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Studies on insect diversity in mustard (*Brassica campestris* L.) ecosystem

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Abstract
A study on the insect diversity in mustard ecosystem was carried out in the field at Student Instructional Farm, C.S.A.U.A & T, Kanpur during winter of 2015-16. Altogether total four insect-pests *Athalia lugens proxima* (Klug), *Bagrada cruciferanum* (Burmeister), *Chromatomyia horticola* (Gourear) *and Lipaphis erysimi* (Kaltenbach) and four natural enemies, *Coccinella septempunctata (*Linnaeus), *Coccinellla transversalis* (Fabricius), *Chrysoperla carnea* (Stephens) and *Xanthogramma scutellarae (*F.) have been recorded. Among these pests, mustard aphid was found as key pest, which appeared on mustard crop at 51st SW with a mean population of 2.25 aphids/10cm shoot/plant and reached its peak (225.5 aphids/10 cm shoot/plant) in the 8th SW, whereas mustard saw fly appeared first from 51st SW having 0.75 larvae/plant and reached to the peak (2.5 larvae/plant) at 2nd SW. Among different predators *C. septempunctata* was observed as a most effective predator of aphid with predation ranging between 5 to 20 per cent in the field as per visual observation. As far as biotic factors of mustard aphid, *L. erysimi* were showed a high positive correlation with predators which indicate an important role of these natural enemies in suppressing the pest population to some extent.

Keywords: *Lipaphis erysimi*, *Athalia lugens proxima*, *Coccinellla septempunctata* and mustard

1. Introduction
Brassica oilseed crops are the major *rabi* oilseed crops grown in India, which are collectively referred to as rapeseed-mustard. Belongs to genus *Brassica* of the family Cruciferae and produce oil having similar fatty acid composition. India holds first place in growing of vegetables and exporter of vegetable oils in the world. India is a third largest producer of oilseeds in the world after China and Canada. It is presently grown in diverse agro-climatic conditions under varied ecological situations *viz.*, irrigated, rain fed and also in salt affected soil. Out of 59.33 million tones of rapeseed produced over 30.74 million hectare in the world, India produce 7.67 million tons from an acreage of 6.51 million hectare with a productivity of 1179 kg/ha. In Uttar Pradesh it occupies an area of 4.35 lakh hectare land and 3.09 lakh tones production with an average productivity of 1256 kg/ha [1]. About 38 species of insects are reported to be associated with the *Brassica* oilseed crops [2]. Out of which *L. erysimi*, *Athalia proxima*, *B. cruciferanum*, *Spilarctia obliqua* Walker, *Chrotomyia horticola* are the pests of major importance. Among these, *L. erysimi* is one of the most destructive insect.
Damage caused by insect pests is an important factor in reducing the yield of oilseed brassicas. Aphid, *L. eyrsimi*, causes 10 to 90 per cent losses in yield in India to these crops depending upon severity of damage and crop stage [3]. *Brevicoryne brassicae* and *L. eyrsimi* are severe pests of *B. napus* and *B. juncea*. Several methods are used to mange aphids to reduce damage to oilseed brassicas. Host plant resistance and biological control methods are environment friendly. Unfortunately available cultivars of *B. napus* and *B. juncea* lack sufficient plant resistance to avoid damage by aphids [4, 5]. Natural enemies like *Chrysoperla* Spp. and lady bird beetles, *C. septempunctata* appear at the later stage of crop when most of the damage has been caused by aphids in mustard. Moreover, populations of these two natural enemies are too low to reduce numbers of aphids [6]. *L. eyrsimi* has been reported to prefer *B. campestris* and *B. juncea* than *B. napus*, *B. nigra*, *Eruca sativa* and *B. carinata* in India [7]. *Sinapis alba* L. and *B. napus* are susceptible to *B. brassicae* and *L. eyrsimi* than *B. juncea* in USA. Moreover, variable losses were observed in yield and yield components and insecticides proved to be effective in reducing losses of yield in these species of Brassica [8].

2. Materials and Methods

A. Experimental site and location: The field experiment was conducted during *rabi* season 2015-16 at Student Instructional Farm (SIF), Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh). It lies between 25° 26`- 28° 58` N latitude 79° 31`- 80° 34` E longitude at an altitude of 125.9 meter above mean sea level. The climate of the district is subtropical, semi arid with hot dry summers and severe cold winters. Average rainfall is about 351.6 mm through summer monsoon during July to October, there being hardly 39.8 mm rain fall in winters. The meteorological observations of temperature (maximum and minimum) and relative humidity (maximum and minimum) and rainfall (mm) for the crop period were obtained from the Department of Agronomy, C. S. Azad University of Agriculture and Technology, Kanpur. The experiment was laid out in Randomized Block Design with four replications. Varuna is a variety. Total area for the experiment was 360 square meter. For each crop sowing 4 plots of 40 square meter (10x4 mt) size was selected in each replication.

B. Observation: The observations were regularly monitored at weekly intervals in 5 randomly selected plants from each plot by following mode of observations as follows: *Athalia proxima lugens* (Number of grubs on 5 randomly selected/plot), *L. erysimi* (Number of aphids on 10 cm central top twig portion). Population of natural enemies was recorded by using visual count and sweep net. For visual method *C. septempunctata, C. transversalis, C. carnea,* and *X. scutellarae* eggs and larvae were collected from field and reared in the laboratory. Parasites that emerged out from eggs and larvae were counted. For sweep net method about 5 strokes of sweeping were made. After each strokes, the predators caught in the net were counted.

C. Identification: Identification of the insect-pests, predator and parasitoids was done through specific literature and taxonomists in the Department of Entomology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (UP).

D. Determination of correlation coefficient: The data recorded on the density of insects in mustard crop were statistically analyzed in order to determine the correlation coefficient between the population dynamics of different insects and their correlation with their natural enemies.

3. Results

A. Insect-pest and natural enemy's complex of mustard

As result stated total four insect pest *Athalia lugens proxima, B. cruciferanum, C. horticola and L. erysimi* have been recorded in the field. The sawfly and painted bug were the first appear in the mustard crop at the early seedling stage. The larval and nymphal population of mustard sawfly and painted bug appeared with peak population at flowering stage. Mustard aphid is the most destructive pest of this crop. Four natural enemies' *C. septempunctata, C. transversalis, C. carnea,* and *X. scutellarae* on mustard aphid were recorded from the study plot.

(i) Population dynamics of mustard saw fly, *Athalia proxima*

The data are presented in the (Table 1) showed that the larval population was not found up to a 50th SW later it appeared from 51st SW having 0.75 larvae/plant *i.e.,* five weeks after sowing. The larval population was fluctuated and reached to the peak of 2.5 larvae/plant at 2nd SW when the corresponding temperature were 25.4 °C (maxi.) and 4.3 °C (min.) with the RH of 69.00 per cent and 0.0 mm rainfall. Subsequently the population was further reduced with the maturity of crop and disappeared after 7th SW.

(ii) Population dynamics of mustard aphid, *L. erysimi*

The population of *L. erysimi* presented in the (Table 1) reveals that pest appear initially in the middle of January, during flower initiation of mustard crop coincided with alates aphid settling. Peak activity period of aphid was recorded during 5th to 8th SW (133.25 to 225.50 Aphid/10 cm shoot/plant) with temperature of (Max. 27 to 32.4° C and Min. 6.5 to 13.7° C) and RH (81.5 to 65.5 %) and rainfall (3.66 mm in 6th SW and 2.2 mm in 8th SW). During the 9th and 10th SW, its population started declining and later disappeared from the study plot (78.50 to 28.75 Aphid/10 cm shoot/plant).

Table 1: Population dynamics of mustard sawfly and mustard aphid, in mustard crop in relation to weather parameters during *rabi* 2015-2016.

SW	Mustard sawfly Larvae/plant	No. of Mustard Aphid/10 cm shoot/plant	Weather parameters			
			Temp. (°C)		Av. RH (%)	Rainfall (mm)
			Max.	Min.		
51	0.75(0.86)	2.25 (1.65)	23.8	0.8	63.5	0.0
52	1.75(1.50)	8.25 (2.95)	25.4	1.6	60.0	0.0
1	2.50(1.65)	28.25 (5.36)	28.0	7.5	67.0	0.0
2	2.50 (1.73)	35.25 (5.93)	25.4	4.3	69.0	0.0
3	1.75 (1.50)	68.50 (8.30)	20.2	3.8	74.0	1.2
4	1.25 (1.32)	104.25 (10.23)	27.2	5.5	61.5	1.6
5	0.50 (1.00)	133.25 (11.56)	27.0	6.5	81.5	0.0
6	0.25 (0.86)	146.50 (12.12)	26.8	9.2	84.5	3.6
7	0.00 (0.70)	142.50 (11.95)	30.4	11.7	75.0	0.0
8	0.00 (0.70)	225.50 (15.03)	32.4	13.7	65.5	2.2
9	0.00 (0.70)	78.50 (8.88)	33.2	16.6	77.5	0.0
10	0.00 (0.70)	28.75 (5.40)	32.0	13.8	82.5	1.7

Figures within parentheses √x+0.5 are transformed value

(iii) Correlation between larval populations of mustard saw fly and abiotic factors

Correlation between larval population and weather parameters *viz.*, maximum temperature, minimum temperature, RH and rainfall has been given in (Table 2). The correlation and regression analysis of abiotic factors and incidence of mustard saw fly on mustard crop variety 'Varuna' revealed that the sawfly population was significantly negatively correlated with

respect to the minimum temperature (r = -0.6353) and non-significantly negatively correlated with maximum temperature (r = -0.5790), relative humidity (r = -0.4454) and rainfall (r = -0.3162).

(iv) Correlation Coefficient between population of mustard aphid and abiotic factors

Correlation (r) worked out between aphid population and environmental factors presented in (Table 2). It showed a non-significantly positive correlation with relative humidity (r = 0.2616) whereas it was non-significantly negatively correlated with maximum temperature (r = -0.4023), minimum temperature (r = -0.5078) and rainfall (r = -0.5111). Here, the increase of RH showed an increase respective of aphid population. The aphid population have overall (R=0.6461) positive correlation values with environmental factors.

Table 2: Correlation and regression between population of mustard sawfly and mustard aphid and abiotic factors.

Sl. No.	Name of Insect	Physical Parameters	R	Regression Equation
1.	Mustard Saw Fly	Max. Temp.	-0.5790	Y= 5.1292 + (-0.1507)x
		Min. Tem	-0.6353 *	Y= 1.9392 + (-0.1242)x
		R.H.	-0.4454	Y= 4.7700 + (-0.529)x
		Rainfall	-0.3162	Y= 1.2195 + (-0.2517)x
Mustard Saw Fly + Max. Temp + Min. Temp + R. H. + Rainfall			R =0.7232	Y= a+b+c+d+ ex Y= (-0.1113)+ (0.1058) + (-0.0447) + (-0.1992) + (0.0461) x
2.	Mustard Aphid	Max. Temp.	-0.4023	Y= (-114.7862) + (7.1713)x
		Min. Temp.	-0.5078	Y= (29.7866) + (6.7849)x
		R.H.	0.2616	Y= (-66.8324) + (20.940)x
		Rainfall	-0.5111	Y= (58.5163) + (29.1072)x
Mustard Aphid+ Max. Temp. + Min. Temp. + R. H. + Rainfall			R =0.6461	Y= a + b + c + d + ex, Y= (1.84000) + (9.5934) + (-1.1295) + (23.4494) + (0.8425) x

* Test of significance at 5% level

B. Incidence of natural enemies of mustard aphid, *L. erysimi*.

The natural enemies on mustard aphid during the period of study were *C. septempunctata*, *C. transversalis*, *C. carnea*, and *X. scutellarae*. These natural enemies appeared in different stages on mustard crop represented in (Table 3). *C. carnea* appeared first at 51st SW followed by *C. septempunctata* and *C. transversalis* in 52nd SW and 1st SW, respectively. Syrphid fly did not appear till 1st SW of January 2016. It made its appearance in field in 2nd SW. The maximum population of *C. septempunctata* was recorded in 7th SW, while *C. transversalis* population was highest in 6th SW. *C. carnea* showed its maximum appearance in 4th SW with 3 adults m^{-1} row. *X. scutellarae* maximum population (7 adult m^{-1} row) was recorded in 7th SW. It was observed that these natural enemies remained in the field with their fluctuating population till maturing of crop *i.e.,* 10th SW.

i. Lady bird beetle, *C. septempunctata*: Is an aphidophagous predator of mustard aphid. It was noticed on mustard crop in 52nd SW. First the coccinellid population was very low in 2nd SW *i.e.,* 7 in number, thereafter its population increased gradually with aphid population up to a peak level of 142.5/10 cm shoot/plant. *C. septempunctata* was highest at maximum temperature of 30.4 °C, minimum temperature of 11.7 °C, RH of 75.0 per cent with no rainfall. Therefore, weather conditions favored multiplication of *C. septempunctata* along with aphid population.

ii. Green lace wing, *C. carnea*: *C. carnea* population in the mustard crop was not observed more in number to prey significantly on mustard aphid. Its population ranged from 1 to 3 in field. Its highest population was observed in the last week of January (4th SW) and middle February when aphid population was increasing at flowering stage of the crop.

iii. Syrphid fly, *X. scutellarae*: Syrphid fly inhabited mustard during peak flowering and pods formation growth stages. It was noted much later in mustard crop *i.e.,* 2nd SW, and its population was fluctuated high to low. It gained peak population (7 in number) in 7th SW. After this it declined.

Table 3: Incidence of natural enemies of mustard aphid, *L. erysimi* in mustard crop.

SW	Aphid/10 cm twig	Predators				Weather Parameters			
		C. septempunctata	*C. transversalis*	*C. carnea*	*X. scutellarae*	Temp.(°C) Max.	Temp.(°C) Min.	RH (%)	RF(mm)
51	2.25	0	0	1	0	23.8	0.8	63.5	0.0
52	8.25	2	0	2	0	25.4	1.6	60.0	0.0
1	28.25	3	4	0	0	28.0	7.5	67.0	0.0
2	35.25	7	3	1	2	25.4	4.3	69.0	0.0
3	68.5	13	1	0	1	20.2	3.8	74.0	1.2
4	104.2	5	8	3	1	27.2	5.5	61.5	1.6
5	133.2	6	8	2	3	27.0	6.5	81.5	0.0
6	146.5	11	16	1	5	26.8	9.2	84.5	3.6
7	142.5	17	5	3	7	30.4	11.7	75.0	0.0
8	225.5	9	2	1	6	32.4	13.7	65.5	2.2
9	78.75	14	7	1	1	33.2	16.6	77.5	0.0
10	28.75	3	3	0	0	32.0	13.8	82.5	1.7

C. Correlation between aphid population and its natural enemies

Mustard variety attracted more aphid population at the flowering stage and therefore the natural enemies made their appearance during 52nd SW (Table 3). The correlation and regression analysis between *L. erysimi* population and abiotic factors has been depicted in (Table 4). On the basis of value of correlation coefficient between aphid population and its

predators, it was found that mustard aphid population is positively correlated with its predators, which were present in the field *i.e., C. sepempunctata* (r = 0.572496), *C. transversalis* (r = 0.461152), *C. carnea* (r = 0.32637) and *X. scutellarae* (r = 0.88097). The predation of aphids started in the field from 52nd SW having slower rate of 10 per cent on initial aphid population as per visual observation. It was observed that 5th to 9th SW having the maximum temperature ranged between 27°C to 32°C, minimum temperature 6.5 to 16.5°C, RH 81.5 to 77.5 per cent and nil rainfall was most favorable for predators of aphids in the field. *C. septempunctata* was noticed as a most effective predator of aphid.

Table 4: Correlation coefficient and Regression between Aphid Population and its Natural Enemies.

Insect	Predators	R	Regression equation
Mustard Aphid	*C. septempunctata*	0.572496	Y= (-0.42136) + (0.891552) x
	C. transversalis	0.461152	Y= (1.984616) + (0.51308) x
	C. carnea	0.32637	Y= (-2.76961) +(0.829161)x
	X. scutellarae	0.88097	Y= (23.32193) + (0.011045)x
Mustard Aphid + *C. septempunctata* + *C. transversalis* + *C. carnea*+ *X. scutellarae*		R = 0.88937	Y= a+b+c+d+ ex, Y= (32.10789) + (24.82537)+ (0.236932) + (0.0.671538) + (0.790979) x

4. Discussion

During the study, it was observed that mustard crop was infested by four insect pest *Athalia lugens proxima, B. cruciferanum, C. horticola and L. erysimi* and four natural enemies' *C. septempunctata, C. transversalis, C. carnea,* and *X. scutellarae* have been recorded. Mustard aphid is the most destructive pest of this crop. *C. septempunctata* was effective in suppression of population of aphid. Our findings were close to that of Singh [9] who reported occurrence of mustard aphid (*L. erysimi)*, mustard sawfly (*Athalia lugens proxima*) and painted bug (*B. cruciferanum*) and their natural enemies *i.e.*, lady beetles, green lacewing (*C. carnea*), spider (*T. oblongus*) and syrphid fly (*S. balteaus*) on different *Brassica* spp.

The grubs of mustard saw fly on mustard crop was very low till 50th SW. It was observed in field ranged from 0.75-2.50 larvae/plant. In seedling stage of mustard crop when temperature was rising up slowly in 51st to 2nd SW from 23.8 °C to 25 °C, saw fly population increased significantly and reached its peak population of 2.50 grubs/plant. Thereafter its population subject to decline in further standard week. In the present study accordance with early records by several workers Sing and Singh [10] and Thakur [11] observed that the insect from middle December to last week of February, maximum population of mustard saw fly was observed at 25.4 °C in field study. In agreement with Bhgawat [12] reported that the maximum pupation and adult emergence of *Athalia proxima* was at 25 °C toria, yellow sarson, *B. juncea* and 20 °C on *Raphanus sativus.*

The activity of mustard aphid was observed from November to February, increase in temperature significant increase in population of mustard aphid was recorded during 3rd to 8th SW and reached at its peak *i.e.*, 225.5 aphid/10 cm shoot/plant during 8th SW. The similar findings by Ansari *et al.* [13] and Manzar *et al.* [14] support the present findings who reported peak aphid population at average temperature of 15.76 °C and 54.75 per cent RH on 10th February. These observations are also in conformity with the findings of Garni *et al.* [14] who recorded that the aphid appeared on cabbage at 1st week of January and reached its peak (315 aphid/plant) with 100 per cent infestation during second week of February and continued till the end of March. Population dynamics of mustard aphid and found its peak in the last week of January and 1st week of February in 15th October and 30th October sown mustard crops respectively, by Rana [16].

Based on correlation coefficient, it was found that the incidence of mustard saw fly on mustard crop was significantly negatively correlated with respect to the minimum temperature and mustard aphid showed both positive and negative correlation ship. Similar to above findings Singh and Singh [17] reported that the incidence of sawfly was negatively correlated with minimum temperature, relative humidity and rainfall, whereas the incidence of this insect showed positive correlation coefficient with maximum temperature and sunshine hours. Ahuja [18] where he noted negative correlation of mustard aphid with minimum and maximum temperature, while positive correlation with relative humidity. The temperature and rainfall had a negative role in the multiplication of mustard aphid by Mar *et al.* [19]. Contrary to the present findings Rana *et al.* [20] observed that the increase in aphid population was positively correlated with temperature. The aphid abundance and infestation had significant positive correlation with environmental factors (R= 0.95 & 0.91) by Garni *et al.* [15].

The four natural enemies *C. septempunctata*, *C. transversalis, C. carnea,* and *X. scutellarae* appeared in different stages of mustard crop. Syrphid fly was noted much later in mustard crop *i.e.,* 2nd SW, and its population was fluctuated high to low. It gained peak population (7 in number) in 7th SW by Singh and Singh [17]. *C. septempunctata*, a potential predator of *L. erysimi*, 1st on mustard during December increasing gradually with increase of aphid population. *C. carnea* appeared in February in small numbers by Sahito *et al.* [7]. Yellow sarson attracted predators including *C. septempunctata* and *C. carnea* which were maximum when the mustard aphid was in abundance by Singh *et al.* [21].

Correlation coefficient between aphid population and its predators revealed that mustard aphid population was positively correlated with its predators, which were found in the field mainly *C. sepempunctata* (r=0.572496), *C. transversalis* (r=0.461152), *Chrysoperla carnea* (r=0.32637) and *Xanthogramma scutellarae* (r=0.88097). *C. septempunctata* preyed the highest number of mustard aphids followed by *C. transversalis*. Our findings were close to that of Dwivedi *et al.* [22] and Narjary *et al.* [23] noted the role of the predator syrphid, in regulating the field population of the mustard aphid, *L. erysimi*. The numerical density of the predator was recorded to increase in response to density of the aphid prey in the field. The correlation analysis showed significant positive correlationship between the predator and prey species i.e. *L. erysimi*. Abiotic factors on *L. ereysimi* Kalt. on *B. juncea* and noticed a positive correlation with *C. sepempunctata, C. transversalis, M. sexmaculata* and *I. scutellari* by Ali and Rizvi [24] and Devi *et al.* [25]. The preying

capability of different stages of larvae of coccinellid and syrphid flies on the mustard aphid, *L. erysimi* in a laboratory and observed that grubs of the *C. septempunctata* preyed the highest number of mustard aphids (average 61.42 aphids/day) followed by *Syrphus confracter* (34.81 aphids/day), *Syrphus balteatus* Deg. (32.26 aphids/day) and *Ischiodon scutellarae* Fab. (27.76 aphids/day) during their larval span by Thakur [11].

5. Conclusion

In view of vast array of biotic and abiotic factors affecting pests and natural enemies of mustard. The development of integrated pest management based system is imperative. For this understanding of agro-ecosystems for monitoring of insect pests and exploration of superior biological agent should be needed. The mass-rearing of entomophagous arthropods in augmentive releases for better pest control. Understanding the complex interactions among the prey, the augmentive entomophage and their biotic and abiotic environment for future pest control. The present investigations will definitely throw a light on potential predator and parasitoids *Coccinella* spp., *Chrysoperla carnea* and *X. scutellarae* as biological control agents of *L. erysimi* under IPM and crop management strategy to procure economic production of affected commodities.

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