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Population dynamics of potential bioagents of mustard aphid, *Lipaphis erysimi* (Kaltenbach) on different cultivars of rapeseed-mustard

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Abstract: Field experiment was conducted to study the population dynamics of potential bioagents of mustard aphids on 9 different cultivars which included: *Brassica alba* cv. PSB-I, *Eruca sativa* Mill cv. T-27, *Brassica campestris* cv. BSH-I, *Brassica napus* cv. Sheetal, *B. carinata* Braun cv. CCN-06-1, *B. juncea* L. cv. Varuna, *B. nigra* Koch. cv. PBR-I, *Brassica campestris* cv.YST-151 and *Brassica campestris* cv. PT-30. Population of aphid and natural enemies was recorded at weekly intervals. The results indicated that the first appearance of coccinellids and syrphids has been observed during 4th standard week, which gradually build up population and attained peak during 9th (pooled mean 1.42 coccinellids/ plant and 0.122 syrphid larva/plant) and 8th standard week (pooled mean 3.96 coccinellids/plant and 0.228 syrphid larva/plant) in 2008-09 and 2009-10 respectively, followed by a declining trend in the following weeks. Similarly first appearance of parasitization has been found to occur from 4th standard week followed by a gradual increase in the following weeks with maximum parasitization on PT-30 (33.32%) and BSH-1 (35.25%) during 2008-09 and 2009-10 respectively. Correlation between abiotic factors and these natural enemies was also studied. It has been observed that with the increase of aphid population the population of natural enemies also increased. The population dynamics of mustard aphids and its natural enemies varied according to climatic situations and between host plant species. So by computing population trends of both natural enemies and aphids with meterological records would generate information on relative abundance and would certainly help in formulating sound pest management strategies against mustard aphid.

Keywords: Coccinellids, *Diaeretiella rapae, Lipaphis erysimi*, Percent parasitization, Syrphids

INTRODUCTION

Brassicas are an important group of crops which have great economic importance all over the world (Trdan *et al.*, 2005; Suwabe *et al.*, 2006; Hong *et al.*, 2008; Golizadeh *et al.*, 2009). They can be grown as vegetables and oilseeds (Kumar, 2015). In India, under the name rapeseed and mustard, three cruciferous members of *Brassica* species are cultivated; *B. juncea* (Indian mustard or commonly called *rai*) being the chief oil-yielding crop, while three ecotypes of *B. rapa* ssp. *oleifera*, viz. brown *sarson*, yellow *sarson*, *toria* and *B. napus* are grown to a limited extent (Bhatia *et al.*, 2011). Rapeseed mustard accounts for nearly one-third of the oil produced in India, making it the country's key edible oilseed crop. In India, during 2013-14 area and production of rapeseed mustard was 6.70 million hectare and 7.96 million tons respectively (ASG, 2014).

Among the insect pests, the mustard aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae) is a serious threat to successful cultivation of oilseed *Brassicas* in India (Kumar *et al.*, 2011; Atri *et al.,* 2012) and it infest the crop right from seedling stage to maturity (Singh, 2013). For the management of mustard aphids at present farmers spray systemic insecticides which not only pollute the environment but also kill several natural enemies which have been reported naturally in mustard ecosystem.. Several natural enemies of mustard aphids have been reported from time to time. Among the several bio-agents, syrphid flies (*S. confrater*, *S.balteatus* and *I. scutellaris*) and lady bird beetle, *C. septempunctata* are the important entomophagous predators and in field they are observed as an efficient predator of *L. erysimi* (Singh *et al.,* 2012; Singh, 2013). *Diaeretiella rapae* (Mc Intosh) (Hymenoptera: Aphidiinae) is an important primary, polyphagous parasitoid of many aphid species throughout the world (Kumar 2015). In India, the rate of parasitism of mustard aphid, by *D. rapae* on rape-seed mustard crop varied from 20% to 51% in Himachal Pradesh to 60-97% in Maharashtra (Dogra *et al.*, 2003; Kumar, 2015). The population dynamics of both mustard aphid as well as its associated bioagents with particular reference to the agro-ecological conditions has an added significance in pest management. The knowledge of

L. erysimi–natural enemies' relationships will also help to improve conservation biological control strategies as many of the natural enemies are present in mustard ecosystem. The population dynamics of mustard aphids and its natural enemies vary according to climatic situations and between host plant species. Keeping the above view in mind, the ecological study of bioagents viz. coccinellids, syrphids and *Diaeretiella rapae* of mustard aphid on 10 different varieties of mustard was conducted with the objective to generate information on the suitability of these bioagents to reduce aphid population and to know whether resident natural enemies can be used for conservation biological control of this pest.

MATERIALS AND METHODS

The seasonal occurrence of bioagents of *Lipaphis erysimi* (Kaltenbach) on oleiferous *Brassicas* was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during rabi season, for two consecutive years, 2008-09 and 2009-2010. Experiments were laid down in Randomized Block Design (RBD) with three replications. 9 oilseed *Brassica* species viz. *Brassica alba* (syn. *Sinapis alba*) cv. PSB-I, *Eruca sativa* Mill cv. T-27, *Brassica campestris* cv. BSH-I, *Brassica napus* cv. Sheetal, *B. carinata* Braun cv. CCN-06-1, *B. juncea* L. cv. Varuna, *B. nigra* Koch. cv. PBR-I, *Brassica campestris* cv.YST-151 and *Brassica campestris* cv. PT-30 were taken. Each *Brassica species* was treated as one treatment. Sowing of different oilseed *Brassica* was done on 10th November in both the years, 2008 and 2009. The plot size of 5m×3m was maintained with row to row and plant to plant distances of 30 and 10 cm respectively. During experimentation all the recommended cultural practices were followed to raise the healthy crop except plant protection measures. Daily and weekly average data on maximum temperature, rainfall, relative humidity, sunshine hours, wind velocity and evaporation prevailed during the course of present study were recorded at meteorological observatory of this University.

Insect sampling: Field surveillance was regularly carried out from crop sowing to maturity at weekly intervals to record appearance of mustard aphids and natural enemies. At pest appearance, data on the incidence of *L. erysimi* and different natural enemies *viz*. Coccinellid adults and grubs, syrphid fly larvae and number of parasitized/mummified aphids were recorded at weekly intervals from 5 plants selected randomly. The sampling methods used to assess the number of *L. erysimi* and different predators involved whole plant visual inspection (Patel *et al.*, 2004). All life stages of different natural enemies were recorded on whole plant basis. The immature stages were brought to the laboratory to develop to adult stage for their accurate identification. All the natural enemies were identified up to species level.

Observation on the percent field parasitization of mustard aphid by the parasitoid *Diaeretiella rapae* was also recorded in the mustard field by counting the number of healthy and mummified (parasitized) aphids from selected tagged plants of each variety. Percent parasitization was worked out according to the formula as given by Root and Skelsey (1969).

$$\text{Per cent parasitization} = \frac{\text{Number of parasitized aphids}}{\text{Total number of aphids (healthy and parasitized)}} \times 100$$

Statistical analysis: Randomized block design (RBD) was used to compute the variance. The correlation was also worked out between environmental parameters (maximum and minimum (0C) temperature, relative humidity, rainfall (mm), wind velocity (Km/h), sunshine hours) and the population of Coccinellids, syrphid larvae and per cent parasitization under field conditions.

RESULTS AND DISCUSSION

Population dynamics of Coccinellids (Coleoptera: Coccinellidae) on different cultivars of rapeseed-mustard: In both the years the activity of coccinellids was initiated during 4th standard week on all cultivars except T-27, Sheetal, CCN-06-1 and PBR-1 and continued till 10th week except PT-30. After the initiation of activity, on all cultivars the population of coccinellids in both the years gradually increased, attained maximum population (9th standard week in 2008-09 and 8th standard week in 2009-10) followed by a decline (Table 2).

In 2008-09 maximum population of coccinellids was observed in 9th standard week on all cultivars except

Table 1. Population buildup of *L. erysimi* on different cultivars of rapeseed-mustard under field conditions.

Average number of aphid population per 10 cm central twig during standard weeks on 9 cultivars							
2008-09				2009-10			
Standard week	Pooled mean	S. Em	CD at 5%	Standard week	Pooled mean	S. Em	CD at 5%
04	117.17	3.82	11.48	04	132.79	6.01	18.02**
05	143.88	5.17	15.51	05	162.30	3.75	11.26**
06	149.89	5.73	17.20	06	189.35	3.63	10.88**
07	107.98	9.60	28.19	07	171.90	4.23	12.68**
08	71.44	3.92	11.72	08	139.45	4.05	12.15**
09	30.07	3.25	9.75	09	99.12	3.26	9.77**
10	6.47	1.40	4.22	10	12.22	1.13	3.40**

Table 2. Population buildup of Coccinellids on different cultivars of rapeseed-mustard under field conditions.

Cultivar	Average number of lady bird beetles per plant during standard weeks															
	2008-09	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**
	04	**04**	**05**	**05**	**06**	**06**	**07**	**07**	**08**	**08**	**09**	**09**	**10**	**10**	**Mean**	**Mean**
Brassica alba	0.33	1.13	0.60	1.93	1.73	3.00	1.80	5.06	2.66	7.66	3.0	8.20	2.93	7.40	1.86	4.91
cv. PSB-1	(0.911)	(1.27)	(1.04)	(1.55)	(1.49)	(1.86)	(1.51)	(2.35)	(1.77)	(2.85)	(1.87)	(2.94)	(1.85)	(2.80)		
Eruca sativa	0.00	0.26	0.00	0.46	0.00	1.06	0.00	1.53	0.60	2.26	1.0	1.20	0.60	0.66	0.31	1.06
cv. T-27	(0.70)	(0.87)	(0.70)	(0.975)	(0.70)	(1.24)	(0.70)	(1.42)	(1.04)	(1.65)	(1.22)	(1.29)	(1.04)	(1.07)		
B.campestris	0.20	0.86	0.33	1.53	0.60	2.66	1.40	3.93	1.80	5.06	2.0	3.20	1.33	2.73	1.09	2.85
cv. BSH-1	(0.83))	(1.15)	(0.911)	(1.42)	(1.04)	(1.77)	(1.37)	(2.10)	(1.51)	(2.35)	(1.58)	(1.92)	(1.35)	(1.79)		
B. napus cv.	0.00	0.00	0.00	1.13	0.00	1.86	0.00	2.40	0.53	3.06	0.80	5.0	1.26	3.86	0.37	2.47
Sheetal	(0.70)	(0.70)	(0.70)	(1.27)	(0.70)	(1.53)	(0.70)	(1.70)	(1.01)	(1.88)	(1.13)	(2.33)	(1.32)	(2.08)		
B. carinata	0.00	0.00	0.00	1.03	0.00	2.13	0.00	3.06	0.33	3.60	0.40	5.60	0.66	4.20	0.19	2.80
cv. CCN-06-1	(0.70)	(0.70)	(0.70)	(1.423)	(0.70)	(1.62)	(0.70)	(1.88)	(0.911)	(2.02)	(0.94)	(2.46)	(1.07)	(2.16)		
B. juncea cv.	0.26	0.66	0.53	1.33	0.93	2.60	1.46	3.40	2.20	4.20	2.26	2.53	1.66	2.06	1.32	2.39
Varuna	(0.87)	(1.07)	(1.01)	(1.35)	(1.19)	(1.76)	(1.40)	(1.97)	(1.64)	(2.16)	(1.65)	(1.73)	(1.46)	(1.59)		
B. nigra cv.	0.00	0.33	0.00	0.93	0.26	1.33	0.66	1.93	1.06	3.40	1.33	2.20	1.53	1.80	0.69	1.70
PBR-1	(0.707)	(0.911)	(0.70)	(1.189)	(0.87)	(1.35)	(1.07)	(1.55)	(1.24)	(1.97)	(1.35)	(1.64)	(1.42)	(1.50)		
B. campestris	0.13	0.53	0.26	1.33	0.46	1.73	0.73	2.93	1.20	3.86	1.60	1.86	1.13	1.26	0.78	1.92
cv. YST-151	(0.793)	(1.01)	(0.87)	(1.35)	(0.98)	(1.48)	(1.10)	(1.85)	(1.30)	(2.08)	(1.44)	(1.52)	(1.27)	(1.32)		
B. campestris	0.13	0.33	0.26	0.86	0.33	1.40	0.53	2.00	0.93	2.60	0.40	1.60	0.00	0.933	0.36	1.3
cv. PT-30	(0.793)	(0.911)	(0.87)	(1.16)	(0.911)	(1.37)	(1.01)	(1.57)	(1.19)	(1.75)	(0.94)	(1.44)	(0.70)	(1.19)		
Average	0.11	0.45	0.22	1.17	0.47	1.97	0.73	2.91	1.25	3.96	1.42	3.48	1.23	2.76		
S.Em	0.046	0.151	0.090	0.199	0.111	0.221	0.117	0.190	0.113	0.248	0.121	0.343	0.095	0.320		
CD at 5%	0.139	0.455	0.270	0.599	0.333	0.665	0.350	0.570	0.340	0.745	0.340	1.03	0.287	0.960		

Figures in parentheses are $\sqrt{(x+0.5)}$ transform value.

Table 3. Population buildup of Syrphid larvae on different cultivars of rapeseed-mustard under field conditions.

Cultivar	Average number of Syrphid larvae per plant during standard weeks															
	2008-09	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**
	04	**04**	**05**	**05**	**06**	**06**	**07**	**07**	**08**	**08**	**09**	**09**	**10**	**10**	**Mean**	**Mean**
Brassica alba cv. PSB-1	0.13 (.793)	0.46 (0.98)	0.33 (0.911)	0.66 (1.07)	0.73 (1.10)	1.0 (1.22)	1.20 (1.30)	1.66 (1.46)	1.66 (1.46)	2.26 (1.65)	2.40 (1.70)	2.80 (1.81)	1.93 (1.55)	2.20 (1.64)	1.19	1.57
Eruca sativa cv. T-27	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.13 (0.793)	0.00 (0.70)	0.40 (0.94)	0.00 (0.70)	0.66 (1.07)	0.40 (0.94)	0.93 (1.19)	0.26 (0.87)	0.60 (1.04)	0.13 (1.79)	0.20 (0.83)	0.11	0.41
B. campestris cv. BSH-1	0.13 (0.793)	0.26 (0.87)	0.20 (0.83)	0.53 (1.01)	0.33 (0.911)	0.80 (1.13)	0.73 (1.10)	1.26 (1.32)	0.86 (1.16)	2.00 (1.57)	0.53 (1.01)	1.73 (1.48	0.40 (0.94)	1.26 (1.32)	0.43	1.12
B. napus cv. Sheetal	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.33 (0.911)	0.00 (0.70)	0.53 (1.01)	0.46 (0.98)	1.06 (1.24)	0.73 (1.10)	1.20 (1.30)	1.20 (1.30)	1.53 (1.42)	0.34	0.66
B. carinata cv. CCN-06-1	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.00 (0.70)	0.46 (0.98)	0.00 (0.70)	0.60 (1.04)	0.26 (0.87)	1.13 (1.27)	0.60 (1.04)	1.33 (1.35)	0.80 (1.13)	1.60 (1.44)	0.23	0.73
B. juncea cv. Varuna	0.13 (0.793)	0.33 (0.911)	0.26 (0.87)	0.53 (1.01)	0.46 (0.98)	0.73 (1.10)	0.80 (1.13)	1.13 (1.27)	1.20 (1.30)	1.86 (1.53)	1.46 (1.40)	1.60 (1.44)	0.73 (1.10)	1.33 (1.35)	0.72	1.07
B. nigra cv. PBR-1	0.00 (0.707)	0.13 (0.793)	0.00 (0.70)	0.33 (0.911)	0.13 (1.79)	0.46 (0.98)	0.26 (0.87)	1.20 (1.30)	0.53 (1.01)	1.40 (1.37)	0.80 (1.13)	0.93 (1.19)	1.20 (1.30)	0.60 (1.04)	0.34	0.72
B. campestris cv. YST-151	0.00 (0.70)	0.26 (0.87)	0.13 (1.79)	0.46 (0.98)	0.33 (0.911)	0.66 (1.07)	0.53 (1.01)	1.06 (1.24)	0.73 (1.10)	1.66 (1.46)	0.26 (0.87)	1.26 (1.32)	0.13 (1.79)	1.06 (1.24)	0.30	0.911
B. campestris cv. PT-30	0.13 (0.793)	0.20 (0.83)	0.20 (0.83)	0.40 (0.94)	0.26 (0.87)	0.53 (1.01)	0.46 (0.98)	0.93 (1.19)	0.73 (1.10)	1.33 (1.35)	0.13 (1.79)	0.80 (1.13)	0.00 (0.70)	0.60 (1.04)	0.25	0.68
Average	0.07	0.18	0.12	0.33	0.24	0.59	0.42	1.00	0.74	1.51	0.79	1.36	0.72	1.15		
S.Em	0.046	0.075	0.037	0.104	0.070	0.157	0.078	0.214	0.109	0.228	0.122	0.182	0.141	0.158		
CD at 5%	0.139	0.225	0.112	0.312	0.210	0.472	0.236	0.642	0.328	0.684	0.367	0.548	0.425	0.473		

Figures in parentheses are $\sqrt{(x+0.5)}$ transform value.

Table 4. Percent field parasitization of *L. erysimi*by *Diaeretiella rapae* on different cultivars of rapeseed mustard under field conditions.

Cultivar	Per cent field Parastization of *L. erysimi* during standard weeks													
	2008-09	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**	**2008-09**	**2009-10**
	04	**04**	**05**	**05**	**06**	**06**	**07**	**07**	**08**	**08**	**09**	**09**	**10**	**10**
Brassica alba cv. PSB-1	2.04	1.02	4.97	3.57	6.07	8.52	8.06	12.23	12.24	16.38	19.12	21.89	25.44	26.97
Eruca sativa cv. T-27	0.00	0.00	0.00	0.00	0.00	0.726	0.00	0.876	0.85	1.22	1.15	2.01	1.94	2.29
B. campestris cv. BSH-1	2.63	5.41	6.05	10.32	7.27	15.32	10.34	20.46	15.40	27.23	24.26	31.92	30.35	35.25
B. napus cv. Sheetal	0.00	0.00	0.00	0.00	0.00	1.45	3.42	2.55	5.71	6.47	8.65	10.24	14.90	15.15
B. carinata cv. CCN-06-1	0.00	0.00	0.00	0.00	0.00	2.51	4.98	3.34	6.74	7.69	10.41	12.48	16.31	18.50
B. juncea cv. Varuna	0.00	0.00	5.10	3.20	6.06	5.31	9.32	9.21	14.60	14.53	22.36	19.49	28.85	25.38
B. nigra cv. PBR-1	0.00	0.00	0.00	2.44	2.63	4.55	5.49	7.25	9.31	10.46	13.65	15.35	17.08	19.06
B. campestris cv. YST-151	2.45	4.06	5.31	7.48	6.35	13.23	11.60	18.30	16.00	25.12	23.15	29.78	29.02	33.33
B. campestris cv. PT-30	3.28	3.02	6.63	5.34	11.75	10.45	17.53	16.19	24.99	19.47	30.19	25.15	33.32	30.17
Average	1.15	0.455	3.11	1.15	4.45	1.87	7.86	3.08	11.76	4.52	16.99	3.60	21.92	2.96
S.Em	0.116	0.074	0.157	0.229	0.151	0.212	0.182	0.216	0.196	0.216	0.422	0.142	0.204	0.217
CD at 5%	0.349**	0.222**	0.472**	0.688**	0.453**	0.635**	0.548**	0.649**	0.588	0.647**	1.26**	0.425**	0.613**	0.652**

Table 5. Correlation co-efficient between the population of Coccinellids and weather parameters on different cultivars of rapeseed mustard.

Cultivar	Temperature (^{0}C)				Relative humidity (%)				Rainfall (mm)		Wind velocity (km/h)		Sunshine hours	
	Maximum		Minimum		0712 AM		1412 PM							
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Brassica alba cv. PSB-1	0.919**	0.791*	0.773*	0.882*	-0.711 ^{NS}	-0.950**	-0.820*	-0.629^{NS}	-0.054 ^{NS}	-0.286 ^{NS}	0.863*	0.489 ^{NS}	0.951**	0.828*
Eruca sativa cv. T-27	0.758*	0.285^{NS}	0.792*	0.443^{NS}	-0.708 ^{NS}	-0.488^{NS}	-0.582^{NS}	-0.135 ^{NS}	-0.494 ^{NS}	-0.003^{NS}	0.937**	0.249 ^{NS}	0.720 ^{NS}	0.504^{NS}
B. campestris cv. BSH-1	0.698*	0.500 ^{NS}	0.715^{NS}	0.598^{NS}	-0.461 ^{NS}	-0.639^{NS}	-0.532 ^{NS}	-0.296^{NS}	0.012 ^{NS}	-0.061 ^{NS}	0.878**	0.440 ^{NS}	0.910**	0.672 ^{NS}
B. napus cv. Sheetal	0.888**	0.799*	0.805*	0.908**	-0.939**	-0.980**	-0.857*	-0.612 ^{NS}	-0.474 ^{NS}	-0.159 ^{NS}	0.836*	0.541 ^{NS}	0.601^{NS}	0.716^{NS}
B. carinata cv. CCN-06-1	0.896**	0.777*	0.821*	0.90*7*	-0.144**	-0.967**	-0.848*	-0.561^{NS}	-0.484 ^{NS}	-0.153 ^{NS}	0.844*	0.536 ^{NS}	0.607^{NS}	0.710^{NS}
B. juncea cv. Varuna	0.762*	0.423^{NS}	0.727 ^{NS}	0.542^{NS}	0.527 ^{NS}	-0.552^{NS}	-0.592^{NS}	-0.187 ^{NS}	-0.052 ^{NS}	0.074 ^{NS}	0.878**	0.445 ^{NS}	0.932**	0.578^{NS}
B. nigra cv. PBR-1	0.906**	0.578^{NS}	0.844*	0.660^{NS}	-0.802*	-0.755*	-0.831*	-0.476 ^{NS}	-0.184^{NS}	-0.167 ^{NS}	0.923**	0.395 ^{NS}	0.837*	0.763*
B. campestris cv. YST-151	0.798*	0.283^{NS}	0.770*	0.328^{NS}	-0.624 ^{NS}	-0.430^{NS}	-0.649^{NS}-	-0.186 ^{NS}	-0.187 ^{NS}	-0.080 ^{NS}	0.932**	0.283 ^{NS}	0.899**	0.529 ^{NS}
B. campestris cv. PT-30	0.055^{NS}	0.328 ^{NS}	0.144^{NS}	0.448^{NS}	-0.223 ^{NS}	-0.526^{NS}	0.205^{NS}	-0.177 ^{NS}	0.190^{NS}	-0.005 ^{NS}	0.248^{NS}	0.320 ^{NS}	0.434 ^{NS}	0.520 ^{NS}

Table 6. Correlation co-efficient between the population of syrphid larvae and weather parameters on different cultivars of rapeseed mustard.

Cultivar	Temperature (^{0}C)				Relative humidity (%)				Rainfall (mm)		Wind velocity (km/h)		Sunshine hours	
	Maximum		Minimum		0712 AM		1412 PM							
	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10
Brassica alba cv. PSB-I	0.837*	0.743^{NS}	0.773*	0.872**	-0.666 ^{NS}	-0.953**	-0.733 ^{NS}	-0.581 ^{NS}	-0.130^{NS}	-0.284 ^{NS}	0.920**	0.435^{N}S	0.913**	0.756*
Eruca sativa cv. T-27	0.623^{NS}	0.304 ^{NS}	0.721 ^{NS}	0.487^{NS}	-0.527 ^{NS}	-0.561 ^{NS}	-0.330 ^{NS}	-0.150^{NS}	-0.457^{NS}	-0.025 ^{NS}	0.814*	0.246 ^{NS}	0.632^{NS}	0.489 ^{NS}
B. campestris cv. BSH-I	0.515 ^{NS}	0.633 ^{NS}	0.537 ^{NS}	0.760*	-0.230 ^{NS}	-0.861*	-0.305 ^{NS}	-0.505^{NS}	0.170 ^{NS}	-0.224 ^{NS}	0.634 ^{NS}	0.388 ^{NS}	0.776*	0.759*
B. napus cv. Sheetal	0.882**	0.872*	0.793*	0.929**	-0.941*	-0.915**	-0.865*	-0.667 ^{NS}	-0.466 ^{NS}	-0.239 ^{NS}	0.820*	0.570 ^{NS}	0.587^{NS}	0.844*
B. carinata cv. CCN-06-1	0.858**	0.865*	0.779*	0.951**	-0.907*	-0.922**	-0.842*	-0.634^{NS}	-0.461^{NS}	-0.184 ^{NS}	0.835*	0.581 ^{NS}	0.605^{NS}	0.822*
B. juncea cv. Varuna	0.645^{NS}	0.687^{NS}	0.666^{NS}	0.791*	-0.401 ^{NS}	-0.885**	-0.446^{NS}	-0.567^{NS}	-0.060^{NS}	-0.266 ^{NS}	0.858*	0.410 ^{NS}	0.896**	0.809*
B. nigra cv. PBR-I	0.916 **	0.437^{NS}	0.811 ^{NS}	0.505^{NS}	-0.902 ^{NS}	-0.624^{NS}	-0.904**	-0.297^{NS}	-0.295^{NS}	-0.247 ^{NS}	0.850*	0.329 ^{NS}	0.707^{NS}	0.639^{NS}
B. campestris cv. YST-151	0.250 ^{NS}	0.641 ^{NS}	0.221 ^{NS}	0.734 ^{NS}	-0.086 ^{NS}	-.824*	-0.068 ^{NS}	-0.510 ^{NS}	0.398 ^{NS}	-0.233 ^{NS}	0.287^{NS}	0.416 ^{NS}	0.604^{NS}	0.795*
B. campestris cv. PT-30	-0.129 ^{NS}	0.449 ^{NS}	-0.054 ^{NS}	0.520 ^{NS}	-0.397 ^{NS}	-0.627^{NS}	-0.263 ^{NS}	-0.342^{NS}	0.414 ^{NS}	-0.183 ^{NS}	-0.018 ^{NS}	0.330 ^{NS}	0.242 ^{NS}	0.673^{NS}

Table 7. Correlation co-efficient between the percent field parasitization of *Lipaphis erysimi* (Kalt.) and weather parameters on different cultivars of rapeseed-mustard.

Cultivar	Temperature (^{0}C) Maximum 2008-09	Temperature Maximum 2009-10	Temperature Minimum 2008-09	Temperature Minimum 2009-10	Relative humidity (%) 0712 AM 2008-09	Relative humidity 0712 AM 2009-10	Relative humidity 1412 PM 2008-09	Relative humidity 1412 PM 2009-10	Rainfall (mm) 2008-09	Rainfall (mm) 2009-10	Wind velocity (km/h) 2008-09	Wind velocity (km/h) 2009-10	Sunshine hours 2008-09	Sunshine hours 2009-10
Brassica alba cv. PSB-I	0.892**	0.910**	0.746^{NS}	0.941**	-0.868*	-0.932**	-0.90**	0.67 ^{NS}	-0.294^{NS}	-0.202^{NS}	0.820*	0.65 ^{NS}	0.71^{NS}	0.83*
Eruca sativa cv. T -27	0.890**	0.861*	0.806*	0.959**	-0.945*	-0.914**	-0.860*	-0.59 ^{NS}	-0.474^{NS}	-0.14 ^{NS}	0.828*	0.60^{NS}	0.59^{NS}	0.74*
B. campestris cv. BSH-I	0.888**	0.901**	0.756*	0.937**	-0.854*	-0.961**	-0.89**	-0.68 ^{NS}	-0.290^{NS}	-0.21 ^{NS}	0.841*	0.59 ^{NS}	0.73^{NS}	0.85*
B. napus cv. Sheetal	0.878**	0.877**	0.787*	0.877*	-0.88**	-0.861*	-0.88**	-0.710^{NS}	-0.291 ^{NS}	-0.27 ^{NS}	0.821*	0.57 ^{NS}	0.64 ^{NS}	0.78*
B. carinata cv. CCN-06-1	0.862*	0.881**	0.792*	0.890*	-0.85**	-0.860*	-0.86**	-0.69 ^{NS}	-0.244^{NS}	0.239 ^{NS}	0.842*	0.57 ^{NS}	0.68^{NS}	0.78*
B. juncea cv. Var-una	0.889**	0.919**	0.736^{NS}	0.909**	-0.838*	-0.924**	-0.89**	-0.73 ^{NS}	-0.267 ^{NS}	-0.26 ^{NS}	0.829*	0.62 ^{NS}	0.75*	0.85*
B. nigra cv. PBR-I	0.918**	0.914**	0.831*	0.920**	-0.854*	-0.933**	-0.87**	-0.715^{NS}	-0.236^{NS}	-0.244^{NS}	0.896*	0.56 ^{NS}	0.78*	0.82*
B. campestris cv. YST-151	0.887**	0.891**	0.774*	0.941**	-0.835*	-0.952**	-0.876*	-0.67 ^{NS}	-0.246 ^{NS}	0.215 ^{NS}	0.861**	0.59 ^{NS}	0.763*	0.84*
B. campestris cv. PT-30	0.910**	0.904**	0.798*	0.933**	0.732*	-0.938**	-0.847*	-0661 ^{NS}	-0.164^{NS}	-0.25 ^{NS}	0.895*	0.59 ^{NS}	0.871*	0.83*

Sheetal, CCN-06-1,PBR-1 and PT-30 while the peak activity of mustard aphid was recorded from 6th-9th SW on most of the cultivars. In 8th standard week, during 2008-09 PT-30 showed peak coccinellids activity (0.93 coccinellids/ plant) followed by decline. Similarly in 9th SW, PSB-1, T-27, BSH-1, Varuna and YST-151 (3.00,1.00, 2.00, 2.26 and 1.60 coccinellids/ plant) exhibited peak coccinellids activity while Sheetal (1.26 coccinellids/ plant), PBR-1(1.53 coccinellids/ plant) and CCN-06-1 (0.66 coccinellids/ plant) showed peak activity of coccinellids in 10th SW followed by decline. The first appearance of coccinellids on Sheetal, T-27 and CCN-06-1 was noticed during 8th standard week with 0.53, 0.60, and 0.33 coccinellids/ plant respectively. In 2009-10, peak activity of coccinellids was observed in 8th standard week on all cultivars except PSB-1, Sheetal and CCN-06-1 which showed peak activity in 9th SW while the peak activity of mustard aphid was recorded from 6th-9th SW on most of the cultivars. It is clear that the population dynamics of coccinellids beetles indicated that its population increased gradually with the increase of aphid population and decreased gradually with the decrease in aphid population. Similar results were observed by Soni *et al*., 2013 and Khan *et al.* (2011) who reported that *C. septempunctata* populations in wheat had a strong positive and significant correlation with the aphid numbers in the field.

The present finding are in close agreement with Kulkarni and Patel (2001) reported that population of lady bird beetles appeared during the last week of January (5th SW), attained peak during the third week of February (8th SW) and thereafter, it declined in last week of February (9th SW). While Singh *et al.* (2006) observed that population of *Coccinella septempunctata* started from 9th week, after sowing of the crop. Thereafter, the populations of this predator gradually increased and attained peak on the 2 March.

Population dynamics of syrphid larvae on different cultivars: The perusal of data depicted in Table 3 revealed in both the years that the first appearance of syrphid larvae on the cultivars occurred in 4th standard week except few cultivars. After the initiation of activity, on all cultivars the population of syrphid larvae in both the years gradually increased, attained maximum population (8th-10th standard weeks in both the years) followed by a decline on respective cultivar. The peak activity of mustard aphid was recorded from 6th-9th SW on most of the cultivars.

In 8th standard week, during 2008-09 maximum syrphid population was recorded on PSB-1 (1.66 syrphids/plant with aphid population 224.20) followed by Varuna (1.20 syrphids/plant with aphid population 48.06), BSH-1 (0.86 syrphids/plant with aphid population 126.23), YST-151(0.73 syrphids/plant with aphid population 102.67), PT-30 (0.60 syrphids/plant with aphid population 63.87) and PBR-1(0.53 syrphids/ plant with aphid population 14.33). PSB-1 (2.40 syr-

phids/plant) and Varuna (1.46 syrphids/plant) exhibited highest syrphid population in 9th SW while Sheetal, CCN-06-1 and PBR-1 exhibited highest syrphid population (1.20, 0.80 and 1.20 syrphids/plant) in 10th SW. first appearance of syrphid population on T-27, Sheetal and CCN-06-1 was noticed during 8th standard week (Table 3). During 2009-10, in 8th standard week the cultivars BSH-1, Varuna, YST-151, PBR-1, PT-30 and T-27 exhibited maximum syrphid population (2.00, 1.86, 1.66, 1.40, 1.33 and 0.93 syrphids/plant, respectively) followed by a declining trend of larvae population. Highest syrphid population (2.80 syrphids/plant) on PSB-1 was observed during 9th SW while CCN-06-1 and sheetal exhibited highest syrphid population (1.60 and 1.53 syrphids/plant) in 10th SW. (Table 3). Devi *et al*. (2011) reported that syrphids attained maximum population in 6th SW which is coincided with the maximum population of aphids and then gradually decreased. Our findings are in close conformity with Kulkarni and Patel (2001) and Vekaria and Patel (2005) who observed that the activity of syrphid larvae started during 4th SW and lasted up to the 9th SW.

Per cent field parasitization of mustard aphid by the parasitoid, *Diaeretiella rapae* on different cultivars in different standard weeks: Appearance of parasitized aphids occurred from 4th standard week, at flowering stage of the crop increased gradually in the following weeks, and attained peak parasitization in the 10th standard week at maturity stage of the crop. Nevertheless, the extent of parasitization varied with respect to different cultivars and ecological conditions in different years. Thus among all the cultivars maximum aphid parasitization during 2008-09 in the present study was recorded with PT-30 (33.32%) followed by BSH-1, YST-151, Varuna, PSB-1, PBR-1, CCN-06-1, Sheetal and T-27 (30.35, 29.02, 28.85, 25.44, 17.08, 16.31, 14.90 AND 1.94%, respectively) while during 2009-2010 it was maximum with BSH-1 (35.25%) followed by YST-151, PT-30, PSB-1, Varuna, PBR-1, CCN-06-1, Sheetal and T-27 (33.33, 30.17, 26.97, 25.38, 19.06, 18.50, 15.15 and 2.29%, respectively) **(**Table 4).The present findings are in close agreement with Dogra *et al*. (2003) and Raj and Lakhanpal (1998) who reported the first appearance of *D. rapae* on *L.erysimi* in the field occurred during the second week of January which gradually increased and attained maximum parasitization (51.07%) in the second or first week of March.

It was evident from the study that during both the years mustard aphid started appearing from 51st SW on all cultivar except few and peak activity of mustard aphid was observed in 6th -9th SW on most of the cultivars while predators activity was started from 4th SW and peak was observed from 8th week onwards. Highest % parasitization observed in 10th SW at the maturity of crop. In the present study, coccinellids were the predominant natural enemies. There were changes in the abundance of natural enemies in different cultivars through the years as well as among cultivars within a year. There may be different causes like climate (Rotheray and Gilbert, 2011), prey density on different cultivars (Thalji, 2006), insolation, quality of host plants (Alhmedi *et al.*, 2009), and adjacent habitats (Alhmedi *et al.*, 2009; Vandereycken *et al.,* 2013). Straub and Snyder (2006) demonstrated that coccinellids are the key species in a natural enemy guild in organic brassica fields in Canada and cabbage aphid, *Brevicoryne brassicae*.

Coccinellids, syrphid larvae and parasitoid exhibited positive correlation with maximum and minimum temperatures, wind velocity and sunshine hours in most of the all cultivars. Population of bioagents exhibited negative correlation with morning and evening relative humidity and rainfall on all cultivars in both the years of study (Tables 5-7). The reason for this negative correlation could possibly be due to the fact that population of natural enemies did not synchronize with respective parameters. These abiotic factors influence the growth of insects which further depends on their thermal requirements and host specificity.

Conclusion

From the present study, it can be concluded that the activity and the population density of aphidophagous insects in particular varied with the different standard weeks (with varied ecological conditions) and with cultivars. The aphid attained marked higher population on most of the cultivars during 6th SW (pooled mean 149.89 aphids/10 cm apical shoot during 2008-09 and 189.35 aphids/10 cm apical shoot during 2009-10), in both the years followed by higher coccinellids (pooled mean 1.42/plant in 9th SW and 3.96/ plant in 8th SW during 2008-09 and 2009-10 respectively) and syrphid population (pooled mean 0.122/plant in 9th SW and 0.228/ plant in 8th SW during 2008-09 and 2009-10 respectively). To make biological control of mustard aphid more effective and efficient, we should also promote conservation of natural enemies by providing alternative and essential food for natural enemies and by avoiding/delaying spray of insecticides especially early in the season. Regular monitoring should be done if, natural enemies population is less initially, they can be released in field so that aphid population can be managed effectively.

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