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Abiotic determinants of the incidence of the insect pests on fenugreek in gangetic alluvial plains of West Bengal

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Abstract
A study was conducted during two consecutive year of 2019 and 2020 to assess the effects of various abiotic determinants on incidence of various insect pest along with its natural enemies and pollinators of fenugreek under gangetic alluvial plains of West Bengal. Sucking pests appeared as the major pest complex and aphid (*Apis craccivora*) was found to be as the major pest. It appeared on third week of November and continued till second week of March of the next year, and was predominantly a pest of the vegetative stage of crop. Other important pests were white fly, thrips and jassid which appeared at early stage of crop and continued till harvest of the crop while leaf miner and ash weevil appeared at later stage during the crop growing season. Temperature was found to be the most important abiotic determinant for pest population build up in fenugreek ecosystem. Natural enemy population comprised of generalist predators like spiders, coccinellids, syrphid fly, mantids etc. Amongst the pollinators, wild honey bee (*Apis dorsata*) was recorded in comparatively higher numbers over others.

Keywords: fenugreek, insect pests, meteorological determinants

Introduction
Fenugreek, *Trigonella foenum graecum* L. (Leguminosae) commonly known as methi, menthalu, greek hay etc. a native of South-Eastern Europe and Western Asia (Pruthi, 1976) [17], and is grown for seeds, leafy vegetables and fodder besides it poses an immense value for its medicinal properties *viz*. prevent constipation, remove indigestion, anti-inflammatory, internal healer, antiulcer, sexual stimulant (Mishkinsky *et al.*, 1977) [12], lowering glycemia (Raghuram *et al.*, 1994) [18] and with antioxidant properties (Ravikumar and Anuradha, 1999) [19]. A number of factors are known to appear as barrier in attaining the potential yield of the crop and yield loss due to insect pests is an important one. Manjula *et al.* (2015) [10] recorded 37 pests on the crop while about thirty number of insect pests were recorded to infest fenugreek by some other workers (Mittal and Butani, 1994; Kakani and Anwer, 2012) [13].

Findings of earlier workers showed that aphids (*Aphis craccivora* Koch. *Acyrthosiphon pisum* (Harris), whitefly (*Bemisia tabaci* (Genn.), jassids (*Emopasca kerri* (Pruthi), leaf miner (*Liriomyza* sp.) etc. were the important pests of fenugreek (Kalra *et al.*, 2002, Manjula *et al.*, 2015) [10].

Evidently, sucking insect pests are the most damaging ones of fenugreek and they developed on the crop during vegetative stages but heavy population developed during flowering and fruiting stages causing significant losses in yield in major spice growing areas of India (Mondal *et al.*, 2019; Abro *et al.*, 2016) [1]. Excepting chillies, West Bengal does not come under the prime spice growing tracts of India but some of the common seed spices like fenugreek, fennel, coriander etc. are grown in different areas of the state on regular basis. However, the systematic documentation of the incidence of the insect pests and their damages on this crop there is very limited. This necessitated the present study and the findings will facilitate development of appropriate management strategies in future.

Materials and Methods
The investigation was conducted for two successive years during 2019-2020 in farmers' field at Barrackpur, North 24 Parganas and Research Plot of Mohanpur, Nadia district of West Bengal during the period from November to March with standard package of practices, except the plant protection measures. To study the natural incidence of different insect pests and their natural enemies a fixed plot survey was conducted and the observations were recorded at weekly interval from a block of ten unsprayed plant in each location starting from thirty days after seed sowing. Direct count method was applied against aphid, whitefly, jassid, thrips population in the morning hours on three leaflets *viz*., upper, middle and lower on each of the ten tagged plants in each plot while number of spodoptera, flea beetle, ash weevil, painted bug, green stink bug were recorded on sum total per plant basis. Considering the natural enemy population such as coccinellids and spiders, ten plant per plot were selected and number of natural enemy was noted per plant basis. Meteorological parameters *viz*., maximum and minimum temperature (°C), relative humidity percentage, rainfall (mm) and bright sunshine hours, were collected from both the respective meteorology department. Correlation and regression were made between insect pests, natural enemies and their mean weather parameters by using IBM SPSS® version 25.

Results and Discussion
The incidence pattern was more or less similar in both the location while numbers may varies among creatures.

Aphid (*Aphis craccivora* Koch; Aphididae, Hemiptera)

Aphid population (*Aphis craccivora* Koch; Aphididae, Hemiptera) invaded quite early, during in the third week of November, 47th standard week of the year, in both the location coinciding with the vegetative growth period of the crop which was in accordance with Kant *et al.*,(2017) [8]. Population increased steadily and showed a peak in between 12 January – 2 February (mean 18.3 – 32.0/plant) at the peak vegetative growth period of the crop.

With the onset of the reproductive growth period of the crop, the aphid population build up started to climb down and 2nd March onward no aphid could be recorded in the field. Table: 1 indicates that both maximum and minimum temperature has a significant negative correlation with aphid population buildup, r = -0.857, -0.611 and -0.635, -0.677 in Mohanpur and Barrackpore respectively while other abiotic parameters such as minimum relative humidity, rainfall and bright sunshine hour found to be only negatively correlated and maximum relative humidity found with positive correlation with aphid population. All the six meteorological parameters were responsible for 80.90% variation for abundance of aphid population in the field. It was also observed that among the all parameters maximum temperature and minimum relative humidity responsible for 76.3 % variation in aphid population when variation calculated by stepwise regression model (Table: 2). *A. cracccivora* has been reported as a most serious pest of fenugreek in India that causes maximum yield losses to the crop at field level (Brar and Kanwar 1994; Pawar *et al.*, 2001) [3, 16].

Thrips (*Scirtothrips dorsalis* Hood; Thripidae, Thysanoptera)

Thrips (*Scirtothrips dorsalis* Hood; Thripidae, Thysanoptera) infestation was first recorded in the fourth week of November (0.8 thrips/leaf on 24th November). The population steadily increased and peak was noticed during 16th February – 23rd February (8.3 – 9.6 thrips/leaf). Thereafter, population declined quite notably and presence of a fluctuating population was recorded in the field after attending the peak period Kant *et al.*, (2017) [8]. Daily temperature correlates with thrips population having the significant value, r = 0.568, 0.758 and r = 0.700, 0.524 in both Mohanpur and Barrackpore for maximum and minimum temperature respectively. While the maximum and minimum relative humidity found to be significant but negatively correlates with thrips population buildup (r = -0.586, -0.624 and -0.713, -0.548 in respect to location). Among the other abiotic parameters rainfall has an adverse effect and bright sunshine hour have an influential effect over the thrips population (Table 1).

Table 1: Correlation studies between insect pests of Fenugreek with weather parameters (Pooled value of two years, 2019-2020).

Insect pests	Location	T max	T min	RH max	RH min	RF	BSS
Aphid	Mohanpur	-0.857**	-0.611*	0.082	-0.201	-0.204	-0.171
	Barrackpore	-0.635*	-0.677**	0.062	-0.037	-0.096	-0.097
Thrips	Mohanpur	0.568*	0.758**	-0.586*	-0.624**	-0.376	0.315
	Barrackpore	0.700**	0.524*	-0.713**	-0.548*	-0.228	0.234
White fly	Mohanpur	-0.774**	-0.822**	0.253	0.171	0.191	-0.301
	Barrackpore	-0.758**	-0.703**	0.158	0.159	0.289	-0.268
Jassid	Mohanpur	-0.480	-0.736**	0.565*	0.538*	0.409	-0.432
	Barrackpore	-0.877**	-0.725**	0.413	0.543*	0.583*	-0.482
Serpentine Leaf miner	Mohanpur	0.847**	0.728*	-0.618	-0.278	-0.100	0.142
	Barrackpore	0.828**	0.720*	-0.667	-0.368	-0.132	0.197
Spodoptera	Mohanpur	0.168	0.418	-0.355	-0.410	0.028	0.001
	Barrackpore	0.047	0.242	-0.257	-0.435	-0.124	0.192
Flea beetle	Mohanpur	-0.295	-0.053	0.068	-0.409	0.005	0.112
	Barrackpore	-0.353	-0.278	-0.154	-0.386	-0.306	0.327
Ash weevil	Mohanpur	0.567*	0.671*	-0.533	-0.490	-0.147	0.103
	Barrackpore	0.653*	0.678*	-0.552	-0.362	-0.229	0.266
Painted bug	Mohanpur	-0.422	-0.402	0.211	-0.205	-0.198	0.181
	Barrackpore	-0.011	-0.246	-0.180	-0.431	-0.489	0.432
Green stink bug	Mohanpur	-0.184	-0.144	0.187	-0.266	-0.122	0.047
	Barrackpore	0.073	-0.140	-0.104	-0.316	-0.096	0.040

(* at 5% level of significance, **at 1% level of significance)

Table 2: Multiple effect of abiotic parameters on the incidence of insect-pests under fenugreek ecosystem.

SL No.	Insect pests	Regression	Equation	R^2	F Value
1.	White fly	Multiple	$Y= -10.30 - 0.35 X_1 – 0.108 X_2 +0.034 X_3 - 0.024 X_4 + 0.109 X_5 + 0.102 X_6$	0.713	3.308*
		Stepdown	$Y= 13.35 - 0.351 X_2$	0.698	30.109**
2.	Thrips	Multiple	$Y= 32.403 + 0.358 X_1 -0.314 X_2 - 0.252 X_3 - 0.123 X_4 + 0.162 X_5 – 0.689 X_6$	0.635	2.61
		Stepdown	$Y= 12.641 - 0.320X_4$	0.469	12.367**
3.	Aphid	Multiple	$Y= 117.874 – 1.773 X_1 -0.435 X_2 - 0.344 X_3 - 0.118 X_4 – 1.914 X_5 – 2.655 X_6$	0.809	5.65*
		Stepdown	$Y= 78.79 – 2.035 X_1 -0.256X_4$	0.763	19.33**
4.	Jassid	Multiple	$Y= 0.220 + 0.129 X_1 -0.227 X_2 + 0.021 X_3 - 0.019 X_4 + 0.212 X_5 - 0.286 X_6$	0.469	1.178
		Stepdown	$Y= 2.58 + 0.151 X_1 - 0.251X_2$	0.361	0.385
5.	Leaf miner (infestation %)	Multiple	$Y= -10.76 - 0.091 X_1 + 0.147 X_2 + 0.141 X_3 - 0.035 X_4 + 0.013 X_5 - 0.304 X_6$	0.944	2.791
		Stepdown	$Y= -3.761 + 0.369 X_1 + 0.045X_3$	0.937	37.469**
6.	Spodoptera	Multiple	$Y= -10.76 - 0.091 X_1 + 0.147 X_2 + 0.141 X_3 - 0.035 X_4 + 0.013 X_5 - 0.304 X_6$	0.414	1.296

		Stepdown	$Y= -7.889 + 0.077 X_3 + 0.418X_6$	0.335	3.775*
7.	Flea beetle	Multiple	$Y= -5.166 - 0.065 X_1 + 0.146 X_2 + 0.172 X_3 - 0.129 X_4 + 0.225 X_5 + 0.247 X_6$	0.825	6.28**
		Stepdown	$Y= 9.921 - 0.083 X_4 + 0.546 X_6$	0.600	8.984**
8.	Ash weevil	Multiple	$Y= -2.752 + 0.203 X_1 + 0.058 X_2 - 0.052 X_3 + 0.238 X_4 + 0.136 X_5 – 0.093 X_6$	0.657	1.599
		Stepdown	$Y= 0.554 + 0.161 X_1$	0.430	7.54*
9.	Painted bug	Multiple	$Y= 2771 + 0.08 X_1 - 0.182 X_2 - 0.003 X_3 - 0.008 X_4 + 0.019 X_5 – 0.095 X_6$	0.298	0.779
		Stepdown	$Y= 4.254 - 0.101 X_2 - 0.014 X_4$	0.264	2.688
10.	Green stink bug	Multiple	$Y= -0.873 + 0.053 X_1 - 0.055 X_2 + 0.047 X_3 - 0.043 X_4 + 0.076 X_5 – 0.081 X_6$	0.335	0.923
		Stepdown	$Y= -1.685 + 0.046 X_3 - 0.024 X_4$	0.202	1.901

(X1 = Maximum temperature, X2 = Minimum temperature, X3 = maximum RH%, X4 = minimum RH% X5 = Rainfall, X6 = Bright sunshine hour)

Regression analysis (Table 2) shows that all six weather parameters are responsible for 63.5 % variation in thrips abundance while in step-down regression analysis it shows that only minimum relative humidity contributes a significant variation (46.9%) in development of thrips population in the fenugreek field. Abro *et al.*, 2016 [1], reported that thrips as a serious pest of fenugreek and other seed spice crops in Pakistan.

White fly (*Bemisia tabaci* Genn; Aleyrodidae, Homoptera)

White flies appeared at early stage on the crop and present throughout the crop growing period while a quite low as the crop mature. First appearance recorded on 17th November (32 days after sowing) with a mean population of 0.3 white fly/leaf. The population gradually increased and reached its peak 5.3-5.5 white fly/leaf during the middle of January and decreases its number there after which has a more similarity with Deshwal (2007)[4]. It appeared that maturing plants were gradually becoming less attractive to the insect and they started to disperse somewhere else from fenugreek field. Correlation study (Table: 1) shows that whitefly population have a highly negative correlation with both maximum and minimum temperature (r = -0.774, -0.758 and -0.822, -0.703) in Mohanpur and Barrackpore respectively and daily average rainfall (Mondal *et al.*, 2019) [14] and relative humidity plays a positive role with the abundance of whitefly in the ecosystem besides bright sunshine hours have a negative interaction on it. Babu and Meghwal (2014) [2] who reported that that white fly follow a similar interaction where maximum temperature and bright sunshine hour follow negative interaction with whitefly population while rainfall and relative humidity have positive effect. Regression analysis revealed (Table:2) all six weather parameters are responsible for 71.3 % variation while in step-down regression analysis it was observed that only minimum relative humidity contributes 69.8 % variation for development of whitefly population in the fenugreek field.

Jassid (*Ambrasca sp.*; Cicadellidae, Hemiptera)

Jassid population follow a quite similar trend with aphid population and first noticed on the crop after about five weeks after sowing, on 17th November (0.6 jassid/leaf). Mittal and Butani, 1994 [13] who reported jassid as one of the serious pest of fenugreek at early crop growth stage. Thereafter, the population started to climb up and recorded at higher number during 22nd December-12 January (4.6-7.6 jassids/leaf) followed by sharp decline in population and no population could be traced 2nd March onward. Jassid population have a negatively significant correlation with maximum (r = -0.847 and -0.828) and minimum temperature (r = -0.728 and -0.720) while only negatively correlates with bright sunshine hours and rest other parameters *viz*. maximum (r = 0.538 and 0.548) and minimum (r = 0.538) relative humidity and rainfall (r = 0.583) have positive significant values with abundance of jassid in the fenugreek field (Table 1) which is in accordance with Babu and Meghwal (2014) [2], who reported that Jassid population follows a significantly negative correlation with maximum temperature and negatively correlated with sunshine hours while rest of other parameters found to have a positive interaction among them morning relative humidity found to be highly significant in cotton ecosystem. Regression analysis (Table 2) shows that all weather parameters responsible for only 46.9% variation while in stepdown regression it was estimated that 36.1% variation due to maximum temperature and maximum relative humidity.

Serpentine leaf miner (*Liriomyza trifolii* Burgess; Agromyzidae, Diptera)

The damage caused by the leaf miner was found during January to March in both the years (damage: 0-18.5 and 0-16.5 % respectively) with a peak of its activity after first week of February to end of third week of February. Evidently, they preferred the vegetative growth and along with the reproductive stage, the infestation rate gradually came down and 2nd March onward no infestation was recorded which is in contrary with Manjula *et al.* (2015) [10] who have reported leaf miner infestation started from early crop growth period. Correlation study in between Serpentine Leaf miner infestation percentage and abiotic parameters shows that a positive correlation with both maximum and minimum temperature (r = 0.847, 0.728 and 0. 828, 0.720) in Mohanpur and Barrackpore respectively (Table: 1) while the other abiotic parameters such as minimum and maximum relative humidity and rainfall have a negative correlation and bright sunshine hour have a positive correlation value with it. Regression analysis shows here all weather parameters are responsible for 94.4% variation with infestation percentage while stepwise regression denotes that the parameters like maximum temperature and maximum relative humidity responsible for 93.7 % variation in infestation percentage in field condition (Table 2).

Spodoptera (*Spodoptera litura* F.; Noctuidae, Lepidoptera)

This defoliating caterpillar was found to invade the fenugreek field in early vegetative stage of the crop and first recorded on end of November (0.2/plant). Then, a quite variable population fluctuation was observed throughout its growth period and attend its peak during third week of February (2.6–3.0 larva/plant) and declined subsequently. The caterpillar has definite preference for vegetative stage of the crop and also infestation on reproductive stage also observed. It was observed (Table : 1) that temperature and bright sunshine hour have only positive association and relative humidity and rainfall have a negative correlation with caterpillar population in field ecosystem. Murúa *et al.*, (2006) [15] reported temperature and rainfall are the most preferred climatic factor that affect the spodoptera density in the open field

ecosystem while in this experiment a variation of 41.4 % in population abundance recorded under multiple regression analysis besides stepwise analysis shows that 33.5% variation due to maximum relative humidity and bright sunshine hours (Table :2).

Flea beetle (*Phyllotreta* sp.; Chrysomelidae, Coleoptera)

Flea beetle was found to be an important pest of the crop in the area. It appeared quite early in the season, recorded first on 10th November (0.3/plant). The growth and development of the population of the insect was gradual and steady, reached a peak (3.0 – 7.0 beetles/plant) during 2nd – 9th February and then gradually declined although they were recorded till the harvest of the crop. It indicates that the insect might prefer the vegetative stage but it also has some preference for the reproductive stage, both flower and pod. Zhang *et al.*, (2000) [21] reported its infestation during the spring in China and has highly correlated with mean daily temperature. Records on the damage showed that it was directly linked with the population density of the pest and peak leaf damage ranged in between 12.6 – 18.2% coinciding with peak beetle population in the field. Flea beetle population development was found to be negatively correlate with maximum and minimum temperature, relative humidity and average rainfall while bright sunshine hour found to be positively correlate with flea beetle population (Table: 1). Ghosh (2014) [6] also reported that flea beetle population showed significant positive correlation (p=0.05) with average temperature, relative humidity, whereas significant negative correlation with rainfall. Multiple regression analysis shows that 82.5 % variation of flea beetle population due to all six abiotic parameters while in stepwise regression it was observed that minimum relative humidity and bright sunshine hour have a significant role in population development and contribute 60.0% variation (Table : 2) for flea beetle population development in fenugreek ecosystem.

Ash weevil (*Myllocerus* sp.; Chrysomelidae, Coleoptera)

Another coleopteran, ash weevil also infested the crop but its population load was quite lower than flea beetle. It also appeared quite late on the crop, first recorded on end of December (1.8 beetle/plant). Its population gradually increased and the peak was noticed during 23rd February – 9th March (3.6 – 4.6 beetles/plant) with recorded leaf damage by 7.6 – 9.8%, but the damage was comparatively lower than flea beetle. Here it was found the insect population have only significantly correlate positively with maximum temperature while relative humidity, rainfall found to be negatively correlated while bright sunshine hour have a positive interaction with population abundance (Table: 1). According to Manjunatha and Basha (2019) [11] correlation study revealed that none of the weather parameters had influenced significantly on the incidence of Ash weevil under castor ecosystem. Simple regression analysis (Table: 2) shows that all the weather parameters contribute for 65.7 % variation in population fluctuation among them maximum temperature solely responsible for 43.0 % variation with population abundance.

Painted bug, *Bagrada hilaris* (Burmeister) (Pentatomidae, Hemiptera)

Painted bug was recorded frequently with in lower population starting from very early stage of the crop, specifically of 10th November (0.8 bug/plant). Increase in population was noticed although not significantly high, which reached its peak during 23rd February (2.0- 2.3 bug/plant), coinciding with reproductive stage of the plant Divya *et al.*, (2015)[5]. Presence of the insect even on maturing plants indicate that this sucking pest might be feeding and surviving on the few available green leaves, green terminal shoots and developing pods. Here any meteorological parameters were found to be significantly correlate with population abundance while all other parameters except bright sunshine hour found to be negatively correlate with population distribution (Table : 1) and influence of dependent variances contribute only 29.8 % among them minimum temperature and minimum relative humidity important one (Table : 2).

Green stink bug (*Nezara viridula* (L.); Pentatomidae, Hemiptera)

Green stink bug also infested the crop pretty early in the season along with the painted bug. First it was recorded on 10th November (0.67 bug/plant). Population changes in undulating manner and reached its peak during 26th January to 23rd February i.e. Between 102 – 130 days after sowing. Population declines with maturity of pods while Kumar *et al.*, (2019) [9] reported its abundance during the spring season. As it was appeared with very lesser number in the field condition correlation study shows that maximum and minimum temperature have a negative association along with relative humidity and rainfall while bright sunshine hour have a positive effect over their abundance (Table: 1). From (Table: 2) it was observed that all the weather parameters have only 33.5% contribution in population fluctuation while both maximum and minimum relative humidity contributes for 20.2%.

Natural enemies and Pollinators

Fenugreek filed was rich in natural enemies and 6 species of spiders (*Distina sp*. (Archaeidae), *Marpissa sp*. (Salticidae), *Oxyopes sp*. (Oxyopidae), *Lycosa sp*. (Lycosidae), *Tetragnatha sp*. (Tetragnathidae), *Pardosa sp*. (Lycosidae); Araneae), 5 species of coccinellids (*Micraspis discolor* Fab., *Menochilus sexmaculatus* Fab., *Scymnus sp*., *Coccinella septumpunctata* L., *Coccinella transversalis* Fab.; Coccinellidae, Coleoptera), 3 species of praying mantids and one species of syrphid fly were recorded. Fenugreek is known to harbor a number of natural enemies and provides abundant shelter, pollen and nectar. Natural enemy were traceable in field all the times excepting the early vegetative growth phase of the crop, understandably because of the absence of hosts.

Four species of bees (Rock bee - *Apis dorsata* Fabr., Indian honey bee - *Apis cerana indica* Fabr., European honey bee - *Apis mellifera* L. and one bumble bee, *Bombus sp*.; Apidae, Hymenoptera) were recorded from the field and they were counted as mixed population altogether during the initiation of flowering stage. Still *A. dorsata* was comparatively higher in number over others.

Conclusion

The study during 2019-2020 revealed that cool temperature conditions were favorable for the population buildup of aphid, jassid, and whitefly, flea beetle, painted bug and green stink bug while thrips, leaf miner and spodoptera preferred a moderately high temperature during the entire period of investigation. Temperature was found as most contributing abiotic determinants for population buildup of all the creatures. Among all insect pests,

aphid observed as a most serious pest of fenugreek under this environmental zone and causes maximum yield losses to the crop at field level. Thrips jassid and whitefly are also reported for causing significant loss during the crop growth period. Fenugreek ecosystem provides a good source of natural enemy population all the times excepting the early vegetative growth phase of the crop.

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