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Incidence of aphid (*Lipaphis erysimi* Kalten) in mustard and their fluctuation with biotic and abiotic factors

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Abstract
Infestation of aphid (*Lipaphis erysimi* Kalten) in mustard crop was studied at Sardarkrushinagar in North Gujarat during *Rabi* season of 2016. Mustard aphid population commenced from 4th week of December (51st SMW *i.e.* 7th WAS) with aphid index of 0.4 and reached to its peak during 4th week of February (8th SMW *i.e.* 16th WAS) with aphid index of 5.0. The parasitization by braconid endoparasite, *Diaeretiella rapae* MacIntosh on mustard aphid, *Lipaphis erysimi* Kalten was started during 4th week of January (4th SMW *i.e.* 12th WAS) and it was the highest (54.17 per cent) during the last week of February (8th SMW *i.e.* 16th WAS). The predominant coccinellid predator, *Coccinella septempunctata* Linnaeus (Grub and Adult) was active between 3rd week of January (3rd SMW *i.e.* 11th WAS) and last week of February (8th SMW *i.e.* 16th WAS). The syrphid fly, *Xanthogramma scutellarae* Fabricious was found active between 1st week of January (1st SMW *i.e.* 9th WAS) and 2nd week of February (6th SMW *i.e.* 14th WAS) in mustard ecosystem. Thereafter, larval population decreased gradually and reached up to 0.20 larva per plant during 3rd week of February (7th SMW *i.e.* 15th WAS). Among various weather parameters, wind velocity showed significantly positive correlation with mustard aphid population, whereas, morning relative humidity and evening relative humidity showed significant negative correlation. Weather parameters *viz.*, evening relative humidity which had highly significant and negative association with the activity of grub of coccinellid as well on adult. Among various abiotic factors, evening relative humidity had highly significant and negative correlation with *D. rapae* activity. There was highly significant positive correlation between the activity of aphid and its natural enemies *viz.*, coccinellids Grub, coccinellids adult and *D. rapae*.

Keywords: Aphid, *Lipaphis erysimi* Kalten, mustard, fluctuation, biotic, abiotic factors

Introduction
The brown or Indian mustard locally known as rai (*Brassica juncea* L.) is important cruciferous oilseed crop grown during *Rabi* season. They are considered as "Cash Crop." The oil content in mustard seed varies between 35 and 45 per cent and the protein content is between 20 and 24 per cent. It is a high biomass crop characterised by oblong shaped leaves (Gill *et al.*, 2011) [6]. Mustard meal or cake contains about 12 per cent oil and 38 to 42 per cent protein (Nagraj, 1995) [9]. The seasonal abundance studies are useful in divising ecologically sound and economically feasible "Integrated Pest Management". Insect pest is one of the most important yield limiting factors for the cruciferous oil seed crops. These are attacked by 21 to 38 insect pests at different location in India (Bakhetia and Sekhon, 1989) [3]. Out of an array of insect pests, mustard aphid *Lipaphis erysimi* (Kaltenbach) (Aphididae: Hemiptera) is the most important insect pest (key pest) of mustard crop in India (Rai 1976, Rohilla *et al.* 1987, Bakhetia and Sekhon 1989) [3]. This pest causes as high as 97.6 per cent yield losses in different parts of the country (Patel *et al.*, 2004) [11]. Hence, present investigation was taken to know the succession of important pests of mustard in North Gujarat condition.

Material and Methods
The experiment was conducted at Agronomy Instructional Farm, C. P. College of Agriculture, S. D. Agricultural University, Sardarkrushinagar during *rabi*, 2016. All recommended agronomical practices were followed to raise the crop except spraying with insecticide. Mustard variety "GDM 4" was sown in plots of size 13.5 x 10.0 m at a spacing 45 x 10 cm. Twenty plants were randomly tagged in plot and observations on aphid population and their natural enemies were recorded weekly as under. Aphid index was recorded using the following standard scale given by Patel *et al.*1995 [10].

Aphid index and Criteria

Aphid index	Criteria
0	Plant free from aphid infestation
1	Only a few aphids with very little injury
2	Small aphid colonies on a few twigs, no curling or yellowing of leaves.
3	Aphid colonies on almost all the twigs, stunted growth, curling and yellowing of leaves
4	Very heavy population of aphid on leaves, inflorescences, stem and siliqua
5	Completely drying of plants due to heavy infestation of aphid

The average aphid index was worked out by using following formula:

$$\text{Average Aphids Index} = \frac{0N + 1N + 2N + 3N + 4N + 5N}{\text{Total number of plant observed}}$$

Where,
0, 1, 2, 3, 4 and 5 are the aphid indices.
N = Number of plants showing respective aphid index
Natural enemies of aphid

Predators

Population of ladybird beetle, *Coccinella septempunctata* and syrphid fly, *Xanthogramma scutellarae* larvae were recorded from the twenty plants tagged per plot. From these data mean number of ladybird beetles and syrphid fly larvae per plant were worked out.

Parasite

Periodic observations were on aphid parasite, *Diaeretiella rapae* was also recorded by counting number of live aphids and parasitized (mummified) aphid from randomly selected ten pods per one plant on randomly tagged five plants at weekly. From these data percentage of parasitized aphid was computed.

Correlation of mustard aphid, its associated bioagents and weather parameters

The weekly meteorological observations on maximum and minimum temperature, morning and evening relative humidity, wind velocity, sunshine hours and rainfall was taken. Simple correlations between periodical mean values of mustard aphid and its natural enemies with various weather parameters were computed separately.

Results and Discussion

Aphid, *L. erysimi*

It is clearly evident from the results presented in Table 1 that the aphid population was increased gradually throughout season and reached at peak during 4th week of February (8th SMW *i.e.* 16th WAS) and it was 5.0 aphid index. Looking to the observations, aphid population was initiated during 4th week of December (51st SMW *i.e.* 7th WAS) and it was 0.4 aphid index. The aphid population was increased up to 0.9 aphid index during 5th week of December (52nd SMW *i.e.* 8th WAS) and the trends were continued in January also.

During 1st week of January (1st SMW *i.e.* 9th WAS) population reached to 1.2 aphid index and it increased up to 2.1 aphid index in second week of January (2nd SMW, *i.e.* 10th WAS), 3.3 aphid index in 3rd week of January (3rd SMW, *i.e.* 11th WAS) and 3.55 aphid index in 4th week of January (4th SMW, *i.e.* 12th WAS). Overall, in the month of January, the aphid population was ranged between 1.2 to 3.55 aphid index. Looking to the observations in 1st week of February (5th SMW *i.e.* 13th WAS), the aphid population reached up to 4.25 aphid index and it was increased gradually during 2nd week of February (6th SMW *i.e.* 14th WAS) and recorded 4.75 aphid index.

Table 1: Population of aphid and natural enemies in mustard at S K Nagar (*Rabi* 2016-17)

Month and Weeks		SMW	WAS	Aphid Index (0-5)	Number of natural enemies/plant			Parasitism by *D. rapae* (%)
					Coccinellid		Syrphid fly	
					Grub	Adult	(Larva)	
December	II	49	5	0	0	0	0	0
	III	50	6	0	0	0	0	0
	IV	51	7	0.4	0	0	0	0
	V	52	8	0.9	0	0	0	0
January	I	1	9	1.2	0	0	0.3	0
	II	2	10	2.1	0	0	1.0	0
	III	3	11	3.3	0.8	0.4	1.6	0
	V	4	12	3.55	1.4	0.6	2.65	6.25
February	I	5	13	4.25	2.5	0.9	4.85	18.20
	II	6	14	4.75	3.1	1.3	4.85	30.50
	III	7	15	4.95	3.6	2.6	0.2	45.00
	IV	8	16	5.0	4.45	3.8	0	54.17

SMW: Standard Meteorological Week; WAS: Week After Sowing.

During 3rd week of February (7th SMW *i.e.* 15th WAS), it was 4.95 aphid index and reached to its peak *i.e.* 5.0 aphid index during 4th week of February (8th SMW *i.e.* 16th WAS). Overall, in the month of February the aphid population was ranged from 4.25 to 5.0 aphid index. From the results, it can be inferred that the incidence of aphid occurred between the fourth weeks of December to fourth week of February and population of aphid is varied from 0.4 to 5.0 aphid index. Maximum aphid population was observed during 4th week of February (8th SMW *i.e.* 16th WAS) and it was 5.0 aphid index. The crop was harvested in 1st week of March, 2017.

The results are in close accordance with the findings of Ansari *et al.* (2007) [2], where the appearance of mustard aphid was recorded on 11th January and the peak (83.42 aphids/10 cm

twig) on 10th February.

Natural enemies of mustard aphid Predators

Coccinellids (Grub)

The data presented in Table 1 revealed that, the activity of coccinellid (grub) was increased gradually throughout the season and reached at peak during 4th week of February (8th SMW *i.e.* 16th WAS) and it was 4.45 grub per plant. Looking to the observations on Coccinellids (Grub), the population was commenced during 3rd week of January (3rd SMW *i.e.* 11th WAS) and it was 0.8 grub per plant. The grub population was increased up to 1.4 grub per plant during 4th week of January (4th SMW *i.e.* 12th WAS) and trend was continued in February also. During 1st week of February (5th SMW *i.e.* 13th WAS) it reached to 2.5 grub per plant and the population was increased up to 3.1 grub per plant in 2nd week of February (6th SMW *i.e.* 14th WAS), 3.6 grub per plant in 3rd week of February (7th SMW *i.e.* 15th WAS) and 4.45 grub per plant in 4th week of February (8th SMW *i.e.* 16th WAS). Overall in the month of February the grub population was ranged from 2.5 to 4.45 grub per plant. From the results the activity of Coccinellid grub commenced from 3rd week of January persisted up to 4th week of February and population of grub was varied from 0.8 to 4.45 grub per plant. The population of Coccinellid grub showed gradual increase till harvesting of the crop. The maximum grub population was observed during 4th week of February (8th SMW *i.e.* 16th WAS).

Coccinellids (Adult)

The data presented in Table 1 revealed that the activity of Coccinellid (Adult) was increased gradually throughout the season and reached at peak during 4th week of February (8th SMW *i.e.* 16th WAS) and it was 3.8 adults per plant. Looking to the observations on Coccinellids (Adult) it initiated during 3rd week of January (3rd SMW *i.e.* 11th WAS) and it was 0.4 adult per plant. The adult population was increased up to 0.6 adult per plant during 4th week of January (4th SMW *i.e.* 12th WAS) and trend was continued in February also. During 1st week of February (5th SMW *i.e.* 13th WAS) it reached to 0.9 adults per plant and the population was increased up to 1.3 adults per plant in second week of February (6th SMW *i.e.* 14th WAS), 2.6 adults per plant in 3rd week of February (7th SMW *i.e.* 15th WAS) and 3.8 adults per plant in 4th week of February (8th SMW *i.e.* 16th WAS). Overall in the month of February the adult population was ranged between 0.9 and 3.8 adult per plant.

From the results the activity of coccinellid adult commenced from the 3rd week of January to 4th week of February and population of adult was varied from 0.4 to 3.8 adults per plant. The population of Coccinellid adult gradually increased till harvesting of the crop. The maximum adult population was observed during 4th week of February (8th SMW *i.e.* 16th WAS).

Maximum activity of Coccinellid was recorded in second week of March during *rabi* season (Singh *et al.*, 2011) [15]. Yadav *et al.* (2014) [17] observed that the activity of coccinellid predator was found during second week of January.

Syrphid fly

The data presented in Table 1 revealed that the activity of syrphid fly larvae was increased gradually and reached at peak during 2nd week of February (6th SMW *i.e.* 14th WAS) and it was 4.85 larvae per plant. Looking to the observations on syrphid fly larva, it initiated during 1st week of January (1st SMW *i.e.* 9th WAS) and it was 0.3 larvae per plant. The larval population was increased up to 1.0 larva per plant in second week of January (2nd SMW *i.e.* 10th WAS), 1.6 larvae per plant in 3rd week of January (3rd SMW *i.e.* 11th WAS) and 2.65 larvae per plant in 4th week of January (4th SMW *i.e.* 12th WAS). Overall, in the month of January the larval

population was ranged from 0.3 to 2.65 larvae per plant. Looking to the observations of 1st week of February (5th SMW *i.e.* 13th WAS) the larval population reached up to 4.85 larvae per plant. It was similar during 2nd week of February (6th SMW *i.e.* 14th WAS) that was 4.85 larvae per plant. Thereafter, larval population decreased to 0.20 larvae per plant in 3rd week of February (7th SMW *i.e.* 15th WAS).

From the results, it can be inferred that the incidence of syrphid fly larva started during 1st week of January to 3rd week of February. The maximum syrphid fly larva was observed during 2nd week of February (5th and 6th SMW *i.e.* 13th and 14th WAS).

Zala (1995) [8] from Anand reported that the syrphid fly population was maximum in the month of February. The results are in close accordance with the present findings.

Parasite

***Diaeretiella rapae* MacIntosh**

The data presented in Table 1 revealed that the parasitization due to *D. rapae* on aphid was increased gradually throughout the season and reached at peak during 4th week of February (8th SMW *i.e.* 16th WAS) and it was 54.17 per cent parasitization. Looking to the observation on parasitization due to *D. rapae* on aphid it initiated during 4th week of January (4th SMW *i.e.* 12th WAS) and it was 6.25 per cent. The increased trend was continued in February also. During 1st week of February (5th SMW *i.e.* 13th WAS) it was 18.20 per cent parasitization. The parasitization of *D. rapae* on aphid was increased up to 30.50 per cent in second week of February (6th SMW *i.e.* 14th WAS), 45.00 per cent in third week of February (7th SMW *i.e.* 15th WAS) and 54.17 per cent in fourth week of February (8th SMW *i.e.* 16th WAS). Overall, in the month of February the parasitization of *D. rapae* on aphid was ranged between 18.20 to 54.17 per cent.

From the results, it can be inferred that the parasitization on aphids by *D. rapae* started during 4th week of January to 4th week of February. The rate of parasitization showed gradual increase till harvesting of the crop. The maximum parasitization was observed during 4th week of February (8th SMW *i.e.* 16th WAS).

Similar findings were also reported by Vekaria and Patel (1999) [16] where, the syrphid fly maggots and *Diaeretiella rapae* MacIntosh appeared simultaneously in mustard crop in the 11th WAS and remained active till harvest of the crop.

Correlation of mustard aphid and their natural enemies with weather parameters

To know the effect of various abiotic factors *viz.*, Maximum temperature (MaxT), Minimum temperature (MinT), Morning relative humidity (RH1), Evening relative humidity (RH2) and Bright sunshine (BSS) on the population fluctuation of mustard aphid and natural enemies, correlation coefficients were worked out and presented in Table 2.

Table 2: Correlations among weather parameters and mustard aphid population as well as various bio agents

Weather parameter	Aphid index	Number of natural enemies/plant			Para- sitism by *D. rapae* (%)
		Coccinellid		Syrphid fly (Larva)	
		Grub	Adult		
Maximum Temperature°C (Max T)	0.04	0.385	0.442	-0.186	0.445
Minimum Temperature°C (Min T)	0.230	0.351	0.362	-0.047	0.329
Morning Relative Humidity % (RH1)	-0.601*	-0.554	-0.497	-0.307	-0.496
Evening Relative Humidity % (RH2)	-0.720**	-0.828**	-0.754**	-0.354	-0.790**
Wind velocity (km/hr)	0.668*	0.388	0.284	0.422	0.256
Bright sunshine hours/day	-0.023	0.278	0.195	0.117	0.314
Note : *Correlation is significant at 0.05 level; **Correlation is significant at 0.01 level; *Significant at 5 % level (‘r’ = ± 0.576); **Significant at 1 % level (‘r’ = ± 0.708**)**.					

Aphid, *L. erysimi*

The correlation coefficient between aphid index and weather parameters are presented in Table 2. The aphid population has significant and positive correlation with wind velocity ('r' = 0.668*). It has positive but non-significant correlation with maximum temperature ('r' = 0.04) and minimum temperature ('r' = 0.230). The aphid population showed negative and significant relationship with morning relative humidity ('r' = -0.601*) and the aphid population showed negative and highly significant relationship with evening relative humidity ('r' = -0.720**). The aphid population showed negative and non-significant relationship with bright sunshine ('r' = - 0.023).

The results are in close accordance with findings of Gami *et al*. (2002) [5], where he reported that morning relative humidity, bright sunshine hours and wind velocity did not show any significant effect on aphid population.

Natural enemies Predators Coccinellids (Grub)

The correlation coefficient between coccinellids (Grub) and weather parameters are presented in Table 2 indicated that very few parameters had significant effect on coccinellids (Grub). Maximum temperature ('r' = 0.385), minimum temperature ('r' = 0.351), wind velocity ('r' = 0.388) and bright sunshine hours ('r' = 0.278) found positively, but non significantly correlated with the activity of coccinellids (Grub). Evening relative humidity ('r' = -0.828**) was highly and negatively as well significantly correlated with the activity of coccinellids (Grub), while morning relative humidity ('r' = -0.554) showed negative and non significant correlation with the activity of coccinellids (Grub).

Coccinellids (Adult)

The correlation coefficient between coccinellids (Adult) and weather parameters are presented in Table 2 indicated that none of the parameters had significant effect on coccinellids (Adult) except evening relative humidity. However, maximum temperature ('r' = 0.442), minimum temperature ('r' = 0.362), wind velocity ('r' = 0.284) and bright sunshine hours ('r' = 0.195) found positively and non significantly correlated with the activity of coccinellids (Adult). Evening relative humidity ('r' = -0.754**) showed highly significant negative correlation with the activity of coccinellids (Adult), while morning relative humidity ('r' = -0.497) was negatively correlated (non significant) with the activity of coccinellids (Adult).

The results are in close accordance with the findings of Khedkar (2011) [8] where correlation coefficient between coccinellids and weather parameters *viz.*, bright sunshine (0.138), maximum temperature (0.390), morning relative humidity (-0.034) and wind velocity (-0.161) were negatively correlated, but the impact was non significant.

Syrphid fly

The data on correlation of syrphid fly population with weather parameters are presented in Table 2. Wind velocity ('r' = 0.422) and bright sunshine ('r' = 0.117) showed non significant positive correlation with activity of syrphid fly larva, whereas maximum temperature ('r' = - 0.186), minimum temperature ('r' = -0.047), morning relative humidity ('r' = -0.307), evening relative humidity ('r' = -0.354) had negative correlation with the syrphid fly larva population but were found non-significant.

Parasite

D. rapae

The data on correlation coefficient between *D. rapae* and weather parameters are presented in Table 2. The abiotic factor evening relative humidity ('r' = -0.790**) had highly significant and negative correlation with *D. rapae*. Morning relative humidity ('r' = -0.496) showed negative correlation (non significant) with *D. rapae* population. However, maximum temperature ('r' = 0.445), minimum temperature ('r' = 0.329) wind velocity ('r' = 0.256) and bright sunshine hours ('r' = 0.314) found positively correlated (non significant) with activity of *D. rapae* population.

L. erysimi parasitization by *D. rapae* was positively correlated with minimum temperature and evaporation as per Achintya *et al.* (2012) [1]. As per the results of Kavad (2013) [7] morning and evening relative humidity influenced negatively with the population of *D. rapae.* These results are in accordance with present findings.

Correlation between mustard aphid populations and its natural enemies Aphid and ladybird beetle (Grub)

The correlation of population of aphid with Coccinellid (Grub) was also worked out and presented in Table 3. The Population of Coccinellid (Grub) showed highly significant and positive correlation ('r' = 0.907**) with aphid population.

Table 3: Correlation coefficient ('r') between aphid and natural enemies in mustard

Sr. No.	Natural enemies	Aphid
1	*Coccinellid* (Grub)	0.907**
2	*Coccinellid* (Adult)	0.784**
3	Syrphid fly	0.558
4	*D. rapae*	0.806**
** Correlation is significant at 0.01 level.		

Aphid and ladybird beetle (Adult)

The correlation of population of aphid with Coccinellid (Adult) was also worked out and presented in Table 3. The population of Coccinellid (Adult) showed highly significant and positive correlation ('r' = 0.784**) with aphid population. Thus, it is clearly indicated that as the aphid population

increased, the *C. septempunctata* (Adult and Grub) population was also increased.

As reported by Choudhary and Pal (2006) [4] the lady bird beetle exhibited positive correlation with aphid population. Thus, the present findings are in confirmity with the results of earlier workers.

Aphid and Syrphid fly (Larva)

The correlation of population of aphid with syrphid fly (larva) was also worked out and presented in Table 3. The Population of syrphid fly (Larva) showed high and positive correlation ('r' = 0.558), but the impact was non significant.

As reported by Choudhary and Pal (2006) [4] the syrphid fly exhibited positive correlation with aphid population. Thus, the present findings are in confirmity with the results of earlier workers.

Aphid and parasite

The correlation of population of aphid with *D. rapae* was also worked out and presented in Table 3. Results indicated that there was significant and highly positive correlation ('r' = 0.806**) between the activity of aphid and *D. rapae*. Raghvani (1991) [14] also observed similar association between aphid and its parasite. Thus, the present findings are in concurrence with the earlier results.

Conclusion

Aphid, *L. erysimi*

The population of aphid and coccinellid was increased gradually throughout the season and reached at peak during 4th week of February. Whereas, population of syrphid fly larvae was also increased gradually and reach peak during 2nd week of February.

The parasitization due to *D. rapae* on aphid was increased throughout the season and reached at peak during 4th week of February. Among various abiotic factors evening relative humidity had highly significant and negative correlation with *D. rapae* activity. There was highly significant positive correlation between the activity of aphid and its natural enemies *viz.*, coccinellid grub, coccinellids adult and *D. rapae.*

The population of coccinellid grub and adult showed highly significant and positive correlation with aphid population. Whereas, syrphid fly larvae showed the highly positive correlation, but impact was non significant.

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