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RESEARCH ARTICLE

Reducing the incidence of Fall Army Worm (FAW) in irrigated maize (*Zea mays* L.) through intercropping systems

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Abstract

Pest management strategies involving intercropping systems are being developed in different research stations. However, findings on location specific management are very limited. In order to address these problems and enhance maize productivity by identifying location specific strategies, field experiments were conducted at the Department of Millets, Tamil Nadu Agricultural University, Coimbatore during *kharif*, 2020 and *rabi*, 2020-21 to reduce the incidence of FAW in irrigated maize through different intercropping systems in sandy clay loam soil. The experiments consisted of 5 treatments *viz*., T_1- Maize + Tephrosia, T_2- Maize + Fenugreek, T_3- Maize + Coriander, T_4- Maize + Marigold and T_5- Maize alone and these were laid out in a Randomized Complete Block Design (RCBD) with 3 replications. On the border of experimental field, a row of Bajra Napier Hybrid grass was planted to study the influence on FAW. The results of experiments revealed that the T_4- Maize + Marigold treatment was superior in reducing the incidence of FAW in irrigated maize among the different intercropping systems owing to the occurrence of natural enemies and repelling nature of marigold which recorded higher maize equivalent yield of 6089 kg ha^{-1} with a B:C ratio of 1.84. This system of intercropping should be adopted by the farming community to reduce the incidence of FAW in maize as it is an eco friendly approach, which sustains the productivity of maize.

Keywords

maize; intercropping systems; FAW; yield

Introduction

Maize (*Zea mays* L.) occupies a prime position in India among cereals in respect of area and production next to rice and wheat. It is an all season crop grown throughout the year in most places due to its adaptability to thrive under diverse environment (1). It is regarded as the "queen of cereals" due to its highest genetic yield potential, which is the outcome of genetic makeup, management techniques or practices and environmental interactions (2). Significant efforts are being made by the scientists and research scholars across India to exploit the yield potential of maize. Nevertheless, productivity in India is low compared to other dominant maize growing countries, which is attributed to climatic factors *viz*., intensity, duration and distribution of rainfall, temperature, relative humidity, edaphic factors, frequent occurrence of pests and diseases and dominance of weeds. Among the different pests of maize, Fall Army Worm (FAW), *Spodoptera frugiperda*, is migratory in nature and native to tropical and subtropical America. It was observed for the first time in India in 2018 (3) and spread rapidly to other Asian countries. FAW is a polyphagous pest that has caused severe damage to different kinds of plant species (4-6). Maize is one of the most important crop, which continues to be affected by FAW, resulting in drastic reduction in productivity (7). Newer molecules of insecticides *viz.*, Chlorantraniliprole, Emamectin Benzoate., etc. are recommended to reduce the incidence of FAW in maize (8). However, this method of chemical control involves high costs, besides causing environmental contamination. Frequent usage of pesticides might result in the development of resistance in FAW, reducing effectiveness and leading to the buildup of secondary pests. Location-specific and cost-effective management strategies are required for sustainable management of FAW which is more appropriate for small and marginal farmers thus solving problems encountered in chemical control (9). Multivarious cost effective management approaches *viz.*, cultural, mechanical, botanical, intercropping systems, etc. are available for managing FAW. Among them, intercropping systems involving leguminous and non leguminous crops is a promising approach to mitigate the incidence of FAW in maize. Intercropping of scented plants *viz.*, fennel, coriander, rose and marigold in maize attracted several natural enemies thus reduced the incidence of FAW (10). A greater diversity of natural enemies was observed in intercropping systems compared to monocropping, leading to reduction in pest incidence (11). In this context, this study was conducted to reduce the incidence of FAW in irrigated maize through different intercropping systems.

Materials and Methods

Field experiments were conducted at the Department of Millets, Tamil Nadu Agricultural University, Coimbatore, with geographical coordinates approximately 11.0086°N latitude and 76.09385°E longitude during *kharif*, 2020 and *rabi*, 2020-21 to reduce the incidence of FAW in irrigated maize through different intercropping systems. The texture of the soil was sandy clay loam with low available Nitrogen (229 kg/ha), medium availability of Phosphorus (19 kg/ha) and high availability of Potassium (498 kg/ha). The soil was saline, with a pH of 8.19.

The treatments *viz.*, T_1- Maize + Tephrosia, T_2- Maize + Fenugreek, T_3- Maize + Coriander, T_4- Maize + Marigold and T_5-Maize alone, were laid out in Randomized Complete Block Design (RCBD) with 3 replications. Maize hybrid COH (M) 6 and other intercrops such as *Tephrosia purpurea* (Wild indigo), ***Trigonella foenum-graecum*** (Fenugreek), *Coriandrum sativum* (Chinese parsley) and *Tagetes erecta* (Marigold) were sown in an area of 0.203 acres with a plot size of 9 × 6 m during *kharif* and *rabi* season. Three hundred rooted slips of Bajra Napier Hybrid grass were planted as a border crop around intercropped field to attract FAW. Maize and other intercrops, surrounded by Bajra Napier Hybrid grass, helped push FAW away. Cultural operations from sowing to harvest and post-harvest operations, were conducted based on the Crop Production Guide formulated by TNAU in collaboration with State Department of Agriculture (12). Observations on percent plant infestation and attack intensity on a scale of 1-9 (13), in maize at 20, 30 and 40 DAS (Days after sowing), tassel damage and yield data were recorded. The recorded observations were statistically analyzed and critical differences were worked out at 5 % probability level (14).

Results and Discussion

Infestation of FAW in maize as influenced by intercropping systems

The results of experiments conducted during *kharif*, 2020 and *rabi*, 2020-21(Table 1and Fig. 1) and the combined data from both years indicate that different intercropping systems did not significantly affect the incidence of FAW on 20, 30 and 40 DAS regarding plant infestation. However, lower FAW incidence was recorded in the Maize + Tephrosia (T_1) intercropping system compared to others, with 57.1 % infestation at 20 DAS and 52.1 % at 30 DAS. At 40 DAS, the Maize + Marigold intercropping system recorded the lowest FAW incidence at 78.8 %. This could be due to intercropping of pest repelling or deterring crops such as Tephrosia and Marigold with maize and pest attracting or pulling crop *viz.*, Bajra Napier Hybrid grass as a border crop around the intercropped field. These results align with the findings of previous studies (15-17).

Intercropping systems did not exert significant influence on FAW incidence in maize at 20, 30 and 40 DAS as per Davis scale in both the years which was also in accordance with the mean data of 2 years (Table 2). Lower FAW incidence of 4.3 and 3.9 was observed with Maize + Tephrosia intercropping on 20 DAS and 30 DAS respectively. On the other hand, at 40 DAS, Maize + Marigold intercropping system recorded lower FAW incidence of 5.8. This might be due to release of volatile chemicals from intercrops which helped in repelling FAW and reduced its incidence. These results are consistent with previous findings (18-20). Sole cropping of maize (T_5-Maize alone) recorded higher incidence of FAW at 20, 30 and 40 DAS in respect of percent plant infestation and also as per the Davis scale. The results are corroborating with the findings of previous research (8) which reported that 36 % FAW infestation was observed in intercropped maize as compared to 95 % FAW infestation in sole cropping of maize.

With respect to tassel and cob damage score (Table 3), the Maize + Marigold intercropping system recorded the lowest damage of 49.5 % and 1.8 % respectively. This might be ascribed to occurrence of more number of natural enemies *viz.*, ground beetle, earwig, spider, flower bug, etc. resulting in reduced incidence of pest. This aligns with the previous findings (21-23). Sole cropping of Maize (T5) exhibited higher tassel and cob damage score of 65.9 % and 2.8 % respectively at harvest.

Yield attribute and yield

The various intercropping systems did not significantly influence the 100 seeds weight of maize during *kharif*, 2020 and *rabi*, 2020-21 which was reflected in the mean data also. Nevertheless, among different intercropping system, higher test weight of 38.4 g was recorded in Maize + Marigold intercropping system (Table 4).

Intercropping systems exerted significant effect on grain and stover yield of maize in both the years. Maize + Marigold intercropping system recorded the higher grain yield, of 4545 kg ha^{-1} and 4428 kg ha^{-1} during *kharif*, 2020 and *rabi*, 2020-21 respectively, with a combined mean yield of 4487 kg

Table 1. Infestation of FAW in maize as influenced by intercropping systems

Treatments	% Plant infestation (20 DAS)			% Plant infestation (30 DAS)			% Plant infestation (40 DAS)		
	Kharif, 2020	*Rabi*, 2020-21	Mean	*Kharif*, 2020	*Rabi*, 2020-21	Mean	*Kharif*, 2020	*Rabi*, 2020-21	Mean
T_1	56.5	57.7	57.1	54.1	50.0	52.1	83.9	81.2	82.6
T_2	64.2	65.0	64.6	60.8	61.7	61.3	78.3	79.5	78.9
T_3	58.7	60.0	59.4	60.8	65.0	62.9	87.2	85.1	86.2
T_4	59.8	63.3	61.6	63.0	66.7	64.9	78.3	79.2	78.8
T_5	68.7	70.0	69.4	77.5	80.0	78.8	88.3	90.1	89.2
CD(P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS-Non significant

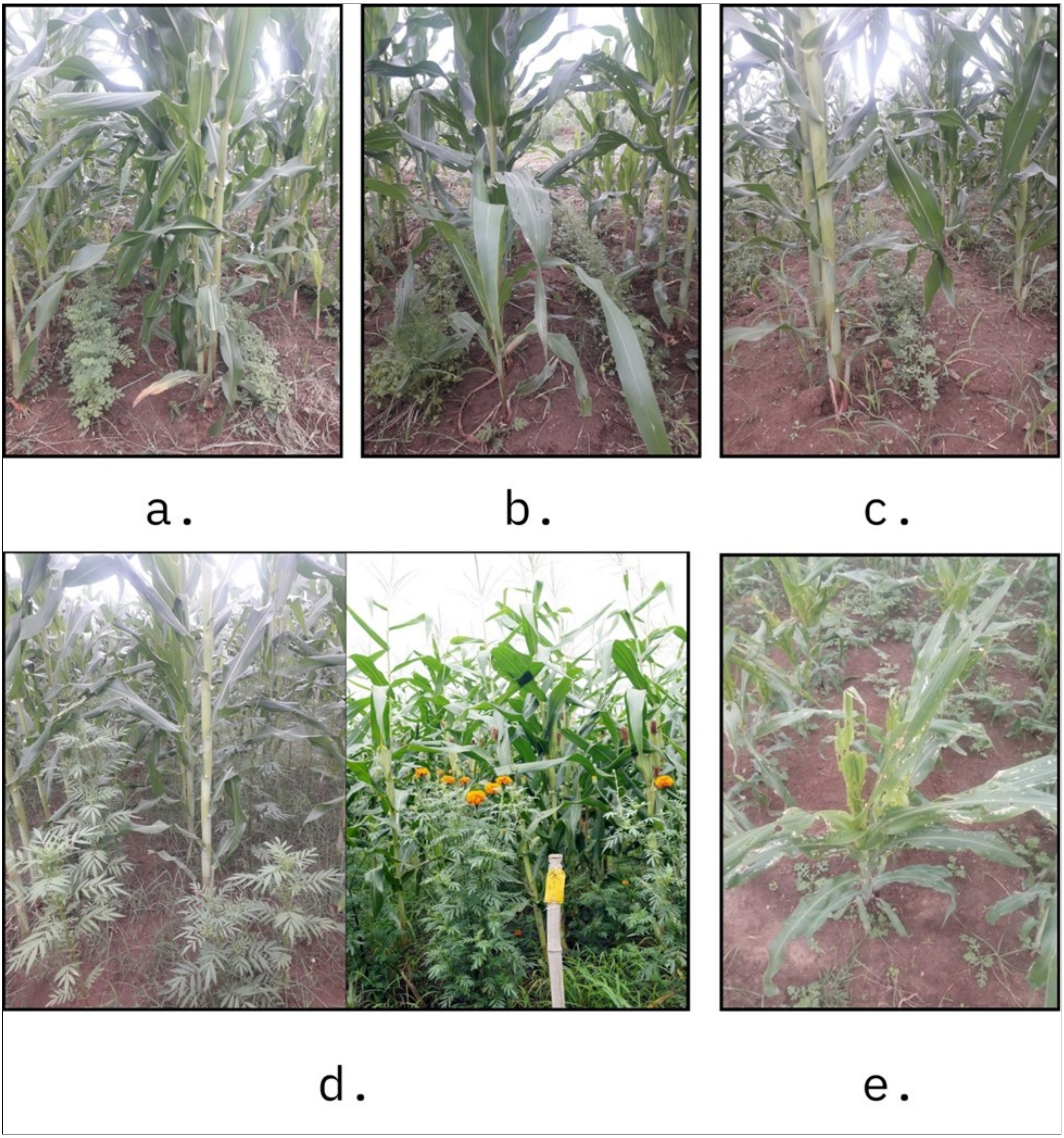

Fig. 1. Shows the effect of intercropping of maize with (a) tephrosia, (b) coriander, (c) fenugreek, (d) marigold and (e) maize alone as control on the infestation of FAW.

Table 2. Effect of intercropping systems on incidence of FAW as expressed by Davis Scale

Treatments	Davis Scale (20 DAS)			Davis Scale (30 DAS)			Davis Scale (40 DAS)		
	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**
T_1	4.4	4.2	4.3	4.0	3.8	3.9	6.8	6.1	6.5
T_2	4.6	4.5	4.5	3.8	3.9	3.9	5.6	5.6	5.6
T_3	4.4	4.1	4.3	5.2	5.4	5.3	6.2	6.4	6.3
T_4	5.1	5.3	5.2	4.9	5.2	5.1	5.7	5.8	5.8
T_5	5.8	5.6	5.7	5.6	5.5	5.6	6.6	6.5	6.6
CD(P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS-Non significant

Table 3. Effect of intercropping systems on Tassel damage and Cob damage score (at harvest) in maize

Treatments	% Tassel damage			Cob damage score (at harvest)		
	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**
T_1	52.2	50.0	51.1	2.3	2.2	2.3
T_2	60	61.7	60.9	2.1	2.4	2.3
T_3	58.9	60.0	59.5	2.2	2.3	2.3
T_4	48.9	50.0	49.5	1.6	1.9	1.8
T_5	66.7	65.0	65.9	2.6	2.9	2.8
CD(P=0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

NS-Non significant

Table 4. Effect of intercropping systems on yield attribute and yield of maize

Treatments	100 seed weight (g)			Grain yield – Maize (kg/ha)			Stover yield (kg/ha)		
	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**	***Kharif*, 2020**	***Rabi*, 2020-21**	**Mean**
T_1	37.6	38.6	38.1	4173	4091	4132	7256	7013	7135
T_2	37.7	39.5	38.6	3819	3796	3808	6484	6366	6425
T_3	37.3	38.1	37.7	3928	3884	3906	6706	6568	6637
T_4	37.5	39.3	38.4	4545	4428	4487	7853	7664	7759
T_5	38.1	37.9	38.0	3638	3602	3620	6092	5993	6043
CD(P=0.05)	**NS**	**NS**	**NS**	**547**	**508**	**517**	**933**	**702**	**798**

NS-Non significant

ha^{-1}. Although this system was on par with Maize + Tephrosia, it demonstrated significant superiority over other systems. The higher yield could be due to presence of Ichneumonids, braconids and other natural enemies and repelling nature of intercrop due to the release of volatile compounds, which reduced FAW incidence. These findings are consistent with previous research (24-26). In contrast, sole maize cropping (T_5-maize alone) recorded lower yields, with 3638 kg ha^{-1} in *kharif* 2020 and 3602 kg ha^{-1} in *rabi* 2020-21 with a mean of 3620 kg ha^{-1} attributed to severe FAW infestation. With respect to stover yield of maize, higher stover yield was observed with Maize + Marigold intercropping system which recorded a mean yield of 7759 kg ha^{-1}. This was on par with Maize + Tephrosia intercropping system. In both the years, maize alone (T_5) recorded lower stover yield of maize, which was ascribed to severe infestation of FAW. The results are in accordance with the findings of earlier studies (27, 28).

Yield of intercrops and economics

Among different intercrops, Marigold registered higher yield of 4904 kg ha^{-1}, and 4712 kg ha^{-1} during *kharif*, 2020 and *rabi*, 2020 -21, respectively with a mean yield of 4808 kg ha^{-1} (Table 5). The higher yield is likely due to the lower FAW incidence facilitated by the volatiles produced by Marigold, which attract natural enemies (29-31). This trend was also observed in the maize equivalent yield, where the Maize + Marigold intercropping system produced a significantly higher equivalent yield in both the years among other intercropping systems with a mean of 6089 kg ha^{-1}.

With respect to economics of different intercropping systems in maize (Table 6 and 7), Maize + Marigold intercropping system recorded higher gross return (Rs. 99094/ ha), net return (Rs. 45124/ha) and B:C ratio (1.84). This was followed by Maize + Tephrosia intercropping. Sole cropping of maize registered lower net return (Rs. 20217/ha) and B: C ratio (1.50).

Conclusion

The results of the experiments revealed that the Maize + Marigold intercropping system was superior in reducing the incidence of FAW in irrigated maize among different intercropping systems. It recorded a higher maize equivalent yield of 6089 kg ha^{-1} with a B: C ratio of 1.84. 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.

Looking ahead, future research should focus on expanding these findings by testing various intercropping systems in different environments and studying the defensive phytochemicals involved. The role of edaphic factors is also to be studied to confirm their impact. Additionally, investigating a wider range of companion plants and their interactions with FAW will provide more options for integrated pest management. Long-term studies assessing the sustainability and economic viability of intercropping strategies will be crucial for widespread adoption. Moreover, educating farmers about the benefits and practical implementation of these systems will help in promoting sustainable pest management

Table 5. Yield of intercrops and maize equivalent yield of intercrops as influenced by intercropping systems

Treatments	Yield of intercrops (kg/ha)			Maize equivalent yield of intercrops (kg/ha)			Equivalent yield of maize + intercropping system (kg/ha)		
	Kharif, 2020	*Rabi*, 2020-21	Mean	*Kharif*, 2020	*Rabi*, 2020-21	Mean	*Kharif*, 2020	*Rabi*, 2020-21	Mean
T_1	72	61	67	720	610	665	4893	4701	4797
T_2	105	97	101	280	259	270	4099	4055	4077
T_3	162	149	156	324	318	321	4252	4202	4227
T_4	4904	4712	4808	1635	1570	1603	6180	5998	6089
T_5	0	0	0	0	0	0	3638	3602	3620
CD(P=0.05)	**229**	**236**	**NS**	**102**	**131**	**113**	**538**	**482**	**504**

NS-Non significant

Table 6. Effect of various intercropping systems on economics of maize

Treatments	Gross return (Rs./ha)			Net return (Rs./ha)			B:C ratio		
	Kharif, 2020	*Rabi*, 2020-21	Mean	*Kharif*, 2020	*Rabi*, 2020-21	Mean	*Kharif*, 2020	*Rabi*, 2020-21	Mean
T_1	80651	77533	79092	36,575	33457	35016	1.83	1.76	1.80
T_2	67969	67186	67578	24,643	23860	24252	1.57	1.55	1.56
T_3	70486	69598	70042	26,760	25872	26316	1.61	1.59	1.60
T_4	100553	97634	99094	46,583	43664	45124	1.86	1.81	1.84
T_5	60662	60023	60343	20,536	19897	20217	1.51	1.49	1.50

NS-Non significant

Table 7. Cost and price of inputs and outputs

Sl. No.		Rs/kg
	Cost of seed	
1	Maize	150
2	Tephrosia	150
3	Fenugreek	100
4	Coriander	100
5	Marigold	0.20/seedling
	Manures and Fertilizers	
6	Farm Yard Manure	3000/ton
7	Urea	5.50
8	Single Super Phosphate	7.60
9	Muriate of Potash	17
10	Azospirillum	8/200 g
11	Phosphobacteria	8/200 g
	Price of grain	
12	Maize	15
13	Tephrosia	150
14	Fenugreek	40
15	Coriander	30
16	Marigold	5
17	Maize stover	1

practices, ultimately leading to more resilient agricultural systems.

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Authors' contributions

APS and AS were responsible for conducting field experiments, preparation and communication of manuscript. SP has conceptualized the work and provided guidance for the experiments and VM, MR and CB have provided the study materials, reviewed and edited the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Adhikari K, Bhandari S, Aryal K, Mahato M, Shrestha J. Effect of different levels of nitrogen on growth and yield of hybrid maize (*Zea mays* L.) varieties. J Agric Nat Resources. 2021;4(2):48-62. https://doi.org/10.3126/janr.v4i2.33656
2. Jeyaraman S. Field crops production and management. New Delhi: Oxford and IBH Publishing Co. Pvt Ltd. 2017;1:74-75.
3. Sharanabasappa D, Kalleshwaraswamy CM, Asokan R. First report of the fall armyworm, *Spodoptera frugiperda* (J E Smith) (Lepidoptera: Noctuidae), an alien invasive pest on maize in India. Pest Manag Horti Eco. 2018;24:23-29. https://www.cabidigitallibrary.org/doi/full/10.5555/20183320211
4. Goergen G, Kumar PL, Sankung SB, Togola A, Tamo M. First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. PLoS. 2016;1:46-52.
5. Roger DA, Melanie BP, Tim B, Victor C, Matthew C, Yelitza C. Fall armyworm: Impacts and implications for Africa. Outlooks on Pest Manage. 2017;28(5):196-201.
6. Montezano DG, Specht A, Sosa-Gómez DR. Host plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. Afr Entomol. 2018;26:286-300. https://doi.org/10.4001/003.026.0286
7. Hassanali A, Herren H, Khan ZR, Pickett JA, Woodcock CM. Integrated pest management: The push-pull approach for controlling insect pests and weeds of cereals and its potential for other agricultural systems including animal husbandry. Philos Trans Lon B Soc Biol Sci. 2008;363:611-21. https://doi.org/10.1098/rstb.2007.2173
8. Assefa F, Ayalew D. Status and control measures of fall armyworm

(*Spodoptera frugiperda*) infestations in maize fields in Ethiopia: A review. Cogent Food and Agriculture. 2019;5(1):1641902. https://doi.org/10.1080/23311932.2019.1641902

9. Chormule A, Deshmukh S, Shejawal N, Kalleshwaraswamy C, Asokan R, Mahadeva SH. First report of the Fall Armyworm, *Spodoptera frugiperda* (Lepidoptera, Noctuidae) on sugarcane and other crops from Maharashtra, India. J Ento Zoo Stu. 2019;7(1):114-17.
10. Ipsita S, Bhupen KS. Fall army worm: Current status and management in India. Journal of Entomology and Zoology Studies. 2020;8(3):330-34.
11. Liu H, Cheng YM, Wang C. Push-pull plants in wheat intercropping system to manage *Spodoptera frugiperda*. J Pestic Sci. 2022;1-15. https://doi.org/10.1007/s10340-022-01547-8
12. TNAU crop production guide, Tamil Nadu Agricultural University, Coimbatore. 2019; 48.
13. Davis F, Williams W. Visual rating scales for screening whorl-stage corn for resistance to fall armyworm. Technical Bulletin: Mississippi State University, USA. 1992;186:MS39762.
14. Gomez KA, Gomez AA. Statistical procedures for agricultural research: John Wiley and Sons. 2010;54.
15. Midega CAO, Pittchar JO, Pickett JA, Hailu GW, Khan ZR. A climate-adapted push-pull system effectively controls fall armyworm, *Spodoptera frugiperda* (J E Smith) in maize in East Africa. Crop Protect. 2018;105:10-15.
16. Guera OGM, Castrejon-Ayala F, Robledo N, Jimenez-Perez A, Sanchez-Rivera G, Salazar-Marcial L, Flores Moctezuma HE. Effectiveness of push-pull systems to fall armyworm (*Spodoptera frugiperda*) management in maize crop in Morelos, Mexico. Insects. 2021;12:298. https://doi.org/10.3390/insects12040298
17. Maryam Yousefi, Riho Marja, Elias Barmettler, Johan Six, Anne Dray, Jaboury Ghazoul. The effectiveness of intercropping and agri-environmental schemes on ecosystem service of biological pest control: A meta-analysis. Agronomy for Sustainable Development. 2024;44:15. https://doi.org/10.1007/s13593-024-00947-7
18. Midega CAO, Toby JAB, Pickett JA, Pittchar JO, Murage A, Khan ZR. Climate-adapted companion cropping increases agricultural productivity in East Africa. Field Crops Res. 2015;180:118-25.
19. Early R, Gonzalez-Moreno P, Murphy ST, Day R. Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm. Neo Biota. 2018;40:25-50. https://doi.org/10.3897/neobiota.40.28165
20. Zeng H, Yu LL, Liu P. Nitrogen fertilization has a stronger influence than cropping pattern on AMF community in maize/soybean strip intercropping systems. Appl Soil Ecol. 2021;2:67-73.
21. Gabriela Murúa M, Molina-Ochoa J, Fidalgo P. Natural distribution of parasitoids of larvae of the fall armyworm, *Spodoptera frugiperda*, in Argentina. J Insect Sci. 2009;9:1-17. https://doi.org/10.1673/031.009.2001
22. Harrison RD, Thierfelder C, Baudron F, Chinwada P, Midega C, et al. Agro-ecological options for fall armyworm (*Spodoptera frugiperda*) management: Providing low-cost, small holder friendly solutions to an invasive pest. J Environ Manag. 2019;243:318-30. https://doi.org/10.1016/j.jenvman.2019.05.011
23. Kumela T, Mendesil E, Enchalew B, Tefera T. Effect of the push-pull cropping system on maize yield, stem borer infestation and farmer's perception. Agronomy. 2019;9:452. https://doi.org/10.3390/agronomy9080452
24. Hailu G, Niassy S, Khan RZ, Ochatum N, Subramanian S. Maize-legume intercropping and push-pull for management of fall armyworm, stem borers and striga in Uganda. Agron J. 2018;110:1-10. https://doi.org/10.2134/agronj2018.02.0110
25. Haftay GG, Fissiha GG. Effect of integrating night-time light traps and push-pull method on monitoring and deterring adult fall armyworm (*Spodoptera frugiperda*). Intl J Ento Res. 2020;5(1):28-32.
26. Gahatraj S, Tiwari S, Sharma L, Kafle S. Fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae): A recent threat and future management strategy in Nepal. Agrl Sci Tech. 2020;12(2):157-64. https://doi.org/10.15547/ast.2020.02.027
27. Ndayisaba PC, Kuyah S, Midega CAO, Mwangi PN, Khan ZR. Push-pull technology improves maize grain yield and total above ground biomass in maize-based systems in Western Kenya. Field Crop Res. 2020;256:1-12. https://doi.org/10.1016/j.farsys.2023.100020
28. Suby SB, Soujanya1 PL, Yadava P, Patil J, Subaharan K, Prasad GS, et al. Invasion of fall armyworm (*Spodoptera frugiperda*) in India: Nature, distribution, management and potential impact. Curr Sci. 2020;119(1):44-51. https://doi.org/10.18520/cs/v119/i1/44-51
29. Khan ZR, Amudavi DM, Midega CAO, Wanyama JW, Pickett JA. Farmer's perceptions of a 'push-pull' technology for control of cereal stem borers and striga weed in Western Kenya. Crop Protection. 2008;27:976-87.
30. Khan Z, Midega C, Pittchar J, Pickett J, Bruce T. Push-pull technology: A conservation agriculture approach for integrated management of insect pests, weeds and soil health in Africa. Int J Agri Sust. 2011;9(1):162-70.
31. Zhou Y, Wu QL, Zhang HW. Spread of invasive migratory pest *Spodoptera frugiperda* and management practices throughout China. J Integr Agric. 2021;20:637-45. https://doi.org/10.1016/S2095-3119(21)63621-3