity was observed with marigold intercrop with maize when compared to other crops (Tables 7 and 8). Same trend was observed with the findings of Cheruiyot *et al.* (2021).

Table 7. Effects of Agro-ecological options for Fall Armyworm management with Push-pull strategy on yield attributes of maize on % FAW infestation.

	% FAW infestation								
	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS	100DAS
Maize + fenugreek	40.5	41.9	94.6	95.2	95.5	95.7	95.7	95.7	96.1
Maize + coriander	51.0	41.3	86.1	88.7	89.0	89.3	89.3	89.3	89.7
Maize + marigold	46.2	41.9	83.1	85.2	86.0	86.3	86.3	86.3	88.2
Maize + Tephrosia	51.9	47.3	84.2	86.8	88.2	88.4	88.4	88.4	90.1
C.D.	NS	NS	8.2	NS	NS	NS	NS	NS	NS
SE(m)	5.0	6.9	2.6	2.8	2.8	2.8	2.8	2.8	2.4
C.V.	21.1	31.8	6.1	6.3	6.2	6.2	6.2	6.2	5.3

Table 8. Effects of Agro-ecological options for Fall Armyworm management with Push-pull strategy on yield attributes of maize on Severity of FAW infestation.

	Severity of FAW infestation (as per Devis scale)								
	20DAS	30DAS	40DAS	50DAS	60DAS	70DAS	80DAS	90DAS	100DAS
Maize + fenugreek	2.8	4.1	5.1	5.8	6.7	7.0	7.4	7.7	8.1
Maize + coriander	2.7	4.0	5.1	5.9	6.6	7.1	7.3	7.7	8.1
Maize + marigold	2.6	4.0	5.1	5.7	6.6	7.1	7.4	7.6	8.1
Maize + Tephrosia	2.7	4.0	5.1	6.0	6.8	7.0	7.4	7.7	8.1
C.D.	NS	NS	NS	NS	NS	NS	NS	NS	NS
SE(m)	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.1
C.V.	4.6	5.7	4.8	6.2	2.0	1.7	1.4	1.3	1.3

The reduction in pest infestation within the field was observed, due to specific inter-crops can be used by reducing the movement of larvae between crop plants (Pats *et al.* 1997) and also harbouring natural enemies and increasing their activity (Landis *et al.* 2000, Midega *et al.* 2006). The introduction of different intercropping systems such as marigold with maize will increase the presence of natural enemies while the repellent properties of intercrop contribute to the lower pest populations and enhanced crop yields. Many natural enemies respond to plant volatiles that are released when the plant is damaged by herbivore (Hoballah *et al.* 2002).

Maize + green gram intercropping effectively reduced FAW infestation and severity while maintaining higher maize grain yield. Thus, maize + green gram can be considered a promising intercropping option for sustainable FAW management and improved maize productivity.

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