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SEASONAL DYNAMICS OF FALL ARMYWORM AND IMPACT OF BORDER CROP IN MAIZE ECOSYSTEMS

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ABSTRACT

The fall armyworm (*Spodoptera frugiperda*), a highly polyphagous and invasive lepidopteran pest, was investigated over two cropping seasons *Rabi* 2021 and pre-*Kharif* 2022 to study its population dynamics and the influence of prevailing meteorological factors in maize ecosystems. Field observations revealed larval densities ranging from 0.30 to 0.44 larvae/plant, with infestation levels between 23.10 and 33.77%. Natural regulation of the pest was recorded through parasitization by two larval parasitoids, *Campoletis chlorideae* (Hymenoptera: Ichneumonidae) and *Exorista xanthaspis* (Diptera: Tachinidae), along with infection by the entomopathogenic fungus *Metarhizium rileyi*. Correlation and regression analyses indicated that fluctuations in pest population were significantly influenced by key weather parameters. The introduction of Napier as a border crop effectively reduced the populations of major pests like FAW, while enhancing the abundance of beneficial predators such as coccinellid beetles and spiders. These findings aid in developing ecologically based pest management strategies for maize ecosystems.

Key words : *Spodoptera frugiperda*, Maize, Predators, Parasitoids, Entomopathogenic fungus, Population dynamics, Correlation coefficients, Hybrid napier, Parasitization, Pest management.

Introduction

Maize (*Zea mays*) is a vital cereal crop, serving as both human food and animal fodder. Despite increased cultivation in India, productivity remains below the global average, largely due to biotic and abiotic constraints—among which insect pests are the most significant (Ngoko *et al.*, 2002). Over 141 insect species are known to damage maize from sowing to harvest (Reddy & Trivedi, 2008). The fall armyworm (*Spodoptera frugiperda*), recently reported as an invasive pest in Karnataka (Sharanabasappa *et al.*, 2018), poses a threat of rapid spread to neighboring Indian states and other Asian countries due to its high migratory capacity. Understanding the pest's ecology under varied agro-climatic conditions is essential for identifying vulner*abi*lities in its life cycle and formulating effective management strategies (Fand et al., 2018). In this context, the population dynamics of *S. frugiperda* and its natural enemies were examined in relation to prevailing weather conditions.

Materials and Methods

The investigation into the seasonal incidence of *S. frugiperda* (J.E. Smith) and its associated natural enemies was carried out at the Central Research Farm, Gayeshpur (22.9554°N, 88.4961°E), Bidhan Chandra Krishi Viswavidyalaya. The study utilized the maize hybrid cultivar P3396, sown in 20 m² plots (5 × 4 m) with inter-row and intra-row spacings of 50 cm and 30 cm, respectively. The experimental layout followed a

randomized block design with three replications for each of two cropping seasons: *Rabi* 2021 and pre-*Kharif* 2022. Standard agronomic practices were adhered to throughout the trial, with the deliberate exclusion of chemical pest management to facilitate natural infestation dynamics. In a parallel treatment, maize was cultivated with hybrid Napier grass as a border crop under identical agronomic and experimental conditions.

Weekly observations of *S. frugiperda*, associated pests, and natural enemies were recorded on ten randomly selected plants from each plot (four corners and center), beginning three weeks after sowing until harvest. Larvae were periodically collected from maize plots at the Central Research Farm, Gayeshpur, and reared in the laboratory to assess parasitization. Emerged parasitoids were preserved in 70% ethyl alcohol and identified using standard taxonomic references. Population data were correlated with meteorological parameters—maximum and minimum temperatures (°C), relative humidity (%), and rainfall (mm)—sourced from the Department of Agrometeorology and Physics, Mohanpur, West Bengal.

Results and Discussion

Occurrence of insect pests on maize and associated natural enemies

In new alluvial zone of West Bengal, six species of insect pests, fourteen species of parasitoids and predators and two species of fungi and one bacterial infection as natural enemies were encountered on maize in *Rabi* and Pre *kharif* season during 2021-2022.

Seasonal incidence of *S. frugiperda* and other major insect pests and natural enemies on maize in relation to abiotic factors

The population trends of *S. frugiperda*, *Chilo partellus*, *Aleurodicus rugioperculatus*, grasshoppers, *Spodoptera litura*,*Helicoverpa armigera*and natural enemies (coccinellid beetles and spiders) during the *rabi* and pre-*Kharif* season, along with their correlations with meteorological parameters, are presented in Tables 1and 2, Figures 1 and 2 respectively.

Rabi season, 2021

FAW infestation was first detected at the 3–4 leaf stage during the 44th SMW (4th week of October), with a population of 3.22 larvae/plant, peaking at 4.67 larvae/plant in the 45th SMW, followed by a steady decline until harvest. FAW population showed a significant positive correlation with maximum temperature (r = 0.761**) and minimum temperature (r = 0.441), and a significant negative correlation with maximum relative humidity (r = –0.798**). *C. partellus* incidence began in the 44th SMW (2.44 larvae/plant), persisted at low levels through the season, with the lowest count (0.22 larvae/plant) in the 49th SMW. Grasshopper populations ranged between 3.44 and 6.11 insects/plant, peaking in the 45th SMW and reaching a minimum in the 49th SMW (Table 1). Though correlations were not statistically significant, there population showed a positive trend with temperature and a negative association with humidity. *A. rugioperculatus* appeared in the 44th SMW (2.83/plant), fluctuated throughout the season, and peaked again during the 51st SMW (2.11/plant). Its population was significantly and positively correlated with maximum temperature (r = 0.781**) and negatively with relative humidity (r = –0.763**), accounting for 82% of population variability.

Populations of *S.litura* and *H. armigera* were observed between the 44th and 46th SMWs, with peak densities of 2.28 and 1.56 larvae/plant, respectively. Both species declined sharply thereafter. *S. litura* showed a significant positive correlation with maximum temperature (r = 0.726*) and a negative correlation with relative humidity (r = –0.703*), a pattern mirrored by *H. armigera*. Among natural enemies, coccinellid beetle populations ranged from 4.26 to 6.50/plot, with peak abundance in the 44th SMW. Spider populations remained consistent across the season (3.22–5.83/plot), with the highest counts during the 52nd SMW. Correlation with weather parameters was non-significant(Table 1).

Pre-*kharif* season, 2022

FAW was first observed at the 3–4 leaf stage in the 8th SMW (late February) with 2.44 larvae/plant, peaking at 3.44 larvae/plant in the 14th SMW, followed by a sharp decline to 0.78 larvae/plant by the 15th SMW. Its population showed significant negative correlations with both maximum (r = –0.868**) and minimum temperatures (r = –0.748**), and a significant positive correlation with relative humidity (r = 0.844**). *C. partellus* appeared concurrently in the 8th SMW (2.33 larvae/plant), with a peak of 2.50 larvae/plant in the 9th SMW and a decline to near zero by the 17th SMW. The population showed significant negative correlations with maximum (r = –0.909**) and minimum temperatures (r = –0.721*), and a positive correlation with relative humidity (r = 0.742**).Grasshopper populations ranged from 4.33 to 6.67 insects/plant, peaking in the 11th SMW. Though correlations were non-significant, weak positive associations with all-weather variables were observed (Table2).

The *A. rugioperculatus* maintained a continuous presence throughout the crop season, with a peak of 5.54/plant in the 14th SMW. Its population was significantly

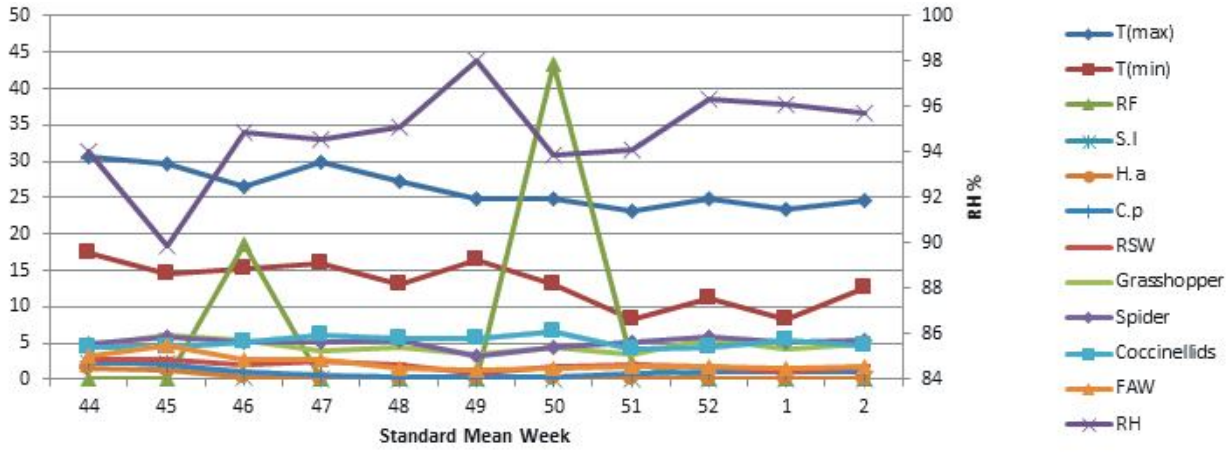

Fig. 1 : Seasonal incidence of FAW and other insect pests on Maize, *Rabi*- 2021.

Table 1 : Correlation of maize insect pests and natural enemies with weather parameters (*Rabi* 2021).

Insect pests/ Natural enemies	Temp Max. (X_1)	Temp min. (X_2)	R.F. (X_3)	RH Max. (X_4)	Coccine-llids	Spiders	R^2	Regression equation
S. frugiperda	0.761**	0.441^{NS}	-0.171^{NS}	-0.798**	-0.401^{NS}	0.438^{NS}	0.87	$40.834 + (-0.014)X_1 + 0.142X_2 + (-0.022)X_3 + 0.422X_4$
C. partellus	0.538^{NS}	0.244^{NS}	-0.231^{NS}	-0.582^{NS}	-0.671*	-0.519^{NS}	0.48	$19.323 + 0.017X_1 + 0.039X_2 + (-0.015)X_3 + (-0.202)X_4$
RSW	0.781**	0.363^{NS}	-0.069^{NS}	-0.763**	-0.328^{NS}	0.544^{NS}	0.82	$6.756 + 0.227X_1 + (-0.080)X_2 + 0.004X_3 + (-0.103)X_4$
S. litura	0.726*	0.485^{NS}	-0.192^{NS}	-0.703*	-0.486^{NS}	0.224^{NS}	0.78	$35.353 + (-0.084)X_1 + 0.185X_2 + (-0.024)X_3 + (-0.369)X_4$
H. armigera	0.722*	0.488^{NS}	-0.181^{NS}	-0.639*	-0.495^{NS}	0.216^{NS}	0.68	$16.945 + (-0.008)X_1 + 0.088X_2 + (-0.012)X_3 + (-0.185)X_4$
Grasshopper	0.372^{NS}	0.168^{NS}	0.059^{NS}	-0.561^{NS}	-0.408^{N}	0.673*	0.33	$28.207 + (-0.026)X_1 + 0.053X_2 + (-0.002)X_3 + (-0.249)X_4$
Coccinellids	-0.029^{NS}	0.223^{NS}	0.555^{NS}	0.314^{NS}	-	-	0.60	$-31.055 + 0.252X_1 + (-0.108)X_2 + 0.048X_3 + 0.324X_4$
Spiders	0.206^{NS}	-0.329^{NS}	-0.258^{NS}	-0.506^{NS}	-	-	0.62	$3.450 + 0.279X_1 + (-0.265)X_2 + (-0.001)X_3 + (-0.023)X_4$

*Significant at the 0.05 level (2-tailed), ** significant at the 0.01 level (2-tailed). Temp (max) = Average Maximum Temperature (°C); Temp (min) = Average Minimum Temperature (°C); R.F. = Total Rainfall (mm); RH = Relative Humidity (%), R- Correlation co-efficient.

and positively correlated with maximum (r = 0.931**) and minimum temperatures (r = 0.835**), and negatively with relative humidity (r = –0.883**).Populations of *S. litura* and *H. armigera*were observed with peak densities of 2.33 and 1.33 larvae/plant, respectively, followed by complete disappearance by the 13th SMW. Both species showed significant negative correlations with temperature and positive correlations with relative humidity.

Among natural enemies, coccinellid beetle populations ranged from 4.94 to 6.61/plot, peaking in the 8th SMW. Their population showed significant positive correlations with maximum (r = 0.961**) and minimum temperatures (r = 0.956**), and significant negative correlation with relative humidity (r = –0.935**).Spiders were consistently present throughout the season (4.78–6.39/plot), with the highest and lowest counts recorded in the 8th and 18th SMWs, respectively(Table2). Although correlations with weather parameters were not statistically significant, weak negative trends were observed with temperature and rainfall, and a weak positive trend with humidity.

Based on field observations, stem borer infestation appears to decline in areas with high *S. frugiperda* (FAW) incidence. This may be attributed to FAW larvae feeding within the maize whorl, potentially disrupting the

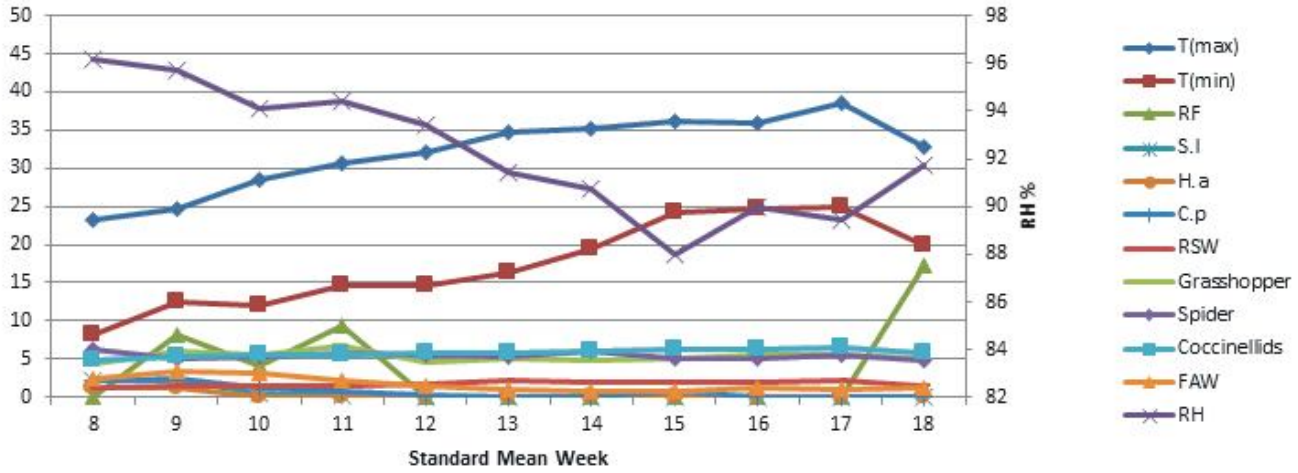

Fig. 2 : Seasonal incidence of FAW and other insect pests on Maize, Pre *kharif*- 2022.

Table 2 : Correlation of maize insect pests and natural enemies with weather parameters (pre-*Kharif*, 2022).

Insect pests/ Natural enemies	Temp Max. (X_1)	Temp min. (X_2)	R.F. (X_3)	RH Max. (X_4)	Coccine-llids	Spiders	R^2	Regression equation
S. frugiperda	-0.868**	-0.748**	0.296^{NS}	0.844**	-0.765**	0.104^{NS}	0.80	$-20.647 + (-0.144)X_1 + 0.108X_2 + (-0.006)X_3 + 0.272X_4$
C. partellus	-0.909**	-0.721*	0.097^{NS}	0.742**	-0.790**	0.234^{NS}	0.94	$22.384 + (-0.322)X_1 + 0.070X_2 + (-0.028)X_3 + (-0.135)X_4$
RSW	0.931**	0.835**	-0.437^{NS}	-0.883**	0.922**	-0.306^{NS}	0.91	$-0.476 + 0.055X_1 + 0.005X_2 + (-0.012)X_3 + 0.004X_4$
S. litura	-0.885**	-0.696*	0.068^{NS}	0.751**	-0.767*	0.295^{NS}	0.90	$2.714 + (-0.286)X_1 + 0.129X_2 + (-0.042)X_3 + 0.053X_4$
H. armigera	-0.868**	-0.681*	0.035^{NS}	0.728*	-0.755**	0.323^{NS}	0.88	$2.375 + (-0.159)X_1 + 0.068X_2 + (-0.025)X_3 + 0.017X_4$
Grasshopper	0.010^{NS}	0.093^{NS}	0.416^{NS}	0.109^{NS}	0.067^{NS}	-0.274^{NS}	0.42	$-40.427 + 0.072X_1 + 0.155X_2 + 0.024X_3 + 0.441X_4$
Coccinellids	0.961**	0.956**	-0.310^{NS}	-0.935**	-	-	0.98	$-1.901 + 0.055X_1 + 0.062X_2 + (-0.013)X_3 + 0.053X_4$
Spiders	-0.319^{NS}	-0.489^{NS}	-0.415^{NS}	0.409^{NS}	-	-	0.54	$-8.207 + 0.060X_1 + (-0.035)X_2 + (-0.045)X_3 + 0.135X_4$

*Significant at the 0.05 level (2-tailed), ** significant at the 0.01 level (2-tailed). Temp (max) = Average Maximum Temperature (°C); Temp (min) = Average Minimum Temperature (°C); R.F. = Total Rainfall (mm); RH = Relative Humidity (%), R- Correlation co-efficient.

stem borer's ability to establish entry points for stem tunneling. Additionally, FAW's cannibalistic behavior could suppress co-occurring larvae. However, when stem borer larvae hatch prior to FAW, successful infestation may still occur due to their early access to the stem.

The seasonal FAW population trends observed in this study align with Kumar *et al.* (2020), who reported significant positive correlations with maximum temperature (r = 0.720) and negative correlations with relative humidity (r = –0.674) and rainfall (r = –0.829). Similar positive associations with temperature were also noted by Paul and Deole (2020) (r = 0.586) and Canico *et al.* (2020), who observed increased FAW incidence during the dry season. *Chilo partellus* dynamics correspond with Sahito et al. (2012), who reported positive correlations of stem borer with temperature and negative associations with relative humidity. However, Kandalkar *et al.* (2000) found a significant negative correlation with minimum temperature (r = –0.734), contrasting our results. Spider populations showed similar trends to Sidar *et al.* (2017), who found no significant correlation with

Table 3 : Population of maize insect pests and natural enemies with and without hybrid napier border (*Rabi* 2021).

SMW	Population/plant												Population/plot			
	FAW		*C. partellus*		RSW adults		Grasshopper		*S. litura*		*H. armigera*		Coccinellids		Spiders	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
44	1.78	4.67	1.89	3.00	2.11	3.56	4.00	5.56	1.22	3.11	0.89	2.22	7.67	5.33	6.00	4.00
45	3.44	5.89	1.33	2.78	2.00	3.56	4.89	7.33	1.00	3.56	0.78	1.67	7.33	4.89	7.25	4.56
46	1.11	4.33	1.00	1.33	1.33	2.56	4.44	6.22	0.22	0.44	0.11	0.33	6.33	4.18	6.44	4.00
47	1.00	4.44	0.33	0.89	1.56	3.44	2.33	5.67	0.00	0.22	0.00	0.00	6.67	4.67	5.78	4.44
48	0.67	2.33	0.22	0.33	1.22	3.00	2.89	5.89	0.00	0.00	0.00	0.11	6.56	4.74	6.89	3.78
49	0.89	1.78	0.11	0.33	0.44	1.11	2.67	4.22	0.00	0.22	0.00	0.00	6.00	4.63	4.00	2.44
50	1.00	2.00	0.33	0.56	1.22	2.33	3.44	5.56	0.00	0.00	0.00	0.00	6.44	2.85	5.33	3.44
51	1.11	2.33	0.56	0.89	1.56	2.67	2.44	4.67	0.00	0.00	0.00	0.00	5.12	3.40	6.44	3.78
52	1.22	2.56	0.67	1.44	1.00	2.56	4.78	6.22	0.00	0.00	0.00	0.00	5.39	3.51	7.67	4.00
1	1.11	2.11	0.78	1.33	0.56	1.33	3.11	5.11	0.00	0.00	0.00	0.00	5.28	3.40	6.78	3.56
2	1.00	2.33	0.67	1.33	1.11	2.33	3.78	6.00	0.00	0.00	0.00	0.00	5.17	3.51	7.22	3.56
Mean	1.30	3.16	0.72	1.30	1.28	2.59	3.52	5.68	0.22	0.69	0.16	0.39	6.18	4.10	6.34	3.78
S.E (M)	0.289		0.123		0.116		0.181		0.268		0.136		0.177		0.242	
t- value	6.434		4.650		11.217		11.89		1.734		1.706		11.736		10.58	
P value (<0.05)	0.000075**		0.001*		0.000000055 **		0.000000032 **		0.114^{NS}		0.119^{NS}		0.000000036 **		0.000000094 **	

NS- Not significant, * - Significant, ** - Highly significant

T_1- Maize with Hybrid Napier as border crop, T_2- Maize without Hybrid Napier as border crop.

weather parameters, but weak negative associations with rainfall and wind velocity. Observations on coccinellid beetles align partially with Rawal et al. (2017) and Kedar *et al*. (2014), who reported varying responses to temperature and humidity, with predominantly negative correlations with maximum temperature and wind speed, consistent with our findings in the *Rabi* season.

Effect of border crop on population dynamics of insect pests on maize and their natural enemies

The mean population of FAW larvae on maize with napier border crop was recorded in the tune of 1.30/ plant and significantly lower than that of 3.16/plant found in maize without border crop during *rabi*, 2021 (Table 3).Similar trend in observation was also found in pre-*kharif*, 2022 and significantly lower population (0.90/ plant) was noted in maize with border crop as compared to without border crop (2.48/plant) (Table 4).

Maize with hybrid napier as border crop had significant effect on reducing the population of other major insect pests of *viz.*, stem borers, rugose spiraling whitefly, grasshopper, *S. litura* and *H. armigera*and the mean population were 0.72, 1.28, 3.52, 0.22 and 0.16/plant, respectively, during *rabi*, 2021. The corresponding values on maize without hybrid napier as border crop were 1.30, 2.59, 5.68, 0.69 and 0.39/plant (Table 3). The strength of the hybrid napier as border crop of maize was also confirmed during season pre *kharif*, 2022. Significantly lower population of *C. partellus*(0.50/plant), RSW (0.97/ plant), grasshopper (4.30/ plant), *S. litura* (0.26/plant) and *H. armigera*(0.16/plant) was found in maize with border crop as compared to maize without border crop and the corresponding values were 0.96, 2.50, 6.36, 0.72 and 0.33/ plant, respectively (Table 4).

The population of natural enemies was also attained in higher number in maize with border crop in comparison with non-bordered maize crop in both the seasons. Consistently higher population of coccinellid predator was observed in different standard meteorological weeks in maize with border crop and the mean population was 6.18/plot whereas in maize without border crop the mean population was 4.10/plot during *Rabi*, 2021 (Table 3).Similarly, in pre-*kharif*, 2022, the population of coccinellid predator was found 7.28 and 4.35/plot in maize with border crop and in maize without border crop, respectively (Table 4). Significantly higher population

Table 4 : Population of insect pests and their natural enemies on maize with and without hybrid napier border crop, during Pre-*kharif*, 2022.

SMW	Population/plant												Population/plot			
	FAW		*C. partellus*		RSW adults		Grasshopper		*S. litura*		*H. armigera*		Coccinellids		Spiders	
	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2	T_1	T_2
8	1.33	3.56	1.56	3.11	0.78	1.56	4.00	4.67	1.11	3.56	0.78	1.89	6.78	3.11	7.78	5.00
9	2.44	4.44	1.67	3.33	1.00	1.89	4.89	7.33	1.33	3.22	0.89	1.44	6.00	4.63	6.78	3.22
10	1.89	4.22	1.11	1.44	0.67	2.22	4.44	6.44	0.33	0.56	0.11	0.22	6.56	4.40	6.33	4.44
11	1.11	3.33	0.44	0.89	0.56	2.56	5.22	8.11	0.11	0.33	0.00	0.00	6.78	4.29	7.44	4.22
12	0.56	2.22	0.22	0.33	0.67	2.67	3.56	5.89	0.00	0.22	0.00	0.11	7.11	4.44	6.89	4.22
13	0.33	1.67	0.00	0.11	1.56	2.67	3.33	6.89	0.00	0.00	0.00	0.00	7.78	3.96	6.78	3.89
14	0.22	1.33	0.00	0.33	0.78	3.11	4.11	5.78	0.00	0.00	0.00	0.00	7.67	4.44	6.78	4.29
15	000	1.56	0.56	0.89	1.44	2.56	4.22	6.00	0.00	0.00	0.00	0.00	8.11	4.44	6.67	3.33
16	0.78	1.89	0.00	0.11	1.11	2.89	4.78	6.22	0.00	0.00	0.00	0.00	8.44	4.22	7.22	3.00
17	0.56	1.44	0.00	0.00	1.56	2.78	4.56	6.67	0.00	0.00	0.00	0.00	7.78	5.44	7.00	3.89
18	0.67	1.67	0.00	0.11	0.56	2.56	4.22	6.00	0.00	0.00	0.00	0.00	7.11	4.44	6.22	3.33
Mean	0.90	2.48	0.50	0.96	0.97	2.50	4.30	6.36	0.26	0.72	0.16	0.33	7.28	4.35	6.90	3.89
S.E (M)	0.162		0.175		0.159		0.229		0.260		0.106		0.258		0.182	
t- value	9.759		2.640		9.599		8.985		1.751		1.611		11.368		16.496	
P value (<0.05)	0.000002**		0.025*		0.000002**		0.000004**		0.111^{NS}		0.138^{NS}		0.000000048 **		0.00000000 13**	

NS- Not significant, * - Significant, ** - Highly significant

T_1- Maize with Hybrid Napier as border crop, T_2- Maize without Hybrid Napier as border crop

(6.34/plot) of spider was recorded in maize with napier border crop compared to 3.78/plot maize as solo crop. This trend in spider population also continued during pre-*kharif*, 2022 and the corresponding values were 6.90 and 3.89/plot in maize with border crop and solo maize crop, respectively(Table 4).

This study found a population difference in maize with and without a napier border crop which is in accordance to Hailu*et al.* (2018), where push pull technology (both climate-smart and conventional) can significantly reduce the FAW infestation in maize and also provide effective control over the pest complex of maize. They also observed a beneficial connection between Napier, Desmodium, Bracharia, and maize in controlling the intricate pests of maize. The findings of Midega*et al.* (2018) in Africa add support to the findings of this study and provide field-based evidence for the benefits of push pull technology for lowering FAW. This shows that conservation agriculture's use of push-pull technologies may have further advantages. Once it is established, the border crop will provide protection, improving the benefits of conservation agriculture.

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