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Relative Abundance of Turnip Aphid and the Associated Natural Enemies on Oilseed *Brassica* Genotypes

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ABSTRACT

A two-year field study was conducted at Punjab Agricultural University, Ludhiana, India, to study the relative abundance of mustard/turnip aphid, *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae) and the associated resident natural enemies on 10 different rapeseed-mustard genotypes which included: *Brassica juncea*: RH 7846, RH 9501, RK 9501, JMM 927, Purple Mutant; *B. napus*: Hyola PAC 401 (Hybrid); *B. rapa* ecotype yellow *sarson* cv. YST 151; *B. rapa* ecotype brown *sarson* cv. BSH 1; *B. carinata*: DLSC 2 and *Eruca sativa*: T 27. The objective was to study whether indigenous natural enemies can be used for biological control of mustard aphid. Population of turnip aphid and different natural enemies was recorded at weekly intervals. There was lack of synchronization in the peak activity of natural enemies with that of the aphids with a time lag of one to two weeks depending upon the genotype. For example, on *B. juncea* cv. RH 7846, the peak aphids' population was recorded during the 10th Standard Meteorological Week (SMW) while that of predators' was recorded during the 12th SMW in 2007-2008 crop season. Among the different natural enemies, coccinellids were the most abundant with grubs being dominant in the initial phase of population development and adults in the later one. There is a need to conserve the resident natural enemies in mustard ecosystem for effective early season suppression of the aphid population or release them early in the season to suppress aphid population in lag phase of its development.

Keywords: Agroecosystem, Ecology, Mustard aphid, Parasitoid, Predator.

INTRODUCTION

Brassicas are an important group of crops which have great economic importance the world over (Trdan *et al.*, 2005; Suwabe *et al.*, 2006; Hong *et al.*, 2008; Golizadeh *et al.*, 2009). The different species of *Brassica* are grown as vegetable and oilseed crops. India is one of the leading producers including Canada, USA, EU, Australia and China (Bhatia *et al.,* 2011). 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). Among the biotic stresses, the turnip/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). Owing to the high fecundity and short generation period, it can reach population densities much higher than the economic threshold levels of 50-60 aphids/10 cm top central twig of plant making them intractable to control. For the management of this notorious pest, at present, farmers have no other option but to spray insecticides which have their own adverse effects. The use of systemic insecticides is highly cost intensive and besides many adverse effects like pollution of environment and toxic effects on non-target organisms including pollinators, the

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residues in the oil and cake poses the bigger threat of their incorporation in dietary chain. However, it has been observed that in mustard agro-ecosystem, an array of parasitoids and predators are associated with *L. erysimi*. These natural enemies, if conserved, have the potential to keep a check on the pest population up to considerable extent.

Unwise and non-judicious use of any insecticide can result in widespread mortality of these natural control agents and can disturb the so called 'natural control'. It, subsequently, results in pest outbreaks and, consequently, the repeated insecticidal applications. Studies that identify natural enemies that coincide spatially and temporally with pest populations and, therefore, have potential to control them, can suggest ways to minimize insecticide applications by targeting them more efficiently, thereby, helping to conserve the natural enemies (Murchie *et al.,* 1997; Holland *et al.,* 1999). Monitoring for the presence and relative abundance of natural enemies is an important component of an area-wide pest control (Sarwar, 2009).

A large number of natural enemies that prey/parasitize *L. erysimi* have been documented in India, particularly in Punjab. Generalist predators, particularly coccinellids and *Chrysoperla* spp. such as *Chrysoperla carnea* Stephens sensu lato (= sl), larvae have been observed to feed on *L. erysimi* (Mathur, 1983; Prasad *et al.*, 2009). The lady bird beetle, *Coccinella septempunctata* L. is one of the important potential predators. Adults and grubs feed voraciously on aphids and consume on average 1203.5 aphids in a period of 17.9 days (Akram *et al.*, 1996).

Diaeretiella rapae (Mc Intosh) (Hymenoptera: Aphidiinae) is an important primary parasitoid of a wide range of aphid species, such as turnip aphid *L. erysimi,* cabbage aphid *Brevicoryne brassicae* (L.), green peach aphid *Myzus persicae* (Sulzer), Russian wheat aphid *Diuraphis noxia* (Kurdjumov), cotton aphid *Aphis gossypi* Glover, bird cherry-oat aphid *Rhopalosiphum maidis* (Fitch) (Elliott *et al.,* 1994; Pike *et al.,* 1999; Mussury and Fernandes, 2002). Although this parasitoid is considered to have a potential host range of more than 60 different aphid species, it is regarded as a specialist parasitoid of brassica aphids (Pike *et al.*, 1999). Pike *et al.* (1999) recorded that of all the parasitoids found in vegetable *Brassica* fields in USA, 82.5% were *D. rapae*. In Poland, the parasitism of cabbage aphids in cabbage fields by naturally occurring *D. rapae* was about 35%, two weeks after the initial parasitism (Gabrys *et al.*, 1998).

Rapeseed-mustard acts as a reservoir of different natural enemies that may act not only against oilseed *Brassica* pests, but also against a number of other surrounding crops such as wheat and gram. Thus, the knowledge of *L. erysimi*–natural enemies' relationships will help improve conservation biological control strategies against this key pest of oilseed *Brassica* in this country. Because the seasonal abundance of these different natural enemies and the aphid hosts vary greatly between host plant species and years, the current study was conducted over 10 different oilseed *Brassica* genotypes from different species and for two crop seasons (Kumar, 2014). The objective of the study was to generate information on relative abundance of *L. erysimi* on different oilseed brassica hosts along with the abundance of different natural enemies to know whether resident natural enemies can be used for conservation biological control of this pest.

MATERIALS AND METHODS

Study Site

The study was carried out at the Oilseeds Research Farm, Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana (30.9°N and 75.85°E, 244 m above msl), India during 2007-2008 and 2008-2009 crop seasons (November to April) on 10 different oilseed *Brassica* genotypes viz. *B. juncea* (L.) Czern.: RH 7846, RH 9501, RK 9501, JMM 927, Purple Mutant; *B. napus* L. hybrid: Hyola PAC 401; *B. rapa* L. ecotype yellow *sarson* cv. YST 151, *B. rapa* ecotype brown *sarson* cv. BSH 1; *B. carinata* A.

Braun: DLSC 2 and *Eruca sativa* (Mill.) Thell.: TMLC 2. This part of the country is characterized by sub-tropical and semi arid climate with hot and dry spring-summer from April to June, and hot and humid summer from July to September. The crop season spans from October-November to April and is characterized by cold winters where the average maximum temperature rises up to 31°C and sometimes even more at the end of the season in March-April, while it falls to minimum of 1°C and sometimes even lower than that during December-January, with RH ranging from 30.0 to more than 90.0 per cent. The average annual rainfall is about 705 mm, most of which is received during monsoon period from July to September, while few showers are received during the winter season from November to March. The crop was sown on canal or tube well irrigated sandy loam soil. The experiment was laid out in randomized complete block design and replicated thrice. The experimental plots were 4×3 m in size in which seeds were sown at plant to plant and row to row spacing of 15 and 30 cm, respectively, during first week of November. At the time of sowing, a uniform dose of nitrogen and phosphorous was applied to all the genotypes. About 20 days after sowing, manual weed removal method was advocated. All the recommended package of practices was followed for raising a good crop, except for spray of insecticides (PAU, 2007).

Insect Sampling

Field surveillance was regularly carried out from crop sowing to maturity at weekly intervals to record appearance of aphids and natural enemies. At pest appearance, data on the incidence of *L. erysimi* and different natural enemies *viz*. Coccinellid adults and grubs, *Chrysoperla* larvae, syrphid fly larvae and number of parasitized/mummified aphids were recorded at weekly intervals from 10 plants selected randomly. The sampling methods used to assess the number of *L. erysimi* and different natural enemies involved whole plant visual inspection (Patel *et al.*, 2004). The border effect was avoided by sampling plants in a plot after leaving the two border rows. 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.

Statistical Analysis

The statistical interpretations were undertaken to correlate the aphid population recorded at weekly intervals with its natural enemies using the statistical software OPSTAT (OPSTAT, 2009). The data were plotted in Standard Meteorological Weeks to compare the relative abundance of *L. erysimi* as well as the associated natural enemies on different genotypes.

RESULTS

Seasonal Abundance of *L. erysimi* and the Associated Resident Natural Enemies

The different natural enemies reported in rapeseed-mustard ecosystem were grubs and adults of lady bird beetles, common green lacewing, *Chrysoperla carnea* Stephens sensu lato (= sl) (Neuroptera: Chrysopidae) and the marmalade hoverfly/syrphid fly, *Episyrphus balteatus* De Geer (Diptera: Syrphidae) and one endoparasitoid, *Diaeretiella rapae* McIntosh (Hymenoptera: Aphidiinae). There were variations in synchronization of natural enemy population with *L. erysimi* from genotype to genotype. In 2007-2008 crop season, the first appearance of *L. erysimi* was recorded during 3rd Standard Meteorological Week (SMW) on *B. juncea* RH 7846, JMM 927, RH 9501, RK 9501, *B. rapa* YST 151 and BSH 1, *B. carinata* DLSC 2, and *E. sativa* T 27. Whereas, on *B. napus* hybrid Hyola PAC 401 and *B. juncea* Purple Mutant, it appeared little late in the 7th and 9th SMW, respectively. The peak activity was recorded during the 10th to 11th SMW on different

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genotypes, except in Hyola PAC 401 and Purple Mutant where it was the 12th SMW (Figure 1).

In contrast to *L. erysimi*, the predators came into sight during the 10th SMW in the respective study year. On RH 7846, the peak aphid population was recorded during the 10th SMW while peak predators' activity was recorded during the12th SMW with a time lag of two weeks. This time lag in peak activity was also observed in RK 9501, DLSC 2 and YST 151 varying from one to two weeks. On the other hand, there was a synchronization of peak prey population with that of the predators on JMM 927 (11th SMW), RH 9501 (11th SMW), Hyola PAC 401 (12th SMW), Purple Mutant (12th SMW), T 27 (10th SMW) and BSH 1 (11th SMW).

In 2008-09, the first appearance of aphids was recorded during 4th SMW except in *B. rapa* where it appeared during 3rd SMW, whereas, predators came into sight during 9th SMW. In this year, there was no proper synchronization between populations of the prey and its predators that appeared late in all the genotypes with a time lag of one to three weeks between the two depending on the genotype. However, in the case of DLSC 2, there was synchronization in the peak aphid population with predators during 11th SMW since it is a late flowering genotype which leads to delayed peak of aphid prey, which further favours movement of resident predators from other genotypes. Hence, the natural enemies that had already been attracted to the experimental field by aphids present on the other genotypes might have moved to DSLC 2. Thus, the observed synchronization may not occur if this genotype is grown alone. It is interesting to note that predators' population showed a one week early peak (0.60 predators plant^{-1}) during 9th SMW in the case of Purple Mutant, where aphid population (71.0 aphids plant^{-1}) peaked during 10th SMW. However, it is important to note that the peak population of resident predators (0.60 plant^{-1}) was much lower than the peak observed in other genotypes.

L. erysimi was found to be parasitized by endoparasitoid, *D. rapae,* during both years of study. Just like predators' activity, variations in synchronization of parasitoid's peak activity with that of *L. erysimi* were recorded from genotype to genotype. The first activity of *D. rapae* as evident from the appearance of mummified aphids was recorded during 10th SMW in the 2007-08 crop season. There was a time lag of two weeks between the peak aphids' activity (10th SMW) and the associated parasitoid (12th SMW) on RH 7846. On the other hand, the peak aphid population during 11th SMW coincided with the peak activity of parasitoid on JMM 927, RK 9501 and RH 9501. Similarly, in Hyola PAC 401 and Purple Mutant, synchronization in peak activity of the pest and parasitoid was recorded during 12th SMW. On the other hand, in YST 151 and BSH 1, there was a time lag of 2 weeks between the peak activity of aphid host and the associated parasitoid.

In 2008-2009, parasitoid's activity was first recorded during 8th SMW. In this year, there was no proper synchronization between populations of the host and its parasitoid that appeared late in all the genotypes with one to two weeks time lag between the two depending on the genotype.

Relative Abundance of Different Natural Enemies

Among the different natural enemies reported, the seven-spotted lady bird beetle, *Coccinella septempunctata,* was the most predominant, though, other species were also reported, namely, *C. transversalis, Cheilomenes sexmaculatus, Brumus* sp. While the relative population of Coccinellid grubs was high during the initial phase just after their appearance, that of adults was high during the later part of the season (Figure 1). During 2007-2008, the different predators were active from 10-12th SMW, while this activity period extended from 7th to 11th SMW during 2008-2009. In 2007-2008, there was late appearance of predators in 10th SMW which remained active till 12th SMW. On the other hand, in 2008-2009, predators appeared comparatively early in

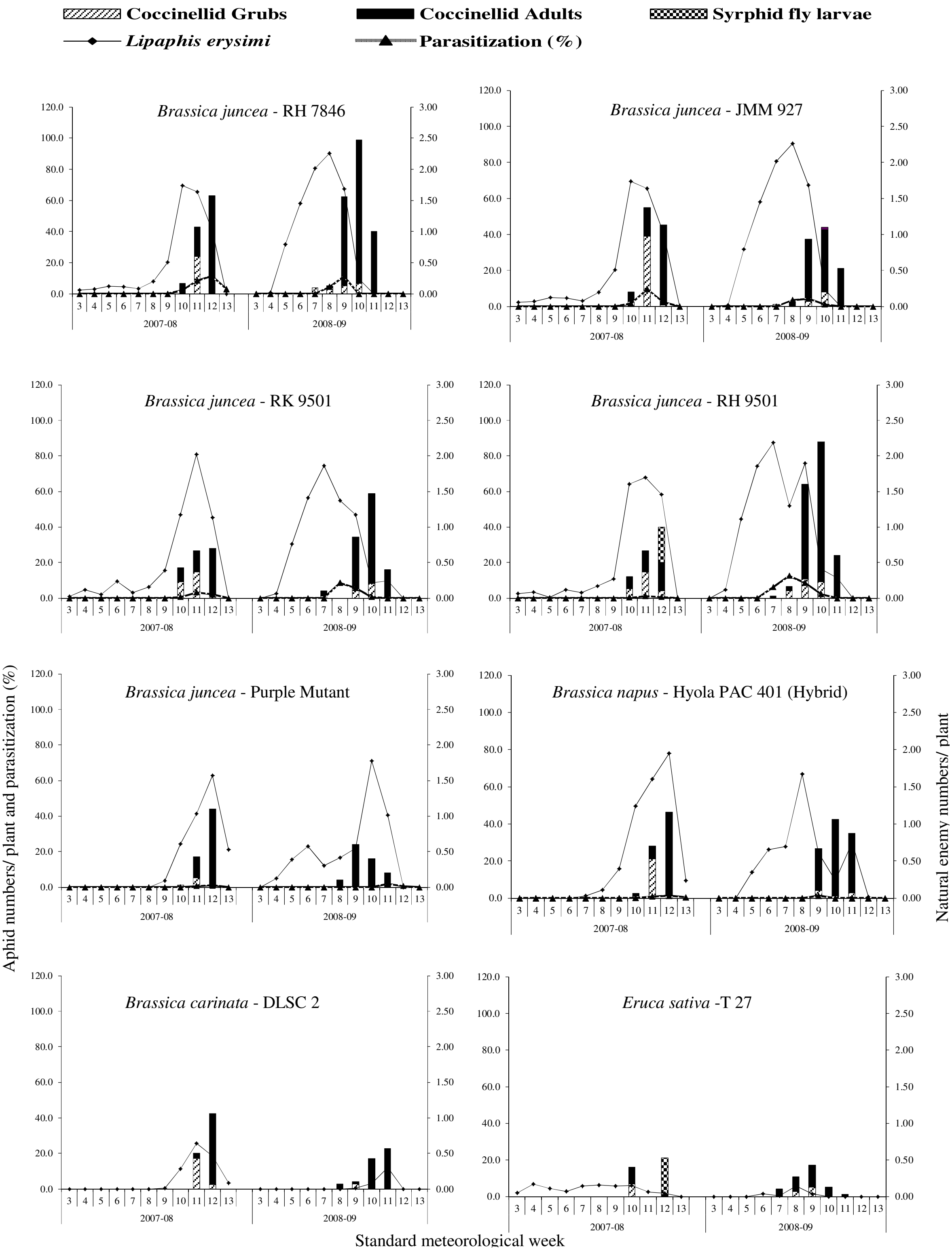

Figure 1. Seasonal abundance of aphids and resident natural enemies on different genotypes of oilseed *Brassica* during 2007-08 and 2008-09 crops seasons at Ludhiana, India.Numbers on the *X*-axis indicate Standard Meteorological Week (SMW) of the year. Primary *Y* axis (0-120) denotes scale for number of aphids/plant and per cent aphid parasitization (see legend). Secondary *Y* axis (0-3) denotes scale for number of predators (coccinellid grubs, coccinellid adults and syrphid fly maggots) per plant.

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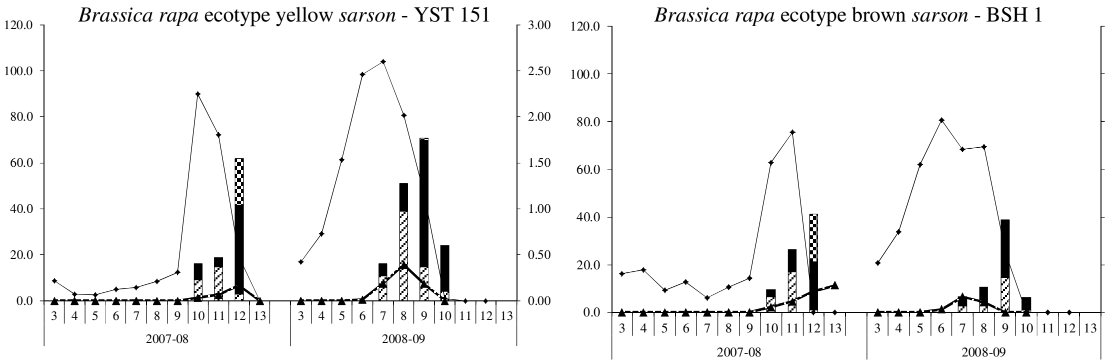

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the season in 7th SMW and remained active till 11th SMW and disappeared one week earlier than that in the previous year. This late appearance of predators in 2007-2008 can be attributed to comparatively low temperature in the early part of the season till 7th SMW. The minimum temperature from 4th to 7th SMW remained below 5°C during 2007-08 with the lowest being 0.9°C during 4th SMW. On the other hand, minimum temperature during the corresponding period in 2008-2009 remained above 5°C favoring the early development of predators. It was also evident from the peak activity of aphid host. In 2007-2008, the aphids' population showed peak activity from 10-12th SMW on most of the genotypes, while in 2008-2009, this peak activity of aphids was recorded during 7th-8th SMW on most of the genotypes. Consequently, in 2008-2009, predators appeared early in the season (7th SMW) and remained active till 11th SMW due to early withdrawal of aphid population as a result of early maturity of the crop (Figures 1 and 2).

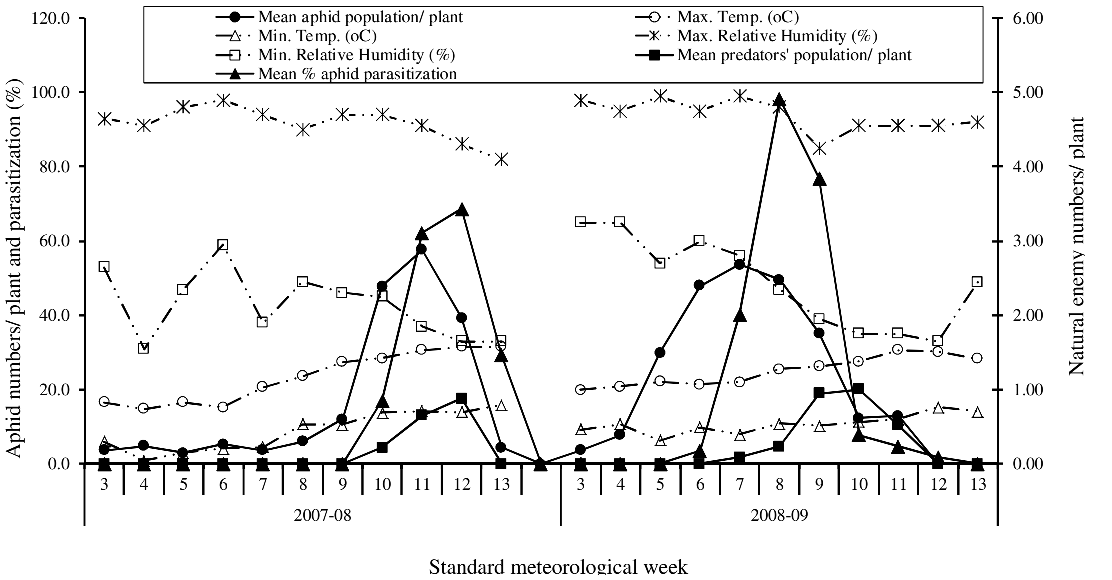

Figure 2. Mean population density of *L. erysimi* in relation to natural enemies' population and abiotic factors. Numbers on *X* axis indicate Standard Meteorological Week (SMW) of the year. Primary *Y* axis (0-120) denotes scale for mean aphid population/plant, maximum temperature, minimum temperature, maximum relative humidity, minimum relative humidity. Secondary *Y* axis (0-6) denotes scale for mean predators' population/plant and mean per cent aphid parasitization.

Relationship of Aphid Population with Natural Enemies

The natural enemies' population showed variable relationship with aphid population on different genotypes. In 2007-2008, there was a strong positive correlation of natural enemies population with aphid population on *B. juncea* cv. RH 7846 (r= 0.63), JMM 927 (0.92), RK 9501 (0.93), Purple Mutant (0.90), RH 9501 (0.86), *B. napus* hybrid Hyola PAC 401 (0.88), *B. carinata* cv. DLSC 2 (0.78) (Table 1). On the other hand, in 2008-2009, no significant relationship was observed on most of the genotypes, except in *B. carinata* cv. DLSC 2 (r= 0.90). The mean predators' population also showed positive correlation with maximum and minimum temperature in addition to that with their aphid prey in 2007-2008 (Table 2). This positive correlation was not very strong in 2008-2009, as a plethora of other factors showed their adverse effects on predators as well as aphids density. For example, there was a negative correlation of aphid population with both minimum and maximum temperature. Likewise, there was a negative correlation of predator activity with both morning and evening relative humidity (Table 2). Thus, the density dependent relationship of the predators with aphid preys depends not merely on the availability and abundance of their prey but also on the abiotic factors particularly temperature and relative humidity.

DISCUSSION

It was evident from the study that there was a time lag between the peak period of aphid activity and natural enemies' activity. However, synchronization in the peak activity of predators with peak aphid density was recorded in JMM 927, RH 9501, Hyola PAC 401, Purple Mutant and BSH 1. This could be due to comparatively late flowering of these genotypes and, consequently, delayed peak of aphid prey leading to inter-genotype movement of resident predators.

Table 1. Relationship of aphid population density with different predators and one parasitoid on different oilseed Brassica genotypes.

Brassica sp.	Genotype	Year/Crop season 2007-2008 Coccinellid Grubs	2007-2008 Coccinellid Adults	2007-2008 Syrphid fly maggots	2007-2008 *Chrysoperla carnea*	2007-2008 % Parasitization	2007-2008 Total	2008-2009 Coccinellid Grubs	2008-2009 Coccinellid Adults	2008-2009 Syrphid fly maggots	2008-2009 *Chrysoperla carnea*	2008-2009 % Parasitization	2008-2009 Total
B. juncea	RH 7846	0.58	0.50	0.0	0.0	0.64	0.63	0.50	-0.09	0.0	0.0	0.53	-0.05
	JMM 927	0.70	0.77	0.0	0.0	0.83	0.92	-0.05	-0.15	0.0	-0.23	0.34	-0.14
	RK 9501	0.90	0.73	0.0	0.0	0.93	0.93	0.04	-0.08	0.0	0.0	0.44	-0.07
	RH 9501	0.85	0.91	0.0	0.45	0.88	0.86	0.22	0.05	0.0	0.0	0.59	0.08
	Purple mutant	0.46	0.87	0.0	0.0	0.91	0.90	0.0	0.62	0.0	0.0	0.23	0.62
B. napus	Hyola PAC 401 (Hybrid)	0.56	0.75	0.0	0.0	0.88	0.88	0.17	0.05	0.0	0.0	0.10	0.06
B. carinata	DLSC 2	0.81	0.54	0.0	0.0	0.00	0.78	-0.08	0.90	0.0	0.0	0.00	0.90
Eruca sativa	T 27	0.30	0.26	0.0	-0.34	0.00	-0.10					0.00	0.57
B. rapa ecotype yellow *sarson*	YST 151	0.92	0.17	0.0	-0.02	0.33	0.34	0.34	-0.19	0.0	-0.09	0.48	0.03
B. rapa ecotype brown *sarson*	BSH 1	0.91	0.14	0.0	-0.27	-0.07	0.29	-0.18	-0.28	0.0	0.0	0.60	-0.24

Table 2. Correlation matrix of mean aphid population with mean natural enemies' population and meteorological parameters.

A. Crop season 2007-2008

	Mean aphid population	Mean predators' population	Mean parasitoids activity	Max temp	Min temp	Morn RH	Even RH	Sunshine hrs.	Rainfall
Mean aphid population	1.00								
Mean predators' population	0.82	1.00							
Mean parasitoids' activity	0.78	0.93	1.00						
Max. temp.	0.66	0.61	0.74	1.00					
Min. temp.	0.63	0.54	0.69	0.95	1.00				
Morn. R.H.	-0.13	-0.35	-0.57	-0.64	-0.62	1.00			
Even. R.H.	-0.28	-0.42	-0.54	-0.47	-0.28	0.69	1.00		
Sunshine hrs.	0.54	0.64	0.73	0.76	0.58	-0.59	-0.82	1.00	
Rainfall	-0.28	-0.22	-0.26	-0.44	-0.28	0.20	0.47	-0.47	1.00

B. Crop Season 2008-2009

	Mean aphid population	Mean predators' population	Mean parasitoids activity	Max temp	Min temp	Morn RH	Even RH	Sunshine hrs.	Rainfall
Mean aphid population	1.00								
Mean predators' population	0.05	1.00							
Mean parasitoids' activity	0.64	0.36	1.00						
Max temp	-0.35	0.43	0.05	1.00					
Min temp	-0.58	0.06	-0.12	0.75	1.00				
Morn RH	0.26	-0.69	-0.19	-0.68	-0.59	1.00			
Even RH	0.18	-0.64	-0.19	-0.92	-0.55	0.71	1.00		
Sunshine hours	0.01	0.66	0.21	0.65	0.07	-0.40	-0.81	1.00	
Rainfall	-0.05	-0.50	-0.36	-0.28	0.10	0.24	0.34	-0.37	1.00

Although a diversity of natural enemies is reported in many agricultural systems including oilseed *Brassicas,* their performance in terms of suppression of pest populations is often inconsistent (Snyder *et al.*, 2006).

There were changes in the abundance of natural enemies in different genotypes through the years as well as among genotypes within a year. The causes of such fluctuations are diverse including the abundance of prey species (Wright and Laing, 1980; Thalji, 2006). A liner relationship has been observed between natural enemies and aphid population, but additional biotic and abiotic factors also contribute to variability of natural enemy abundance. Climate could be one such factor due to its influence on natural enemies, overwintering mortality, and aphid populations (Hodek and Honěk, 1996; Szentkirályi, 2001; Rotheray and Gilbert, 2011). It was evident from the strong positive relationship of aphid as well as natural enemies' population with maximum and minimum temperature in 2007-2008 in the present study. Several other factors could also explain the variation between genotypes such as insolation, quality of host plants (Alhmedi *et al.*, 2009), and adjacent habitats (Colignon *et al.*, 2001; Alhmedi *et al.*, 2009; Vandereycken *et al.,* 2013).

A thorough understanding of the relationships between pests and their natural enemies in an agroecosystem is the key to development of strategies to enhance conservation biological control (Williams, 2004; 2006). Although a number of biological control agents are present in *Brassica* agroecosystems, one or two particularly effective natural enemies are all that is needed for effective pest control (Hawkins *et al.*, 1999). Relatively recent work by Straub and Snyder (2006) has also shown that some species may play a more critical role in aphid control than others and diversity of natural enemy guild is not as important as composition. They have demonstrated that coccinellids are the key species in a natural enemy guild in organic brassica fields in Canada and cabbage aphid, *Brevicoryne brassicae*, populations were suppressed when coccinellids were present, while in their absence aphid populations continued to grow despite equal abundance of other predators.

In the present study, though, coccinellids were the predominant natural enemies in oilseed Brassica ecosystem, yet, there was no satisfactory control of *L. erysimi* because of the lack of synchrony between coccinellids' and aphid populations. One possible reason for this may be that *Brassicas* are grown in an annual cropping system and there are a number of constraints inherent to annual cropping systems that make biological control difficult (Wissinger, 1997; Landis *et al.*, 2000). In annual cropping systems, there is little overwintering habitat for natural enemies and, as a result, natural enemies must overwinter in habitats away from the fields. In spring, it takes long time for these natural enemies to re-establish in the fields and, as a result, the pest aphid populations can grow unchecked until predators arrive (Wissinger, 1997; Wiedenmann and Smith, 1997). The progress of enemy establishment in the fields compared to pest establishment is a critical factor in pest control, since theory predicts that biological pressure applied to pest populations during the lag phase of population growth can dramatically delay pest outbreaks (Wiedenmann and Smith, 1997). Temporal changes in aphid abundance pose a considerable challenge to female ladybirds because aphid colonies rarely exist for much longer than it takes a ladybird larva to complete its development. Ladybirds should synchronize their development with the early stages of the prey because the survival of the newborn coccinellid larva is very dependent on the abundance of young aphids (Hemptinne and Dixon, 1991, 1997; Hemptinne *et al.*, 1992). The natural enemies colonize in the field later in the season when aphids have become well established, which accounts for their failure to suppress the prey population in the field.

In addition to the predominant coccinellids, *Chrysoperla carnea* larvae and syrphid fly/ marmalade hoverfly maggots, *Episyrphus balteatus* were also observed feeding on the aphid preys. Parasitized aphids (mummies) were also observed, indicating the parasitoid(s) to be active in the system. The parasitoid that emerged from mummified aphids was identified to be *Diaeretiella rapae*. It is an important parasitoid of aphids in this part of the country with reports of more than 80 per cent parasitization in Punjab (Atwal *et al.*, 1969). However, parasitization in the present study was low probably due to intraguild competition, which may be low at that time, though, the author has not studied such competition. Snyder *et al.* (2006) found that predator guild composition did not impact cabbage aphid control in collards, but in that study, none of the predator communities were without lady bird beetles, as either *Coccinella septempunctata* or *Hippodamia convergens,* or both, were present. Similarly, Brown (2004) found that although the naturally occurring aphid predator complex was diverse in apples, in exclusion studies, *H. axiridis* was the most important predator. Coccinellids, like other generalist predators, are able to survive on other prey species. Moreover, both adults and grubs are highly mobile, so they can colonize and sustain their population in fields when aphid populations are low. In contrast to this, syrphids do not oviposit until aphid infestations exceed 50 aphids per broccoli plant (Luna and Jepson, 2003). The time of appearance of predators in comparison to pests can also impact pest suppression, in addition to predator-prey composition. For example, generalist predators like coccinellids and lace wings have the maximum impact on pest populations when they are present early in the season, because they can maintain the pest populations at the low levels at which fields are initially colonized (Weidenmann and Smith, 1997). Pressure from specialist natural enemies such as parasitoids and syrphids becomes critical as pest populations begin an exponential growth phase (Weidenmann and Smith, 1997).

In the field, the aphids were first recorded during 3rd SMW during both years of study with continuous increase in population thereafter. On the other hand, first appearance of predators was recorded from 10th and 7th SMW onwards during 2007-2008 and 2008-2009, respectively. While aphids reached peak densities as high as 104 aphids plant^{-1}, the predators peaked to a maximum of 2.47 plant^{-1}. Similarly, parasitoid activity was recorded from 11th and 7th SMW during 2007-2008 and 2008-2009, respectively with maximum parasitization up to 15.6 per cent. This means that natural enemies did not catch up in relation to population growth of aphid preys. Thus, the second major cause of poor aphid control appeared to be slow population growth of natural enemies, especially generalist predators, early in the season when the temperature remained low for their growth and development.

CONCLUSIONS

It can be concluded from this study that there was a lack of synchronization of the peak period of aphid activity with that of different natural enemies in mustard agroecosystem. The observed natural enemies (coccinellid grubs and adults, *Chrysoperla carnea*, syrphid fly and *D. rapae*) did not control *L. erysimi* to a satisfactory degree, which frequently cross economic threshold level. There are two possible explanations for this. First, there is absence of early season activity of natural enemies when aphids are at low densities and can be suppressed effectively at such low densities. Second, the natural enemy populations grow at a slower rate than the aphid populations. The absence of natural enemy activity early in the season gives aphids a window of opportunity to grow unchecked. Because these natural enemies act on aphid populations in a density-dependent manner, the lack of early season

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activity is not surprising. By the time natural enemy populations do establish, aphid damage has likely exceeded threshold. Possible solution to improve aphid control is manipulation of the biological environment to conserve and enhance natural enemies. For example, hibernation shelters can be created in and around the fields to increase populations of indigenous natural enemies. Strips of flowers can be planted around the fields to increase plant diversity and to provide alternative and essential food for natural enemies. The spray of insecticides should be delayed as far as possible, especially early in the season, to avoid widespread mortality of natural enemies. Alternately, voracious predators like coccinellids can be released early in the season, preferably in the first or second week of January when aphid populations are generally at low densities. However, temperature during this time of the year remains too low for the survival and activity of coccinellids, which warrants development of cold tolerant strains of these predators that can sustain at such low temperatures.

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فراوانی نسبی شته شلغم و دشمنان طبیعی آن روی ژنو تیپ های دانه روغنی کلزا *Brassica*

س. کومار

چکیده

به منظور بررسی فراوانی نسبی شته شلغم /خردل *Lipaphis erysimi* (Kaltenbach) (Hemiptera: Aphididae)و دشمنان طبیعی آن پژوهشی دو ساله روی ۱۰ ژنوتیپ کلزا- خردل در دانشگاه کشاورزی پنجاب در لودهیانا در هند انجام شد. ژنوتیپ های مطالعه شامل موارد زیر بودند: *Brassica juncea*: RH 7846، RH 9501 ، RK 9501، JMM 927، Purple Mutant ،

B. rapa ecotype yellow *sarson* cv. ،*B. napus*: Hyola PAC 401 (Hybrid) ; *B. carinata*: DLSC ،*B. rapa* ecotype brown *sarson* cv. BSH 1 ، YST 151 و2 *Eruca sativa*: T 27 . هدف بررسی این بود که آیا می توان دشمنان طبیعی و بومی را برای کنترل شته خردل استفاده کرد یا نه. به این منظور، جمعیت شته شلغم /خردل و دشمنان طبیعی مختلف به طور هفتگی ثبت شد. نتایج نشان داد که جمعیت حد اکثری (peak) دشمنان طبیعی و شته همزمان نبود و بسته به نوع ژنوتیپ ، بین این جمعیت ها یک یا دو هفته تاخیر وجود داشت. مثلا، روی ژنوتیپ *B. juncea* cv. RH 7846 حداکثر جمعیت شته در دهمین هفته استاندارد هواشناسی (SMW) ثبت شد در حالی که جمعیت شکارگر طی دوازدهمین هفته استاندارد هواشناسی در فصل زراعی ۰۸-۲۰۰۷ به حد اثر رسید. از میان دشمنان طبیعی، coccinellids از همه بیشتر بود به این ترتیب که در فاز اولیه افزایش جمعیت، کرم های سفید چیره بود و در مراحل بعدی حشره بالغ بیشترین جمعیت را داشت. برای محدود کردن جمعیت شته در اوایل فصل لازم است که دشمنان طبیعی موجود در زیست بوم خردل را حفظ کرد یا این که آنها را در این زمان رها کرد تا جمعیت شته در مرحله تاخیری افزایش رشد محدود شود.

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