DOI: 10.54083/ResBio/7.1.2025/24-29 *Res. Bio.*, 2025, 7(1):24-29

Research Biotica

e-ISSN: 2582-6743
January-March, 2025

Article ID: RB185 Research Article

Study on the Regional Diversity of Major Insect Pest of Fenugreek (*Trigonella foenum graecum* L.) along with the Prevailing Natural Enemy Fauna

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Conflict of interests: The authors have declared that no conflict of interest exists.

How to cite this article?

Bindhani, G., Das, A., Chakraborti, S., 2025. Study on the Regional Diversity of Major Insect Pest of Fenugreek (*Trigonella foenum graecum* L.) along with the Prevailing Natural Enemy Fauna. *Research Biotica* 7(1), 24-29. DOI: 10.54083/ResBio/7.1.2025/24-29.

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Abstract

An open field experiment was conducted during the rabi season in 2021–2022, to investigate the regional diversity of the major insect pests of fenugreek pests along with their natural enemy fauna across several geographical locations (Kalyani, West Bengal and Jajpur, Odisha). The incidence of insect pest was noticed from the early vegetative growth stage and lasted till the maturity of the seed. Here the aphids were found predominant throughout the crop growth phase, however their intensity varied among the experimental plots. Aphids were mostly prevalent during the month of February in both of the experimental fields of Jajpur (Odisha) and Kalyani (West Bengal), with 19.80 individuals and 25.80 individuals per 10 cm apical shoot, respectively. Simultaneously, the thrips population get peaked during the month of February in both the experimental plots with 8.50 individuals per 3 leaves and 7.35 individuals per 3 leaves, in Jajpur (Odisha) and Kalyani (West Bengal), respectively. In the meanwhile, the experimental plots of Kalyani (WB) and Jajpur (OD), showed the highest whitefly infestation at 5.20 individuals and 6.80 individuals per three leaves, respectively. The fluctuation of fenugreek pest population was negatively impacted in regional diversity by the current maximum temperature (r = -0.84, -0.46, -0.59 and -0.68, -0.12, -0.08 against aphids, thrips and whiteflies, respectively). Both of the experimental areas have benefited from the intense sunshine duration and wind speed. In both experimental regions, the prevailing natural enemy population considerably reduced the pest abundance. The regional diversity indicates, when compared to the whitefly and thrips populations, the aphid density under the Kalyani (WB) experimental plots is somewhat significantly greater than that of the Jajpur (OD) plots, which also justify the impact of agroecological conditions over pest abundance.

Keywords: Fenugreek, Insect, Natural enemies, Pest, Regional diversity

Introduction

Fenugreek, (*Trigonella foenum graecum* L.) is typically referred to as methi, belongs to the family Leguminosae, an indigenous crop to South-Eastern Europe and Western Asia (Ahmad *et al*., 2016). It comes under the most significant leguminous crops grown during the cool season in the Northern parts of India. Rajasthan, Madhya Pradesh, Gujarat, Maharashtra and Punjab are some of the commercial states in India for the production of this spice crop. The young green plant at its tender succulent stage is exclusively used for vegetable purpose, while the mature dough stage specifically used for fodders among the cattle, meanwhile the mature seeds are used for both condiment and medication purposes (Basu *et al*., 2014). A high domestic and international market price fetch the attention of farming community and hence become a permanent part of their cropping strategy, particularly among the regions with troublesome soils. It proves superiority over the other leguminous crops *viz.* gram, lentil due to its exceptional ability to survive and thrive among high-salty environments (Habib *et al*., 1971).

Article History

RECEIVED on 08th June 2024 RECEIVED in revised form 23rd March 2025 ACCEPTED in final form 30th March 2025

Among the diverse insect pest fauna under the fenugreek ecosystem, the aphid population, at early crop stages, triggers a substantial loss during the early crop growth stages (Mishra and Pandey, 2023). Aphids consume the plant sap, which simultaneously lowers the plant's vitality and potential output at varying degrees over times. Entire crop failure foretells when a crop plant withers and dies due as a result of severe insect pest infestation. Additionally, the fenugreek crop is injured by numerous sucking insect pest complexes, including the mites, thrips, jassids and the whitefly (Bindhani *et al*., 2021), where nymphs and adults draw the plant sap from the tender leaves of fenugreek by perforating from underneath the green leaflets in case of whitefly (Nisha *et al*., 2021) and incur damage by injecting its toxic saliva into the delicate tissues of plants *via* jassid (Chandrasekaran *et al*., 2021). The knowledge of periodic variations is also crucial for adopting feasible management practices against insect fauna of fenugreek under unobstructed filed condition. The major abiotic variables such as daily mean temperature, daily mean relative humidity and weekly mean rainfall significantly influence a vital role in oscillation of insect pests (Mishra and Pandey, 2023). It is a notable fact that the prevalence of insect pests is interlinked with the climatic variation and stage of plant growth at a specific time period. Consequently, under the various crop geometries, a slight deviation in the sowing period might have a substantial influence on the infestation of a particular insect pest species. Previously, this practice was evaluated by Meena (1998), while Kanwat (1988) and Yadav (2004) assessed this approach in fenugreek and fennel (*Foeniculum vulgare* Mill.). In coriander (*Coriandrum sativum*), the practice was evaluated by Meena *et al*. (2002).

However, the previous decades faced a significant deviation in the world climatic condition which is said to be taken into consideration while seeding the crop. Under such circumstances an open field trail was undertaken to figure out the spatial variation of crucial fenugreek pests and the prevailing natural enemy fauna under both the experimental plots from Kalyani (West Bengal) and Jajpur (Odisha), respectively.

Materials and Methods

During the rabi agricultural season of 2021-2022, an open field experiment was carried out in the farmer's field in Kalyani, West Bengal (22.9742° N, 88.4332° E) and Jajpur, Odisha (20.834° N, 86.332° E) respectively. In order to achieve a strong crop stand during the season, conventional agronomic and irrigation measures were followed where the seed of fenugreek (genotype RMt-1, which have been shown to be moderate to highly resistant towards the infestation from powdery mildew and root rot pathogens) were seeded during the end of October. Neither of the crop settings included any of the plant protection measures. The modified methods implemented by Tiwari *et al*. (2005) and Kant *et al*. (2017) served as the basis for the data collection from the field. Twenty fenugreek plants were chosen at random form each of the experimental plot. Individually both the adult as well as nymphal aphid were considered from each of the selected fenugreek plant, where the numbers per 10 cm of terminal shoot were taken as a standard sample @ 3 shoots plant^{-1} × 20 plants strip^{-1}. The infestation of thrips and whitefly population were measured as per 3 leaves @ 9 leaves plant^{-1} × 20 plants strip^{-1}. Data of abundance of natural enemy fauna in the crop ecosystem was gathered at weekly interval starting from 10 DAS. Mature and juvenile phases of natural enemy fauna were collected as an individual numbers plant^{-1} from the randomly selected 10 fenugreek plants strip^{-1} × 4 strips. Mean values of all the observations were assessed to correlate their relative performance between two cropping sets. Here the mean abundance of the fenugreek pests, natural enemy fauna along with prevailing climatic data were also tabulated. Correlation coefficient matrix was executed among the prevailing arthropod fauna along with the agro-meteorological variables. Further predictive regression models of pest population were also generated under both the experimental setups.

Results and Discussion

The prevailing agro-meteorological variables represented in table 1 clearly indicates the lower maximum temperature (T_{max}) of 25.03 °C and 21.90 °C during the winter season in December under the open field trail plots of Kalyani (WB) and Jajpur (OD) respectively. Meanwhile, the reported mean higher maximum temperature (T_{max}) in the month of November, it was recorded 30.04 °C at Kalyani (WB) while at Jajpur (OD) it was 27.10 °C. The recorded mean minimum temperature (T_{min}) varied in-between 9.74 °C to 19.82 °C and 11.23 to 14.44 °C at Jajpur (OD). The relative humidity (RH) percentage ranged between 91.77-42.29% and 92.00-32.00% at the experimental field of Kalyani and Jajpur, respectively. During the experiment a very little downpour was recorded in the experimental month from November to January; whereas, the peak was recorded during December having a mean of 0.40 mm rainfall. Simultaneously the crop faced very low to negligible rainfall at Jajpur, OD. Both the experimental stations faced a clam wind breeze, ranged 4.6 to 5.8 kmph.

During the experiment the aphid, thrips and whiteflies are among the significant fenugreek pest population that have been frequently observed in the experimental plots of Kalyani and Jajpur (Table 2), despite the fact that there was a deviation in their distribution pattern. In the heterogeneity of insect-pest abundance, the aphids were spotted comparatively greater in number in both of the research locations, while the minimal is noticed during the month of November with 5.25 aphid population per 10 cm shoot followed by in the month of December (13.15 aphid population per 10 cm shoot length). Meanwhile the higher pest load is noticed during the month of January with 25.80 individuals per 10 cm shoots under the experimental area of Kalyani (WB). The experimental plot of Jajpur (OD) showed almost identical population trend for the aphids, with a lower mean value, where a population varied substantially between the experimental period. In both the experimental regions, there was a comparatively reduced population of whitefly and thrips compared to the aphids and their

Table 1: Prevailing agro-meteorological data on Jajpur (Odisha) and Kalyani (West Bengal)

Period	Kalyani, West Bengal							Jajpur, Odisha						
	T_{max} (°C)	T_{min} (°C)	RH_{max} (%)	RH_{min} (%)	RF (mm)	BSS (hours)	WS (kmph)	T_{max} (°C)	T_{min} (°C)	RH_{max} (%)	RH_{min} (%)	RF (mm)	BSS (hours)	WS (kmph)
Nov, 21	30.04	19.82	91.75	50.97	0.28	7.06	4.6	26.11	14.44	64.00	32.00	0.00	7.24	5.00
Dec, 21	26.46	14.02	91.77	48.06	0.40	5.73	5.2	23.33	12.22	71.00	42.00	0.02	8.21	5.57
Jan, 22	25.03	9.74	90.77	42.29	0.00	7.19	5.8	21.90	11.23	92.00	51.00	0.02	8.27	5.14
Feb, 22	28.20	13.14	89.64	39.68	0.36	7.70	6.1	27.10	12.95	82.00	34.00	0.00	7.63	4.70

Table 2: Incidence of the prevailing insect-pests and their natural enemies Jajpur (Odisha) and Kalyani (West Bengal)

Particulars	Kalyani, West Bengal				Jajpur, Odisha			
	Nov, 21	Dec, 21	Jan, 22	Feb, 22	Nov, 21	Dec, 21	Jan, 22	Feb, 22
Aphid/10 cm shoot	5.25^{a}	13.15^{bc}	25.80^{d}	16.25^{c}	4.00^{a}	10.10^{b}	19.80^{d}	12.50^{c}
Thrips/ 3 leaf	1.20^{a}	3.20^{b}	6.60^{c}	$7.35c^{d}$	1.40^{a}	3.66^{b}	7.66^{cd}	8.50^{d}
Whitefly/ 3 leaf	0.67^{a}	2.34^{bc}	5.20^{d}	2.20^{b}	1.35^{a}	4.70^{b}	6.20^{c}	6.80^{c}
Spider plant^{-1}	1.80^{a}	3.60^{b}	5.33^{d}	4.60^{c}	2.30^{a}	4.33^{b}	6.33^{d}	5.00^{bc}
Coccinellids plant^{-1}	2.60^{b}	1.80^{a}	4.20^{c}	5.0^{d}	2.34^{b}	1.60^{a}	3.70^{c}	5.33^{d}

[*Mean of 3 replications; Means followed by different letters in the same row are significantly different (P≤0.05, Tukey HSD) against each experimental location. All the calculations were made after proper transformation.]

Table 3: Correlation coefficient (r) analysis of the prevailing agro-meteorological variables *vis-à-vis* Fenugreek insect-pests along with their natural enemy fauna in the experimental field of Kalyani (West Bengal)

Particulars	Aphid	Thrips	Whitefly	Spider	Coccinellids	T_{max}	T_{min}	RH_{max}	RH_{min}	RF	BSS	WS
Aphid	1	0.80	0.87	0.83	0.47	-0.84	-0.97*	-0.63	-0.80	-0.56	0.32	-0.21
Thrips	-	1	0.65	0.91*	0.83	-0.46	-0.84	-0.67	-0.84	-0.23	0.55	0.25
Whitefly	-	-	1	0.85	0.37	-0.59	-0.87	-0.19	-0.44	-0.19	0.07	0.05
Spider	-	-	-	1	0.66	-0.47	-0.90*	-0.38	-0.63	-0.06	0.23	0.35
Coccinellids	-	-	-	-	1	-0.02	-0.45	-0.51	-0.61	0.01	0.81	0.41
Tmax	-	-	-	-	-	1	0.79	0.67	0.73	0.84	-0.08	0.62
T_{min}	-	-	-	-	-	-	1	0.57	0.77	0.43	-0.19	0.05
RH_{max}	-	-	-	-	-	-	-	1	0.95*	0.79	-0.68	0.42
RH_{min}	-	-	-	-	-	-	-	-	1	0.69	-0.62	0.26
RF	-	-	-	-	-	-	-	-	-	1	-0.35	0.87
BSS	-	-	-	-	-	-	-	-	-	-	1	-0.07
WS	-	-	-	-	-	-	-	-	-	-	-	1

abundances were observed to differ considerably from one another. The research trail areas of Kalyani and Jajpur faced the lowest thrips population during the month of November with 1.20 and 1.40 individuals per three leaves, whereas the peak infestation was noticed in February, which coincided with increased in daily mean temperatures and crop maturity. Both the experimental plots have faced a very similar fluctuation in whitefly population, with the peak infestation discerned in the month of January at Kalyani and in the month of February at Jajpur, despite having a notable variation the mean abundance.

Natural enemy population is crucial for stabilizing the ecological diversity under varying agro-ecosystem simultaneously lowering the chance of harmful pest outbreak. In the present context in fenugreek crop ecosystem a significantly higher spider population was perceived during the month of January (5.33 and 6.33 individual plant^{-1} in respect to Kalyani and Jajpur) and their population is sustained until the crop reaches maturity (Table 2). In the meantime, the prevailing coccinellid population in Kalyani get decreased in December, but shown a contradiction in the experimental plot at Jajpur, OD, where it flows continues growth (range from 2.34 to 5.33 individuals plant^{-1}).

According to the correlation coefficient matrix the prevailing aphid population has formed a strong negative association with the minimum temperature (T_{min}) (r = -0.97) and only a positive correlation with the bright sunshine hours (BSS) (Table 3). The abundance of natural enemy population in the

fenugreek crop ecosystem was found to be very interlinked with the aphid population. Meanwhile the prevailing abiotic determinants *viz.*, daily mean temperature, relative humidity percentage and the total precipitation (rainfall) have formed a negative alliance with thrips population, while bright daylight hours (BSS) and wind speed established a positive correlation. There is a considerable positive (r = 0.91) association between the spider population and the thrips abundance. Whitefly population data showed a similar pattern, with lower coefficient values (r = 0.07 and 0.05) for wind speed and bright sunlight hours. In the present context, there is an established positive correlation between total rainfall and relative humidity was formed (r > 0.5). Additionally, it was discovered that the population of whiteflies interacted negatively with both maximum and minimum temperatures (with coefficient values, r = -0.59 and r = -0.87, respectively). Here both of the natural enemy population (*viz.*, spider and coccinellid), have formed a substantial negative association with the prevailing minimum temperature (r = -0.90).

In the experimental plots of Jajpur (OD) the correlation coefficient matrix indicated that the prevailing maximum relative humidity percentage and the aphid population have established a strong positive correlation (r = 0.96), but the maximum temperature (T_{max}) and the wind speed have a negative interaction (r = -0.68, -0.76 and -0.25, respectively). Surge of the aphid population had a substantial impact which escalated owing to the presence of spider and coccinellid population (r = 0.81 and 0.29, respectively). With only the exception in daily mean temperature (r = -0.12 and -0.32) and bright sunshine hour (BSS) (r = -0.28), the majority of the dominant agro-meteorological variables had a beneficial impact on the thrips population. In the meanwhile, the prevailing biotic factors and their abundance have been critical under the open field experiment, with coefficient values of 0.86 against coccinellids and 0.95 (significant) against spider populations. The fluctuation in whitefly population have influenced positively with another biotic parameter (0.91 spider population) while only has established a positive reaction with the relative humidity percentage, total rainfall, wind speed and the coccinellid population, with the respective correlation coefficient values being, r = 0.78, 0.42, 0.28, 0.42 and 0.67 (Table 4).

The forewarning regression models clearly justify that all the seven abiotic variables in addition to two biotic variables are responsible for 93.60 to 94.70% variation for the abundance in aphid population under the experimental plots of Jajpur (OD) and Kalyani (WB). The thrips population's coefficient of determination value (R^2) varied between 81.50% and 92.60% in the experimental fields of Jajpur (OD) and Kalyani (WB), respectively, whereas the whitefly population's coefficient of determination (R^2) varied between 76.00% and 88.70% (Table 5).

In the present investigation the fenugreek plants were infested with different insect pest species meanwhile the sucking pests complex (*viz.,* aphid, thrips and whitefly) fetched a significant attention in terms of crop growth starting from germination to the final harvesting operation, meanwhile ash weevil, painted bug, *Spodoptera* sp. and the green stink bug were also found in fenugreek ecology but their presence doesn't produce a substantial economic effect. The aphids, thrips and whiteflies are among the insect pest species whose nymphs and adults feed upon the delicate fenugreek leaves, fragile sprout section as well as the flowers while also developing yellowish to brownish necrotic patches on the foliage parts.

Aphids (*Aphis craccivora* Koch, *Acyrthosiphon pisum* Harris), whiteflies (*Bemisia tabaci* Genn.) and thrips have first appeared on the fenugreek crop about four weeks after sowing in the main field and a large population also persists throughout the blooming and fruiting stages until the pods reached maturity and have been spotted as significant yield reduction in fenugreek which are in lined with Kalra *et al*. (2002), Selvaraj *et al*. (2010), Kakani and Anwer (2012), Manjula *et al*. (2015) and Abro *et al*. (2016). Natural enemy of these insect pest fauna on fenugreek ecosystem comprises mostly of the generalist predators like spiders and coccinellids besides a very little chrysopid and praying mantid population was also noted from few pockets which are also in lined with Kalra *et al.* (2002), Selvaraj *et al.* (2010), Abro *et al.* (2016) and Kant *et al*. (2017).

Additionally, we discovered in the geographical distribution analysis that there was only a negative influence between the prevailing insect populations and the current mean temperature in both of the experimental sites. In this situation, the number of pests increases in proportion to the daily mean temperature and their presence is mostly crowded owing to food availability and along with the aphid populations migration. Mishra *et al*. (2023) observed that aphid population are more frequent throughout the winter, which normally lasts from the months of November to February coinciding with our investigation to promote the aphid population growth and their reproduction.

The infestation of aphid can also happen outside of the customary winter season where the specific changes in microclimates and agro-meteorological circumstances might have an influence on the fecundity of aphid population. Another significant fenugreek insect pest such as thrips and whitefly population also got expanded with more or less identical reasons in the present situation. In the spatial distribution investigation, a conflicting effect regarding the relative humidity percentage (RH %) and the abundance of insect was detected.

Here, a somewhat greater relative humidity percentage (RH %) was seen in Kalyani (WB) as opposed to the open field experimental station of Jajpur (OD). This suggests that widen the relative humidity percentage under a lower temperature regime has a detrimental impact on the surge of insect-pest population. Even though there was no significant total rainfall in any of the research plots, the correlation analysis revealed that the insect population disperses with the sporadic rainfall. Additionally, the pest populace has preferred wind speed in both of the experimental phage. Aphid (*Aphis craccivora*) infestation was recorded peaked

at the end of January in the crop ecosystem which are in accordance to Mishra and Pandey (2023). The correlation coefficient revealed that the maximum relative humidity percentage has favored a positive significant correlation (r = 0.534) with the aphid population. Spider population played a crucial role for suppressing the insect pest population along with maintaining the ecological diversity in agro-ecosystem (Michalko *et al*., 2019) and our present experiment are in lined with under spatial deviation. Minor nuisance sucking insect species like thrips, aphids and whiteflies (both the nymphal and adult populations) may die by being entangled in the webs of the bigger spider species, despite the fact that they are mostly ignored (Nentwig, 1987).

The population of predatory spider species may even kill more the insect pests than if they were in a high-quality preferred prey since the spiders would not be content. In fenugreek crop ecosystem, the coccinellids such as *Epilachna* spp., *Cheilomenes* spp., *Nephus* sp. and *Psylloborab* sp. (Mulsant) were prevalent and greatly reduced the insect pest populations in both of the cropping locations (Kumashiro *et al*., 1983; Cock, 1985; Ignacimuthu, 2002; Kundoo and Khan, 2017).

Table 4: Correlation coefficient (r) of agro-meteorological variables *vis-à-vis* Fenugreek insect-pests along with the prevailing natural enemy fauna in the experimental field of Jajpur (Odisha)

Particulars	Aphid	Thrips	Whitefly	Spider	Coccinellids	T_{max}	T_{min}	RH_{max}	RH_{min}	RF	BSS	WS
Aphid	1	0.75	0.70	0.81	0.29	-0.68	-0.76	0.96**	0.87	0.67	0.30	-0.25
Thrips	-	1	0.95*	0.86	0.80	-0.12	-0.32	0.87	0.39	0.15	-0.28	0.33
Whitefly	-	-	1	0.91*	0.67	-0.08	-0.27	0.78	0.42	0.28	-0.14	0.42
Spider	-	-	-	1	0.52	-0.18	-0.28	0.86	0.66	0.52	-0.02	0.33
Coccinellids	-	-	-	-	1	0.37	0.16	0.51	-0.15	-0.44	-0.79	0.59
T_{max}	-	-	-	-	-	1	0.96**	-0.50	-0.78	-0.75	-0.78	0.85
T_{min}	-	-	-	-	-	-	1	-0.61	-0.73	-0.66	-0.66	0.74
RH_{max}	-	-	-	-	-	-	-	1	0.75	0.48	0.05	-0.07
RH_{min}	-	-	-	-	-	-	-	-	1	0.91*	0.62	-0.42
RF	-	-	-	-	-	-	-	-	-	1	0.834	-0.428
BSS	-	-	-	-	-	-	-	-	-	-	1	-0.706
WS	-	-	-	-	-	-	-	-	-	-	-	1

Table 5: Regression analysis of the major insect-pests influenced by prevailing biotic and abiotic determinants under the open field Fenugreek crop ecosystem of Kalyani (WB) and Jajpur (OD)

Insect-Pest population	Forewarning Regression model	(R^2)
Kalyani, West Bengal		
Aphid	$43.19 + 0.22\ n_1 - 1.98\ n_2 + 0.01\ n_3 + 0.01\ n_4 - 0.26\ n_5 + 0.13\ n_6 - 0.08\ n_7 + 0.03\ n_8 + 0.09\ n_9$	0.947
Thrips	$29.81 - 0.13\ n_1 - 0.18\ n_2 + 0.33\ n_3 - 0.59\ n_4 - 0.09\ n_5 - 0.07\ n_6 + 0.42\ n_7 + 0.25\ n_8 - 0.12\ n_9$	0.926
Whitefly	$24.10 - 0.41\ n_1 - 0.14\ n_2 - 0.16\ n_3 - 0.35\ n_4 + 0.30\ n_5 + 0.12\ n_6 + 0.27\ n_7 + 0.24\ n_8$	0.886
Jajpur, Odisha		
Aphid	$-31.71 - 0.26\ n_1 - 0.26\ n_2 + 0.35\ n_3 + 0.55\ n_4 + 0.27\ n_5 + 0.25\ n_6 + 0.25\ n_7 - 0.98\ n_8 - 0.28\ n_9$	0.936
Thrips	$-2.22 + 0.03\ n_1 - 0.07\ n_2 + 0.45\ n_3 - 0.27\ n_4 - 0.33\ n_5 - 0.22\ n_6 - 0.22\ n_7 + 1.65\ n_8 + 0.43\ n_9$	0.814
Whitefly	$-0.95 + 0.08\ n_1 - 0.02\ n_2 + 0.01\ n_3 - 0.32\ n_4 - 0.22\ n_5 - 0.12\ n_6 - 0.11\ n_7 + 1.28\ n_8 + 0.27\ n_9$	0.760

[$n_1 = T_{max}$; $n_2 = T_{min}$; $n_3 = RH_{max}$; $n_4 = RH_{min}$; n_5 = Rainfall; n_6 = Bright sun shine hours (BSS); n_7 = Wind speed (WS); n_8 = Spider; n_9 = Coccinellids]

Conclusion

In the present experiment, the populations of thrips and whiteflies were comparatively small and had a lower mean value; the populations of *A. craccivora and A. pisum* were widespread under both of the experimental plots and were considered the main pests under the fenugreek habitat. Hence, the early sowing fenugreek crop may be adopted to increase the quality seed percentage from aphid attack and shield the crop from aphid assault. Maximum relative humidity percentage and the aphid population were shown to be considerably positively correlated, whereas the prevailing aphid population at the experimental plots of Kalyani, was adversely correlated with the minimum temperature. The fenugreek crop can easily incorporate as a component of push-pull technology for the sustainable pest management because the avoidable loss in fenugreek seed yield caused by aphid attacks was greatest in control plots, followed by those treated with higher numbers and

feeding propensity of various instars and adults of spiders and coccinellids.

Ethical Statement

The authors declare that no generative artificial intelligence tools were used in drafting or preparing this manuscript. The manuscript was written, interpreted and revised solely by the authors, who take full responsibility for its content.

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