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RESEARCH PAPER

Eco-friendly management of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) in fodder maize

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Abstract: Fall armyworm, *Spodoptera frugiperda* (J.E.Smith) (Noctuidae: Lepidoptera) is a highly destructive invasive insect pest and has become a serious pest on maize across India and other countries. It causes immense damage to leaf, so in order to manage this pest and to overcome health, environmental and resistance related problems due to indiscriminate use of insecticides effective and sustainable pest control eco-friendly approaches are tested here. Among the selected eco-friendly approaches *Metarhizium. rileyi* recorded least larval population with corresponding 51.35 and 60.60 per cent reduction over control in larval population during first and second spray, respectively and with least leaf damage of 27.92 per cent. This stood effective and superior to all the treatments in the trail. This was followed by Azadirachtin 3000 ppm, *B. bassiana* and pongamia oil. Comparatively lesser effectiveness was recorded in the treatment of sand and lime while highest larval population and leaf damage was recorded in untreated check.

Key words: Eco-friendly management, larval population, leaf damage, *Spodoptera frugiperda*

Introduction

Maize (*Zea mays* L.) is one of the most significant fodder as well as cereal crop in India. It is widely cultivated in the tropical, subtropical, and temperate regions of the world. It is also referred to as the "wonder crop" or the "Queen of Cereals" since it has a much better yield potential than any other cereal. Maize is the third most important versatile food grain as well as fodder crop in our country. It is a popular *kharif* and summer forage crop grown across the country, providing extremely delicious, succulent, and nutritious forage for livestock with nutrient-dense fodder. As far as green fodder grows, especially when the leaves and ears are included, it is a high-energy source of feed for ruminants (Brewbaker, 2003). Maize is fast growing, high yielding, rich in essential nutrients and is free of anti-metabolites. Hence, maize fodder can be feed to animals at any stage of the crop. It can be fed either green or dry, and is most suitable for silage production. It yields high-quality herbaceous fodder with high palatability. On dry matter basis, it contains 9-10% crude protein (CP), 60-64 per cent neutral detergent fiber (NDF), 38-41 per cent acid detergent fiber (ADF), 23-25 per cent hemi-cellulose and 28-30% cellulose, when harvested at the milk to early dough stage. Grazing whole maize plants also provides green fodder to livestock during the time of scarcity. Due to several biotic and abiotic factors, India's average fodder yield production reduced. Insect pests have been identified as one of the primary causes of fodder production reductions among biotic factors. It is estimated that numerous insect pest cause damage to fodder maize, among them stem borers cause major damage but in recent past, fall armyworm, *Spodoptera frugiperda* (J. E. Smith) has gaining upper hand and attained the status of serious pest. In Asia, FAW is recently reported for the first time on maize in India, Karnataka (Sharanabasappa *et al.*, 2018a) and total life cycle of fall armyworm ranges from 32 to 46 days (Sharanabasappa *et al.,* 2018b). High levels of infestation of fall armyworm was noticed in Karnataka (Mallapur *et al.,* 2018, Pradeep *et al*., 2022). In a recent study, the average cost on insecticides spent by farmers per 100 kg maize grain during 2017-20 was US$ 0.124, US$ 2.04, US$ 1.68 and US$ 1.39 respectively highlighting the effect of FAW invasion on pest management regime in the maize crops of Karnataka (Deshmukh *et al.,* 2021). Fall armyworm has spread fast across India and other Asian countries due to its ability to travel and migrate long distance in short period of time. Furthermore, the pest has a wide range of hosts, including several of our country's most important crops. Though it is first observed on maize, some reports suggest that it has spread to other economically important crops such as sorghum, wheat, sugarcane, cotton, rice, soybean, peanut and others.

Material and methods

The present investigation was conducted at Indian Grassland and Fodder Research Station, Dharwad (15°26' North latitude, 75°07' East longitude and at an altitude of 731.80 meters above mean sea level, in the Northern transitional zone (Zone - 8) of Karnataka). The trials were laid out during *kharif* 2021-22. The experiment was laid out in a randomised block design with 10 treatments including untreated check. Three replications were followed for each treatment. The African tall variety seeds were sown during last week of July, 2021 and the crop was raised as per the recommended package of practices, except plant protection protocols. Two sprays were taken during the course of study, there were eight eco-friendly treatments comprising of *Metarrhizium anisopliae* (2×10^8 cfu/g) @ 2 g/L, *Beauveria bassiana* (2×10^8 cfu/g) @ 2 g/L, *Metarhizium rileyi* (2×10^8 cfu/g) @ 2 g/L, Pongamia oil 5 ml/L, Azadirachtin (3000 ppm) @ 5 ml/L, Chilli + garlic extract @ 5%+2.5% (Aqueous), Agniastra @ 20 ml/L, Sand +Lime (9:1 ratio) @ 10 kg/acre and one standard check chemical emamectin benzoate 0.5 SG @ 0.2 g/L.

The observations on larval count and leaf damage were recorded at a day before, 3, 7 and 14 days after spray. Observations were recorded on 5 plants per treatment and expressed as their mean. The leaf damage was expressed in percentage using formula

$$\text{Per cent plant infestation (\%)} = \frac{\text{Total number of plant observed}}{\text{Number of plans infested}} \times 100$$

The data in numbers were transformed to √x +0.5 values and that of percentages were transformed to arc sin values and means were gauged with DMRT in WASP 2.0.

Results and discussion

Effect of eco-friendly approaches against larval population of fall armyworm

First spray

The larval population ranged from 2.26 to 2.60/ plant across the treatments a day before spray and wad statistically non-significant with each other. Among the eco-friendly approaches lowest larval population was recorded in azadirachtin (3000 ppm) (1.73/plant) followed by pongamia oil (1.80/plant) and chilli + garlic kerosene extract (1.93/plant) while that of highest was recorded in *Metarhizium anisopliae* (2.33/plant) 3 DAS. At 7DAS larval population ranged from 0.93 to 2.26 per plant. Among all treatments, *M. rileyi* had the least larvae per plant (1.13), which was determined to be on par with azadirachtin 3000 ppm (1.40/plant). *Beauveria bassiana* @ 2 g/l (1.53/plant) and pongamia oil (1.60/plant) treatments. The treatments sand +lime @ 10 g/plant (2.13/plant), chilli + garlic kerosene extract (2.06 larvae/plant) and agniastra @ 20 ml/l (2.00 larvae/plant) were found to be ineffective in controlling the larval population. Similar trends were noticed at 14 DAS (Table 1).

Second spray

The larval population exhibited significant variation amongst each other on day before spray due the effect of first spray. At 3 DAS, Azadirachtin (3000ppm) recorded the lowest larval count of 1.26 per plant and this was followed by Pongamia oil (1.46/plant). However, the highest larval population was noted in *Metarhizium anisopliae* (2.20/ plant). At 7 DAS least larval population was noted in *M. rileyi* (0.93/plant) and it was found on par with azadirachtin 3000ppm (1.13), *B. bassiana* (1.30 /plant) and highest was recorded in *M. anisopliae* and agniastra (1.73/plant) and sand+lime (1.80/plant). Similar trends were observed at 14 DAS. Further, the highest reduction over control was recorded in plots treated with *M rileyi* (60.60%) with lowest mean larval count of 1.15/ plant.

Efficacy of eco-friendly approaches against leaf damage of fall armyworm

First spray

Per cent leaf damage recorded at a day before spray was equable and homogenous and statistically non-significant ranging from 50.33 to 54.33 per cent. At 3 DAS, the lowest leaf damage was recorded in Azadirachtin 3000ppm (37.16%) and was followed by pongamia oil (41.41%). At 7 DAS and 14 DAS, *Metarhizium rileyi* was showed lowest leaf damage of 22.91

Table 1. Evaluation of eco-friendly approaches against fall armyworm in fodder maize during *kharif* 2021 (I & II Spray)

Treatments	Dosage	Number of fall armyworm larvae per plant										
		I Spray					II Spray				%ROC	*Mean
		1DBS	3DAS	7DAS	14DAS	%ROC	1DBS	3DAS	7DAS	14DAS		
1 *Metarrhizium anisopliae* - NBAIR-isolate (2×10^8 cfu/g)	2 g/l	2.26 (1.66)	2.33 (1.68)^{e}	1.73 (1.49)^{de}	1.46 (1.40)^{c}	28.95	2.26 (1.66)^{cd}	2.20 (1.64)^{g}	1.73 (1.44)^{d}	1.06 (1.40)^{c}	37.12	1.75
2 *Beauveria bassiana* (2×10^8 cfu/g)	2 g/l	2.40 (1.70)	2.06 (1.60)^{cde}	1.53 (1.42)^{cd}	1.00 (1.19)^{b}	40.92	2.06 (1.58)^{ab}	1.66 (1.46)^{cd}	1.30 (1.27)^{c}	0.86 (1.16)^{bc}	51.89	1.40
3 *Metarhizium rileyi* (2×10^8 cfu/g)	2 g/l	2.26 (1.76)	2.00 (1.58)^{bcd}	1.13 (1.27)^{ab}	0.66 (1.07)^{a}	51.35	2.13 (1.62)^{b}	1.53 (1.42)^{c}	0.93 (1.07)^{ab}	0.66 (0.91)^{ab}	60.60	1.15
4 Pongamia oil	5 ml/l	2.46 (1.72)	1.80 (1.51)^{bc}	1.60 (1.44)^{cd}	1.86 (1.53)^{de}	32.43	2.26 (1.66)^{cd}	1.46 (1.40)^{bc}	1.30 (1.25)^{c}	1.53 (1.51)^{de}	45.83	1.59
5 Azadirachtin (3000 ppm)	5 ml/l	2.26 (1.66)	1.73 (1.49)^{ab}	1.40 (1.37)^{bc}	1.26 (1.32)^{c}	43.62	2.13 (1.62)^{b}	1.26 (1.32)^{ab}	1.13 (1.21)^{bc}	1.30 (1.07)^{d}	53.40	1.34
6 Chilli + garlic kerosene extract	5%+2.5%	2.60 (1.76)	1.93 (1.55)^{bcd}	2.06 (1.60)^{f}	1.80 (1.51)^{d}	25.48	2.23 (1.65)^{c}	1.86 (1.53)^{de}	1.60 (1.42)^{d}	1.73 (1.53)^{ef}	34.46	1.83
7 Agniastra	20 ml/l	2.53 (1.74)	2.13 (1.62)^{de}	2.00 (1.58)^{ef}	1.86 (1.53)^{de}	23.16	2.13 (1.62)^{b}	1.93 (1.55)^{ef}	1.73 (1.51)^{d}	1.80 (1.62)^{f}	31.06	1.90
8 Sand +lime (9:1 ratio)	10 g/plant	2.60 (1.76)	2.20 (1.64)^{de}	2.13 (1.62)^{f}	2.06 (1.60)^{e}	17.76	2.36 (1.69)^{d}	2.13 (1.62)^{fg}	1.80 (1.62)^{d}	2.06 (1.70)^{g}	24.62	2.06
9 Emamectin benzoate 5SG	0.2 g/l	2.06 (1.60)	1.46 (1.40)^{a}	0.93 (1.19)^{a}	0.60 (1.04)^{a}	61.77	2.00 (1.58)^{a}	1.13 (1.27)^{a}	0.73 (0.98)^{a}	0.46 (0.87)^{a}	70.83	0.88
10 Untreated check	_	2.46 (1.72)	2.73 (1.79)^{f}	2.26 (1.66)^{f}	2.80 (1.81)^{f}	-	2.40 (1.70)^{e}	2.53 (1.74)^{h}	2.80 (1.81)^{e}	2.60 (2.02)^{h}	-	2.61
S.Em. (±)		0.14	0.09	0.10	0.08		0.12	0.08	0.07	0.07		-
C.D. @ 5%		NS	0.29	0.31	0.25		0.36	0.25	0.23	0.23		-
C.V. (%)		10.26	8.41	10.96	9.42		9.90	8.37	9.31	9.47		-

DAS = Days after spray, DBS= Day before spray, 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), *= Mean of I & II spray.

Table 2. Efficacy of eco-friendly approaches on per cent leaf damage by fall armyworm in fodder maize during *kharif* 2021

Tr.No	Treatments	Dosage	Per cent leaf damage per plant								
			I Spray				II Spray				*Mean
			1DBS	3DAS	7DAS	14DAS	1DBS	3DAS	7DAS	14DAS	
1	*Metarhizium anisopliae* - NBAIR- isolate (2×10^8 cfu/g)	2 g/l	54.33 (47.49)	52.08 (46.19)^{ef}	40.16 (39.31)^{cde}	36.41 (37.10)^{cd}	45.66 (42.48)^{ab}	42.50 (40.66)^{cde}	34.08 (35.73)^{def}	28.50 (32.24)^{bc}	38.95
2	*Beauveria bassiana* (2×10^8 cfu/g)	2 g/l	53.66 (47.08)	49.50 (44.71)^{def}	34.58 (36.00)^{bc}	25.08 (30.04)^{b}	47.16 (43.35)^{d}	43.16 (41.05)^{de}	29.66 (32.96)^{cd}	22.75 (28.47)^{b}	34.11
3	*Metarhizium rileyi* (2×10^8 cfu/g)	2 g/l	53.16 (46.79)	46.08 (42.75)^{cde}	22.91 (28.56)^{a}	19.25 (26.00)^{a}	46.00 (42.68)^{b}	44.00 (41.53)^{de}	22.91 (28.55)^{b}	12.41 (20.62)^{a}	27.92
4	Pongamia oil	5 ml/l	50.33 (45.17)	41.41 (40.05)^{bc}	38.83 (38.51)^{bcd}	39.33 (38.77)^{de}	46.33 (42.87)^{bc}	36.16 (36.95)^{bc}	31.66 (34.20)^{cde}	32.83 (34.94)^{cde}	36.70
5	Azadirachtin (3000ppm)	5 ml/l	51.66 (45.93)	37.16 (37.56)^{b}	33.25 (35.16)^{b}	33.91 (35.59)^{c}	47.00 (43.26)^{cd}	34.83 (36.15)^{b}	28.16 (31.87)^{bc}	29.50 (32.88)^{cd}	32.80
6	Chilli + garlic kerosene extract	5%+2.5%	53.00 (46.70)	44.33 (41.73)^{cd}	43.00 (40.94)^{de}	41.83 (40.27)^{ef}	44.50 (41.82)^{a}	39.91 (39.16)^{bcd}	35.41 (36.50)^{def}	33.41 (35.29)^{cde}	39.64
7	Agniastra	20 ml/l	52.00 (46.13)	45.00 (42.11)^{cde}	44.25 (41.68)^{de}	44.00 (41.53)^{ef}	46.16 (42.78)^{bc}	42.00 (40.37)^{cd}	37.16 (37.54)^{ef}	34.66 (36.03)^{de}	41.17
8	Sand +lime (9:1 ratio)	10 g/plant	53.33 (46.89)	46.33 (42.88)^{cde}	45.25 (42.25)^{e}	46.58 (43.02)^{f}	46.25 (42.83)^{c}	43.00` (40.95)^{cde}	38.58 (38.38)^{f}	37.50 (37.74)^{e}	42.879
9	Emamectin benzoate 5SG	0.2 g/l	51.33 (45.74)	21.16 (27.38)^{a}	18.66 (25.48)^{a}	17.83 (24.94)^{a}	45.00 (42.10)^{a}	21.66 (27.37)^{a}	14.83 (22.63)^{a}	12.75 (20.90)^{a}	17.81
10	Untreated check	_	54.33 (47.48)	55.66 (48.27)^{f}	57.08 (49.05)^{f}	53.08 (46.75)^{g}	50.00 (44.98)^{e}	49.33 (44.60)^{e}	51.83 (46.03)^{g}	49.50 (44.68)^{f}	52.74
S.Em. (±)			NS	2.41	1.95	1.74	2.26	2.31	1.95	2.02	-
C.D. @ 5%			NS	7.24	5.84	5.22	6.78	6.93	5.85	6.04	-
C.V. (%)			11.07	9.55	8.94	8.45	8.45	10.12	10.43	11.90	-

DAS = Days after spray, DBS= Day before spray, Figures in parenthesis are arc sine transformed values, means in the columns followed by same alphabet do not differ significantly by DMRT (p=0.05), *= Mean of I & II spray.

and 19.25 per cent, respectively thus proving to be comparatively superior than other treatments (Table 2).

Second spray

There existed a significant difference in leaf damage among the eco-friendly treatment due the effect of the first spray. At 3 DAS, lowest leaf damage was noticed in Azadirachtin (34.83%) and was followed by pongamia oil (36.16%). At 7 and 14 DAS, *M. rileyi* was found to be superior recording lowest leaf damage of 22.91 and 12.41 per cent, respectively and with least mean leaf damage of 27.92 per cent (Table 2).

These results are supported by the findings of Mallapur *et al.* (2018) who reported a 62.50 to 66.46 per cent larval reduction by *M. rileyi.* Under ideal climatic conditions, this pathogenic fungus is self-perpetuating, very cost-effective, and compatible with other eco-friendly management techniques. The current results are also similar to those of Firake and Behere (2020) where *M. rileyi* caused 50 per cent larval mortality throughout the season. These results are in line with Mallapur *et al*. (2018) who reported 66.84 to 73.05 per cent reduction in leaf damage across different locations when *M. rileyi* evaluated in large scale. Dhobi *et al.* (2020) who found that minimum plant damage of 15.34 per cent by *M. rileyi* against fall armyworm. Kammo *et al.* (2019) reported that neem oil @ 1.4 l/ha results least per centage of fall armyworm leaf damage when compared with control in maize.

Conclusion

Studies on efficacy of eco-friendly management against fall armyworm, *S. frugiperda* indicated that *M. rileyi* was very effective in reducing the larval population of fall armyworm and the leaf damage caused by it. Azadirachtin (3000ppm) was found to be next best treatment in managing the pest and was followed by pongamia oil. Sand + lime @ 10 g/plant recorded poor when compared with other treatments in the experiment.

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