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RESEARCH PAPER

Influence of intercrops and border crops on the incidence of fall armyworm (*Spodoptera frugiperda*) on *rabi* sorghum

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Abstract: Effects of intercrops and border crops on the incidence of fall armyworm, *Spodoptera frugiperda* J E Smith, on sorghum was evaluated during *rabi* 2023-24 at All India Coordinated Sorghum Improvement Project, Main Agricultural Research Station, UAS, Dharwad. Among the different treatments consisting of various intercrops and border crops, sorghum intercropped with french bean and napier grass as border crop found effective against fall armyworm with lower larval population (0.61 larvae/plant) and leaf damage(1.42), followed by the treatment sorghum intercropped with coriander and napier grass as border crop with (0.75 larvae/plant and leaf damage of 1.51). Sole crop of sorghum with napier grass as border crop was the next best treatment with 0.93 and 1.63 larval population and leaf damage respectively. Thus, the results clearly indicate the superiority of sorghum intercropped with either french bean or coriander as inter crop along with napier grass as border crop in reducing fall armyworm infestation when compared to other treatments.

Key words: Border crops, Fall armyworm, Intercrops, *Rabi* Sorghum, *Spodoptera frugiperda*

Introduction

Sorghum (*Sorghum bicolor* L.) is an important cereal crop grown in tropical, subtropical and warmer semi-arid regions worldwide. It is vital for providing food to millions of people living in semi-arid areas. Due to its high adaptability to various ecological conditions. Sorghum is the fifth most produced cereal globally, following wheat, maize, barley and rice. Sorghum grains are composed of 70-80 per cent carbohydrates, 11-13 per cent protein, 2.5 per cent fat, 1-3 per cent fiber and 1-2 per cent mineral matter/ash.

Globally, sorghum is grown in 40.76 million ha, yielding 61.51 million MT, with an average productivity of approximately 1.51 tonnes per ha. Currently, it is the fifth most important cereal crop in India where, sorghum is cultivated in 3.65 million ha, producing 4.03 million 1 with a productivity of 1.106 tonnes per ha and Karnataka ranks next to Maharashtra in terms of sorghum cultivation area (586000ha) and production (706000 tonnes), with a productivity of 1,106 kg per ha. In Karnataka, sorghum is primarily grown in 35 taluks across various districts in North Karnataka, with a total area of 943350ha (Anon., 2024).

But, the area under sorghum cultivation has been declining each year due to several factors, among which biotic factors particularly insect pests are major ones. Recently invasion of fall armyworm, *Spodoptera frugiperda* has raised major concerns due to its severe defoliation capacity and it can be managed by using IPM methods like push pull technologies, crop rotation, using resistant varieties, pheromone traps and release of bio control agents (Akinyemi *et al*., 2021). A repelling intercrop (as Push) and an attractive trap/ border crop (as Pull) are used. These companion crops release semiochemicals that repel insect pests from the main crop using an intercrop which is the "push" component and concurrently attract insect pests away from the main crop using a trap / border crop which is the "pull" component (Gaikwad *et al*., 2019).

Material and methods

An experiment was laid out in randomised block design with 9 treatment and 3 replications with plot size of 3×3 m area. The popular *rabi* sorghum variety SPV 2217 was raised as per standard package of practices (UAS, Dharwad) except plant protection measures for insects.The field experiment was carried out at AICRP on Sorghum, Main Agricultural Research Station (MARS), Dharwad during *rabi* season 2023-24. Further, observations on the number of egg masses/10 plants, number of larvae/plant, leaf damage severity and number of natural enemies were recorded on 10 randomly selected plants in each treatment starting from 15 days after emergence till 75 days at 15 days interval. At harvest, grain yield and fodder yield was recorded and converted into hectare basis.

Results and discussion

Number of egg masses

Considering the mean data,sorghum + french bean + napier grass (T_5) recorded lowest number of egg masses of 0.36 per 10 plants followed by sorghum + coriander + napier grass (T_6) (0.52 egg masses/10 plants). Similarly highest number of egg masses were found in sorghum sole crop (T_9) (1.56 egg masses/10 plants) followed by sorghum + coriander + maize as border crop (T_8) (1.20 egg masses/10 plants) and sorghum + french bean + maize as border crop (T_7) (1.04 egg masses/10 plants) (Table 2).

Larval population

The mean larval population showed lower in sorghum + french bean + napier grass (T_5) with 0.61 larvae/plant followed by, sorghum + coriander + napier grass (T_6) (0.75 larvae/plant). Whereas, higher larval population was observed in sorghum sole crop (T_9) with 2.12 larvae/plant followed by, sorghum + maize as border crop (T_3) (1.51 larvae/plant) (Table 3).

Table 1. Inter crop and border crop treatment details

T_1	Sorghum + French bean (4:2)
T_2	Sorghum + Coriander (4:2)
T_3	Sorghum + Maize as border crop
T_4	Sorghum + Napier grass as border crop
T_5	Sorghum + French bean + Napier grass as border crop
T_6	Sorghum + Coriander + Napier grass as border crop
T_7	Sorghum + French bean + Maize as border crop
T_8	Sorghum + Coriander + Maize as border crop
T_9	Sole Sorghum

Leaf damage score

The observations on leaf severity showed, lower leaf damage score in sorghum + french bean + napier grass as border crop (T_5) (1.42) which is at par with sorghum + coriander + napier grass as border crop (T_6) (1.51) and sorghum + napier grass as border crop (T_4) (1.61). And higher leaf damage score was recorded in sorghum sole crop (T_9) (3.29) followed by sorghum + maize as border crop (T_3) (2.07) and sorghum + coriander (T_2) (2.20) (Table 4).

Yield parameters

The treatment sorghum + french bean + napier grass as border crop (T_5) recorded higher grain and fodder yield of 40.59 q/ha and 7.70 t/ha respectively followed by sorghum + coriander + napier grass as border crop (T_6) (37.91q/ha and 6.94 t/ha respectively). However lower grain yield was recorded in sorghum sole crop (T_9) (23.03 q/ha and 5.40 t/ha respectively)

Table 2.Effect of inter crops and border crops on fall armyworm oviposition in sorghum during *rabi,* 2023-24

Treatments	Number of egg masses per/plant					
	15 DAE	30 DAE	45 DAE	60 DAE	75 DAE	Mean
Sorghum + French bean (4:2)	0.40(0.63)^{c}	1.40(1.18)^{d}	1.00(0.99)^{bc}	1.00(0.98)^{c}	0.00(1.00)	0.84(0.96)^{c}
Sorghum + Coriander (4:2)	0.40(0.63)^{c}	1.60(1.26)^{cd}	1.20(1.09)^{b}	1.00(0.98)^{c}	0.00(1.00)	0.88(0.99)^{c}
Sorghum + Maize as border crop	0.60(0.77)^{b}	1.40(1.18)^{d}	1.60 (0.89)^{ab}	1.00(0.98)^{c}	0.00(1.00)	0.80(0.96)^{c}
Sorghum + Napier grass as border crop	0.40(0.63)^{c}	1.20(1.09)^{e}	1.00(0.99)^{bc}	0.80(0.89)^{d}	0.00(1.00)	0.76(0.92)^{d}
Sorghum + French bean + Napier grass as border crop	0.20(0.45)^{d}	0.80(0.89)^{g}	0.40(0.63)^{e}	0.40(0.63)^{f}	0.00(1.00)	0.36(0.72)^{e}
Sorghum + Coriander + Napier grass as border crop	0.20(0.45)^{d}	1.00(0.99)^{f}	0.60(0.77)^{d}	0.60(0.77)^{e}	0.00(1.00)	0.52(0.79)^{cd}
Sorghum + French bean + Maize as border crop	0.60(0.77)^{b}	1.80(1.34)^{bc}	1.40(1.18)^{b}	1.20(1.09)^{b}	0.00(1.00)	1.04(1.08)^{bc}
Sorghum + Coriander + Maize as border crop	0.60(0.77)^{b}	2.00(1.41)^{b}	1.60(1.26)^{ab}	1.40(1.26)^{b}	0.00(1.00)	1.20(1.14)^{b}
Sole Sorghum	1.00(1.00)^{a}	2.40(1.55)^{a}	2.00(1.34)^{a}	1.80(1.41)^{a}	0.00(1.00)	1.56(1.26)^{a}
S.Em±	NS	0.10	0.14	0.07	NS	0.05
C.D.(0.05)	NS	0.29	0.41	0.20	NS	0.22
C.V. %	9.63	8.24	9.38	10.34	0.00	7.52

*DAE: Days after emergence **Figures within the parenthesis indicates square root transformation

Table 3. Effect of inter crops and border crops on larval population of fall armyworm in sorghum during *rabi,* 2023-24

Treatments	Number of larvae per plant					
	15 DAE	30 DAE	45 DAE	60 DAE	75 DAE	Mean
Sorghum + French bean (4:2)	0.30 (0.89)^{cde}	0.96 (1.18)^{d}	1.83 (1.39)^{cd}	1.40 (0.97)^{cde}	0.86 (0.92)^{b}	1.07 (1.06)^{c}
Sorghum + Coriander (4:2)	0.33 (0.91)^{cde}	1.10 (1.20)^{d}	2.03 (1.35)^{bcd}	1.63 (1.02)^{cd}	0.93 (0.96)^{b}	1.20 (1.09)^{bc}
Sorghum + Maize as border crop	0.56^{c} (1.03)^{b}	1.36 (1.22)^{bc}	2.40 (1.43)^{bcd}	1.89 (1.34)^{cde}	1.33 (0.99)^{b}	1.51 (1.20)^{b}
Sorghum + Napier grass as border crop	0.36 (0.93)^{cde}	0.76 (1.12)^{de}	1.46 (1.21)^{cde}	1.26 (1.34)^{de}	0.80 (0.89)^{bc}	0.93 (1.10)^{cd}
Sorghum + French bean + Napier grass as border crop	0.13 (0.79)^{f}	0.36 (0.92)^{f}	1.30 (1.13)^{de}	0.86 (1.32)^{ef}	0.40 (0.63)^{d}	0.61 (0.96)^{de}
Sorghum + Coriander + Napier grass as border crop	0.20 (0.83)^{e}	0.56 (1.03)^{def}	1.33 (1.15)^{de}	1.06 (1.04)^{e}	0.60 (0.77)^{c}	0.75 (0.96)^{d}
Sorghum + French bean + Maize as border crop	0.60 (1.05)^{bc}	1.26 (1.34) ^{bc}	2.06 (1.53)^{bc}	1.80 (1.30)^{bc}	1.26 (1.12)^{a}	1.39 (1.27)^{bc}
Sorghum + Coriander + Maize as border crop	0.66 (1.08)^{bc}	1.60 (1.41)^{bq}	2.17 (1.57)^{ab}	1.76 (1.36)^{ab}	1.00 (1.00)^{ab}	1.49 (1.28)^{b}
Sole Sorghum	1.00 (1.22)^{a}	2.35 (1.63)^{a}	3.12 (1.89)^{a}	2.14 (1.55)^{a}	1.97 (1.10)^{a}	2.12 (1.48)^{a}
S.Em±	0.10	0.15	0.34	0.10	0.11	0.16
C.D. (0.05)	0.31	0.46	1.03	0.32	0.23	0.47
C.V. %	8.67	9.12	10.93	9.85	12.24	10.16

*DAE: Days after emergence **Figures within the parenthesis indicates square root transformation

Table 4. Effect of inter crops and border crops on leaf damage due to fall armyworm in sorghum during *rabi,* 2023-24

Treatments	Leaf damage score (0-9 scale)					
	15 DAE	30 DAE	45 DAE	60 DAE	75 DAE	Mean
Sorghum + French bean (4:2)	0.33(0.93)^{c}	0.96(0.89)^{d}	3.60(1.72)^{cde}	2.96(1.89)^{cd}	2.46(1.64)^{cde}	2.07(1.41)^{d}
Sorghum + Coriander (4:2)	0.36(0.89)^{cd}	1.10(1.01)^{bcd}	3.82(1.86)^{cd}	3.06(1.95)^{bc}	2.65(1.75)^{cd}	2.20(1.49)^{c}
Sorghum + Maize as border crop	0.56(1.00)^{bc}	2.36(1.15)^{b}	4.36(1.93)^{bc}	3.66(2.01)^{b}	2.56(1.71)^{cd}	2.71(1.56)^{b}
Sorghum + Napier grass as border crop	0.36(0.89)^{cd}	0.86(0.93)^{cd}	2.65(1.65)^{ef}	2.23(1.60)^{de}	1.93(1.44)^{f}	1.61(1.30)^{e}
Sorghum + French bean + Napier grass as border crop	0.13(0.77)^{e}	0.76(0.85)^{d}	2.26(1.28)^{g}	2.06(1.45)^{f}	1.63(1.13)^{g}	1.42(1.09)^{ef}
Sorghum + Coriander + Napier grass as border crop	0.20(0.79)^{de}	0.86(0.86)^{d}	2.53(1.60)^{ef}	2.05(1.44)^{f}	1.73(1.23)^{fg}	1.51(1.18)^{e}
Sorghum + French bean + Maize as border crop	0.66(1.05)^{b}	1.26(1.09)^{bc}	3.80(1.84)^{cd}	3.46(1.94)^{b}	2.76(1.85)^{c}	2.39(1.55)^{c}
Sorghum + Coriander + Maize as border crop	0.68(1.05)^{b}	1.86(1.11)^{bc}	3.75(1.88)^{cd}	3.25(1.92)^{bc}	2.86(1.89)^{b}	2.49(1.57)^{bc}
Sole Sorghum	1.02(1.29)^{a}	3.10(1.43)^{a}	4.93(1.95)^{a}	4.06(2.18)^{a}	3.30(2.09)^{a}	3.29(1.79)^{a}
S.Em±	0.07	0.26	0.25	0.11	0.04	0.15
C.D. (0.05)	0.21	0.78	0.76	0.35	0.12	0.44
C.V. %	9.69	10.67	11.72	10.24	11.53	10.77

*DAE: Days after emergence **Figures within the parenthesis indicates square root transformation

Table 5. Effect of inter crops and border crops on yield parameters in sorghum during *rabi,* 2023-24

Treatments ``	Mean egg mass/ 10 plants	Mean larvae /plant	Mean LDS	Grain yield (q/ha)	Fodder yield (t/ha)
Sorghum + French bean (4:2)	0.84^{c}	1.07^{e}	2.07^{d}	35.16^{c}	6.59^{c}
Sorghum + Coriander (4:2)	0.88^{c}	1.20^{bc}	2.20^{c}	32.97^{d}	6.49^{c}
Sorghum + Maize as border crop	0.80^{c}	1.51^{b}	2.71^{b}	28.44^{e}	5.86^{e}
Sorghum + Napier grass as border crop	0.76^{cd}	0.93^{cd}	1.61^{e}	35.47^{c}	6.67^{c}
Sorghum + French bean + Napier grass as border crop	0.36^{e}	0.61^{de}	1.42^{ef}	40.59^{a}	7.70^{a}
Sorghum + Coriander + Napier grass as border crop	0.52^{d}	0.75^{d}	1.51^{e}	37.91^{b}	6.94^{b}
Sorghum + French bean + Maize as border crop	1.04^{bc}	1.39^{bc}	2.39^{c}	31.56^{d}	6.20^{d}
Sorghum + Coriander + Maize as border crop	1.20^{b}	1.49^{b}	2.49^{bc}	31.25^{d}	6.18^{d}
Sole sorghum	1.56^{a}	2.12^{a}	3.29^{a}	23.03^{f}	5.40^{f}
S.Em±	0.05	0.16	0.15	0.51	0.19
C.D. (0.05)	0.22	0.47	0.44	1.53	0.59
C.V. %	7.52	10.16	10.77	11.56	10.42

*DAE: Days after emergence **LDS- Leaf damage score ***In vertical columns, means followed by same letter do not differ significantly by DMRT (p=0.05)

Table 6.Impact of different intercrops and border crops on B:C ratio of sorghum during *rabi,* 2023-24

Treatments	Cost of cultivation (₹ /ha)	Grain yield (q/ha)	Grain return (₹ /ha)	Fodder yield (t/ha)	Fodder return (₹ /ha)	Gross returns (₹ /ha)	Net returns (₹ /ha)	B:C ratio
Sorghum + French bean (4:2)	38875	3.51	111300	6.59	2768	114068	65193	2.9
Sorghum + Coriander (4:2)	38735	3.29	101760	6.49	2726	104486	55751	2.6
Sorghum + Maize as border crop	38600	2.84	90312	5.86	2461	92773	44173	2.4
Sorghum + Napier grass as border crop	38050	3.54	112572	6.67	2801	115373	67323	3.0
Sorghum + French bean + Napier grass as border crop	38860	4.05	128790	7.70	3234	132024	83164	3.3
Sorghum + Coriander + Napier grass as border crop	38540	3.79	120522	6.94	2915	123437	74897	3.2
Sorghum + French bean + Maize as border crop	39058	3.15	100170	6.20	2604	102774	52616	2.6
Sorghum + Coriander + Maize as border crop	40035	3.12	99216	6.18	2595	101811	51776	2.5
Sole sorghum	34085	2.30	73140	5.40	2268	75408	31323	2.2

Cost of sorghum grains: ₹ 3180/q and cost of straw: ₹ 420/t
Cost of cultivation: ₹ 34085/ha

(Table 5). The Benefit Cost ratio (B:C ratio) of all the treatments were computed and highest B:C ratio was found in sorghum + french bean + napier grass as border crop (T_5) (1:3.3) followed by sorghum + coriander + napier grass as border crop (T_6)(1:3.2) and sorghum + napier grass as border crop(T_4) (1:3.0) and sorghum sole crop (T_9) with1:2.2 (Table 6).

Natural enemies

The predator population (*viz.*, coccinellids, green lacewing and spiders) were higher in sorghum + french bean+ napier grass as border crop (T_5) followed by sorghum + coriander + napier grass as border crop (T_6). Whereas, lower predator population was observed in sorghum sole crop (T_9) and sorghum + maize as border crop (T_3) (Table 7).

The lower incidence of fall armyworm on sorghum was observed with intercrops and border crops might be due to morphological features of companion plants such as- presence of long trichomes along with leaf margins which results in less survival of the larvae, delayed larval development and leading

Table 7. Effect of inter crops and border crops on natural enemy population in sorghum during *rabi*, 2023-24

Treatments	No. of predators/plant														
	15 DAE			30 DAE			45 DAE			60 DAE			75 DAE		
	Coccinellids	Green lace wings	Spiders	Coccinellids	Green lace wings	Spiders	Coccinellids	Green lace wings	Spiders	Coccinellids	Green lace wings	Spiders	Coccinellids	Green lace wings	Spiders
Sorghum + French bean (4:2)	0.26	0.39	0.25	0.84	0.45	0.00	1.35	1.17	0.00	1.58	1.10	0.50	1.25	0.84	1.33
Sorghum + Coriander (4:2)	0.10	0.15	0.08	0.27	0.20	0.10	0.98	0.48	0.32	1.23	0.55	0.32	1.03	0.27	0.78
Sorghum + Maize as border crop	0.10	0.10	0.06	0.20	0.25	0.00	0.56	0.27	0.10	0.50	0.35	0.05	0.50	0.20	0.37
Sorghum + Napier grass as border crop	0.50	0.35	0.00	0.97	0.50	0.50	1.00	1.10	0.15	1.33	0.10	0.25	1.53	0.07	1.60
T_1+Napier grass as border crop	0.50	0.45	0.60	1.23	0.85	0.15	1.00	1.60	0.25	1.83	1.50	0.85	2.05	1.23	2.37
T_2+Napier grass as border crop	0.25	0.32	0.41	1.17	0.75	0.25	0.73	1.37	0.00	1.57	1.20	0.55	1.75	1.00	2.23
T_1+Maize as border crop	0.15	0.10	0.00	0.27	0.35	0.15	0.85	1.00	0.33	1.87	0.80	15	1.35	0.25	0.32
T_2+Maize as border crop	0.10	0.13	0.00	0.15	0.45	0.00	0.90	1.03	0.20	0.93	1.15	0.10	0.65	0.10	0.40
Sole Sorghum	0.07	0.10	0.00	0.10	0.05	0.10	0.30	0.57	0.00	0.77	0.50	0.05	0.77	0.10	0.33
S.Em±	0.01	0.01	0.01	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.04	0.06	0.06	0.06
C.D. (0.05)	0.04	0.05	0.05	0.06	0.07	0.06	0.13	0.14	0.12	0.15	0.14	0.12	0.19	0.18	0.19
C.V. %	8.65	8.12	8.56	10.03	9.05	8.63	11.23	10.21	9.60	8.34	9.42	8.16	9.85	8.10	8.58

*DAE: Days after emergence

to high mortality rates (Khan *et al*., 2006; Midega *et al*., 2011). High mortality rate of stem-borer larvae on napier grass is attributed to the sticky sap that the grass produces in response to attacks by first and second instar larvae Khan *et al*. (2000). Additionally, this system increases the abundance, diversity and predatory arthropods activity, further helping to reduce pest populations. Trap/border plants emit semiochemicals that attracts gravid female moths, while intercrops emits semiochemicals that deter egg-laying on the main crop and attract natural enemies of the pests (Chamberlain *et al*., 2007). Analysis of volatile chemicals from trap plants, specifically napier grass, using gas chromatography coupled with electroantennography (GC-EAG) on the antennae of stem borers identified the key compounds responsible for attracting gravid moths (Khan *et al.*, 2000). These compounds included hexanal, (E)-2-hexenal, (Z)-3-hexen-1-ol, and (Z)-3-hexen-1-yl acetate.

Mugwe *et al*. (2011) showed that cowpea and groundnuts contribute significantly to soil nitrogen levels, with cowpea adding between 9-125 kg/ha and groundnuts adding between 27-206 kg/ha. Intercropping maize with legumes often results in increased light interception by the intercrops, reduced water evaporation and improved soil moisture conservation compared to growing maize alone (Ghanbari *et al*., 2010). The higher levels of $NH4^{+}$ and NO^{3-} in the legume-intercropped plots compared with non-legume plots may be attributed to the nitrogen-fixing potential of legumes (Gabasawa *et al*., 2016). Intercropping maize with legumes like cowpea, french bean, soybean, red gram and green gram promotes the increase of natural enemies of the fall armyworm (FAW), helping to manage FAW populations in cereal fields (Reddy *et al*., 2019). Intercropping has been observed to increase parasitism of FAW by braconids and tachinids (Harrison *et al*., 2019).

Conclusion

The utilization of intercrops and trap/border crops showed significantly lower egg masses, larval population and leaf damage score in treatments consisting of sorghum intercropped with french bean and napier grass as border crop followed by sorghum intercropped with coriander along with napier grass as border crop. Whereas, higher number of larvae and leaf injury was noticed in sorghum sole crop. Similarly, higher grain and fodder yield as well as maximum natural enemies were recorded in sorghum +french bean +napier grass treatment which was superior over other treatments.

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