Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(4): 112-116

Received: 16-05-2017
Accepted: 17-06-2017

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Evaluation of efficacy of predators against green apple aphid (*Aphis pomi*) in apple orchards and cabbage aphid (*Brevicoryne brassicae*) in cabbage field of Kashmir

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Abstract
The experiment was conducted to evaluate the efficacy of natural enemies against green apple aphid, Aphis pomiin apple orchards and cabbage *aphid, Brevicoryne brassicae* in cabbage field. 2nd and 3rd instar larvae of three species of coccinellids viz., *Coccinella septempunctata, Adalia tetraspilota* and *Hippodamia verigata* and one species of chrysopid (*Chrysoperla z. sillemi*) were released @ 30/tree (4 weekly release) in apple orchards of Pattan of district Baramulla and 5/ plant in cabbage of farmer field Narkara of district Budgam with a treated check (Imdaclorpid 17.8SL @ 0.28ml/Liter of water) and with an untreated check (use water only) for experiments in both the cases during 2014. Both the stages were monitored for their efficacy on apple aphid and cabbage aphid on the 'Red delicious' varieties and 'Golden acre' variety of cabbage respectively. The 3rd instar stage of *Coccinella septempunctata* exhibited best performance on the basis of reduction of green apple aphid (62.00%) and cabbage aphid (63.98%) with highest recovery of 52.00% and 54.4%, respectively. Hence, *Coccinella septempunctata* may be considered as a potential bio-control agent against green apple aphid and cabbage aphid in respective ecosystems of Kashmir.

Keywords: Biological Control, efficacy, predators, *Aphis pomi, Brevicoryne brassicae*, Apple orchards, cabbage field

Introduction
Aphids are an extremely successful group that occurs throughout the world [1]. So far 800 species of aphids have been described from India [2]. The green apple aphid, *Aphis pomi*De Geer (Hemiptera: Aphididae), is a holocyclic and monoecious aphid species that is widespread in Kashmir region [3]. It is one of the most important pests in apple orchards with infestation occurring regularly each year [4]. Continuous feeding by aphid causes yellowing, wilting and stunting of plant [5]. Sever infestation may curl leaves [6], reduce tree growth and non-structural carbohydrate concentration in young apple tree over the period of May-June [7] and decrease fruit production [8]. Cabbage aphid, *Brevicoryne brassicae* L. (Hemiptera: Aphididae) is an important pest in cabbage fields in Kashmir [3]. Cabbage aphids feed on the underside of the leaves and on the centre of the cabbage head [9]. They prefer feeding on young leaves and flowers and go deep into the heads [10]. Colonies of the cabbage aphid can be seen on upper and lower leaf surfaces, in leaf folds, along the leafstalk, near leaf axils [11]. In cabbage aphid *B. brassicae*, there are two small pipes called cornicles or siphunculi (tailpipe-like appendages) at the posterior end that can be seen if one looks with a hand lens. These short cornicles and the waxy coating found on cabbage aphids help differentiate cabbage aphids from other aphids that may attack the same host plant [12, 5]. Aphids feed by sucking sap causes yellowing, wilting and stunting of plants. Severely infested plants become covered with a mass of small sticky aphids (due to honeydew secretions), which can eventually lead to leaf death and decay.

The green apple aphid, *A. pomi* and the cabbage aphid, *B. brassicae* are two important pests of temperate fruits and cruciferous vegetables, respectively [3]. Damage in agricultural and horticultural crops caused by aphids is very dreaded problem because one aphid is enough to profound damage for large crop area by transmitting the viral diseases [13]. It is especially harmful in nurseries and young orchards [14, 15, 16]. The apple aphid, *Aphis pomi* is an economically important pest of apple throughout the world [17] along with the cabbage aphid. Apple and cabbage are economically two important crops of Kashmir.

The farmers depend on insecticides for their eradication. Their resistance was also found to increase progressively in concurrence with regular use on vegetables and fruits [18]. So presence of predators and parasitoids in orchids and vegetable fields has been a subject for many studies for reducing the insecticide usage and thereby environmental pollution [19, 20]. Usually the role played by the natural enemies minimize the need of application of insecticides and increase the density of natural enemies which results in increased rate of reduction in aphids. Thus conservation biological control aims at enhancing natural enemy densities within the orchard system through attraction and/ or retention [21, 22] and the natural enemy complex of Aphis species has been extensively studied by Oatman and Legner [23]; Holdworth [24]; Carrol and Hoyt [25]; Hagley and Allen [14]; Haley and Hogue [26].

The management of sap sucking insect pests through bio-agents renders it important to record the diversity of natural enemies of aphids, both generalist and specific, commonly occurring in any crop ecosystem to exploit them in favour. The aphidophagous arthropod guild can be divided broadly into specialists that include Baconidae and Aphidiinae parasitoids, predatory coccinellids [27, 28], Lacewings [29, 30] and Hoverflies [4] or generalist that include euryphagous predators like ground beetles and spiders [31]. Intra-guild competition is often reported among aphidophagous natural enemies due to their foraging activity when they frequently encounter hetero-specific aphid predators [32], which may disrupt biological control efforts against aphids where more than one predator species is present; hence, this necessitates carefully choosing a combination of predators for success in biological control of aphids [33].

The aim of present study was to investigate the potential aphicidal efficacy of three species of coccinellids viz., *Coccinella septempunctata, Adalia tetraspoilota, and Hippodamia verigata* and one species of chrysopid viz., *Chrysoperla z. sillemi* against the green apple aphid *(Aphis pomi)* in apple orchards of Pattan (Baramulla) and cabbage aphids (*Brevicoryne brassicae*) in cabbage field of Narkara (Budgam) of Kashmir.

2. Materials and Methods

2.1 Experimental Design

The cultures of predatory natural enemies (Coccinellids and Chrysoperla), green apple aphid (*Aphis pomi)* and cabbage aphid (*Brevicoryne brassicae*) were maintained at 25± 2^0C temperature 60±10 % relative humidity and a photoperiod of 14 hours light: 10hours dark. Three species of coccinellids viz., *Coccinella septempunctata* (Cs), *Adalia tetraspilota* (At) and *Hippodamia verigata* (Hv) and one species of chrysopid, *Chrysoperla zastrowi sillemi* (Czs) were used for experiments during month of June and July, 2014. The aphid and its predators were collected from apple orchards and Cabbage fields of Kashmir. Ten pairs of aphid predators Viz., Coccinellids and Chrysoperla were released for mating and oviposition into plastic container (height 20cm and diameter 15cm) containing moist filter paper and covered with muslin clothfor coccinellids and for Chrysoperla in breeding cage (50x30x20)cm were used, provided daily with sufficient prey for egg lying and survival. Newly hatched larvae were collected from the jar and breeding cage and reared separately to avoid cannibalism in vails (3cm diameter x 5cm height. The 2nd and 3rd instar larvae of Coccinellids and Chrysoperla were collected from stock culture and starved for 24 hrs before the experiments.

Both stages of predatory coccinellids as well as Chrysoperla were released @30/tree in apple orchards of Pattan of district Baramulla and 5/ plant in cabbage of farmer field of Narkara of district Budgam with a treated check (Imdaclorpid 17.8SL @ 0.28ml/L) and an untreated check (use water only) as control. Pre-treatment count was taken one day before the first release and post treatment count were recorded one day after every weekly release(s). The observation regarding recovery of natural enemies was taken one day before treatment (first release) and 30 days after 4th weekly release (last release). Each treatment was replicated 5 times.

2.2 Statistical analysis

The trails were laid out in randomized block design in both apple orchards as well as Cabbage fields. In case of apple orchards the trail was laid on apple trees of "Red delicious" variety of 15-20 years of uniform age and "Golden acre" variety of cabbage in cabbage fields. Percent reduction was worked out by computing the differences between pre and post treatment population of green apple aphid and cabbage aphid by applying Abbot's formula [34]. The data was subjected to analyze of variance and critical differences at 5% level of significance was work out.

3. Results and Discussion

3.1 Efficacy of predators against *Aphis pomi*

In the present study the biological control of *Aphis pomi* and *Brevicoryne brassicae* was evaluated. After first weekly release the highest mean mortality (55.75%) of green apple aphidwas recorded against 3rd instar grab of *Coccinella septempunctata* @30/ tree which was significantly high than other predatory treatments as compared to treated check (Imdaclorpid17.8SL@ 0.28ml/L) and was 76.66%. The other treatments were showed the reduction of green apple aphid population were 47.26% against 2nd instar grub of Cs@ 30/tree; 42.00% against 2nd instar larvae of Czs@ 30/tree; 44.06% against 3rd instar larva of Czs@ 30/tree; 44.42% against 2nd instar grub At @ 30/tree; 44.05% against 3rdinstar grub At@ 30/tree; 46.02% against 2nd instar grub of Hv @30/tree and 47.65% against 2nd instar grub of Hv@ 30/tree after first weekly release (Table 1). The feasibility of using predatory insects for biological control of aphids in protected crops was investigated by Scopes [35] using *Crysoperla carena* L. and by Gurney & Hussey [36] for 4 *Coccinellid sp*. were supported to our findings.

After, 2nd weekly release the maximum reduction of 59.62% of green apple aphid population was recorded against 3rd instar grub of Cs@ 30/tree which was statistically on par with all the predatory treatments and in treated check (Imdaclorpid 17.8SL@ 0.28ml/L) and was 78.39%. Other treatments, showed increasing trend as compared to the data of after 1st weekly release. The green apple aphid population were reduced as 49.36%, 45.86%, 50.88%, 46.18%, 47.70 and 51.07% in case of 2nd instar grub of Cs, 2nd instar larva of Czs, 3rd instar larva of Czs, 3rd instar grub of At, 2nd instar grub of Hv, respectively @ 30/tree and 3rd instar grub of Hv @ 30/tree after 2nd release of green apple aphid predators. Least reduction of green apple aphid was recorded 44.37% against 2nd instar grub of At @ 30/tree after 2nd release. The reductions of green apple aphid increased after 3rd and 4th weekly release of predators and under the treatment of treated check (Imdaclorpid 17.8SL@ 0.28ml/L) were decreased. The highest reduction after 3rd and 4th release were recorded as 64.37% and 68.36% against 3rd instar grub of Cs @ 30/tree and least were recorded 49.02% and 55.59% against 2nd instar grub of At @ 30/tree in apple orchards of Kashmir.

The highest mean reduction of green apple aphid was recorded 62.00% against 3rd instar grub of Cs @ 30/tree followed by 3rd instar grub of Czs@ 30/tree was 55.11% and least mortality (36.34%) was recorded against 2nd instar grub of At @ 30/tree. In other treatment, the reduction of green apple aphid were 51.81%, 48.37%, 50.21%, 52.14% and 54.37% in case of 2nd instar grub of Cs, 2nd instar larva of Czs, 3rd instar grub of At and 2nd instar grub of Hv and 3rd instar grub of Hv, respectively. Under treated check the meanreduction of green apple aphid population was 74.86% as compared quite high then that of the other predatory treatments. The recovery of predatory fauna was also recorded after 30days of 4th weekly release and highest recovery (52.00%) were recordedin case of 3rd instar larvae of *Coccinella septempunctata* treated plot followed by 3rd instar larvae of *Chrysoperla z. sillemi* (40.00%) as compared to the treated check (Imdaclorpid 17.8SL@ 0.28ml/L) showing reduction of 56.25%. Least recovery of 21.05% was recorded against 2nd instar grub of *Hippodamia verigata* @ 30/tree. Rest of treatment showed as 37.50%, 38.46%, 25.00%, 35.71% and 33.33% recovery of predatory fauna against 2nd instar grub of Cs, 2nd instar larvae of Czs, 2nd instar grub of At, 3rd instar grub of At and 3rd instar grub of Hv, respectively. Little informations are available on release of predators by Tauber *et al*., (2000) [37] proved that releases of the second-instar larvae of C. carnea have proven to be very successful for the control of the green peach aphid [14].

3.2 Efficacy of predators against *Brevicoryne brassicae*

The percent reduction of cabbage aphid (*Brevicoryne brassicae*) (57.36%) against 3rd instar grub of *Coccinella septempunctata* @ 5/plant after first weekly release was recorded highest than other treatment as compared to treated check (Imdaclorpid17.8 SL @ 0.28ml/L of water) that was 78.32%. In other treatment the reduction of cabbage aphid population observed were 47.28% against 2nd instar grub of Cs @ 5/plant (3releases), 39.02% against 2nd instar larvae of Czs @ 5/plant, 42.59% against 3rd instar grub of Czs@ 5/plant, 44.36% against 2nd instar larvae of At @ 5/plant, 33.74% against 3rd instar larvae of At @ 5/plant, 35.69% against 2nd instar larvae of Hv@ 5/plant and 44.68% against 3rd instar larvae of Hv@ 5/plant at first days after first weekly release (Table 2). After, 2nd weekly release, the maximum reduction of 62.19% of cabbage aphid was recordedagainst 3rd instar larva of Cs @ 5/plant which was statistically on par with all the predatory treatments and in treated check (Imdaclorpid17.8 SL @ 0.28ml/L) it was 74.12%. The reduction of cabbage aphid showed increasing trend as compared to the data of after weekly release. The cabbage aphid population were reduced as 49.53%, 48.67%,40.20%,39.84%,49.75% and 48.63% against 2nd instar grub of Cs@ 5/plant, 2nd instar grub of Czs @ 5/plant, 3rd instar grub of Czs @ 5/plant, 2nd instar grub of At@ 5/plant, 3rd instar grub of At@ 5/plant, 2nd instar grub of Hv@ 5/plant and 3rd instar grub of Hv@ 5/plant after second weekly release, respectively as compared to treated check Imdaclorpid(17.8 SL) @ 0.28ml/L

The reduction of cabbage aphid population were increase after 3rd and 4th weekly release of predators and under the treated check (Imdaclorpid17.8 SL @ 0.28ml/L) were decreased as 73.22% and 72.24%, respectively. The highest reduction after 3rd and 4th release were recorded as 66.35% and 70.07% against 3rd instar grub of Cs @ 5/plant and least were recorded 46.25% and 53.05% against 2nd instar grub of At @ 5/plant, respectively in cabbage field of Kashmir. The highest mean reduction of cabbage aphid was recorded 66.98% against 3rd instar grub of Cs @ 5/plant followed by 2nd instar of Cs @ 5/plant was 53.51% and least reduction (43.25%) was recorded against 2nd instar grub of At @5/plant. In other treatment, the reduction of cabbage aphid were 49.78%, 51.61%,52.18%, 44.01% and 52.46% against 2nd instar grub of Czs@ 5 /plant, 3rd instar larvae of Czs @ 5/plant, 2nd instar grub of At@ 5/plant, 3rd instar grub of At@ 5/plant, 2nd instar grub of Hv@ 5/plant and 3rd instar grub of Hv@ 5/plant, respectively. Under treated check of Imdaclorpid (17.8 SL) @ 0.28ml/L mean reduction of cabbage aphid was 74.52% as compared to predatory treatments.

The recovery of predatory fauna was also recorded 30days of 4th weekly release and recorded highest recovery (57.10%) in case of 3rd instar grub of Czs@ 5/plant followed by 54.54% in case of 3rd instar grub of Cs@ 5/plant and both are statistically similar to each other as compared to treated check of Imdaclorpid (17.8 SL) @ 0.28ml/L andreduced 50.00%. The least recovery of 33.33% was recorded against 2nd instar grub of Hv @ 5/plant. Rest of the treatments, showed; 50.00%, 42.85%, 40.00%, 50.00% and 41.66% recovery against 2nd instar grub of Cs, 2nd instar larva of Czs, 2nd instar grub of At, 3rd instar grub of At and 3rd instar larva of Hv @ 5/plant, respectively.

Our results showed that *Coccinella septempunctata* being more efficient on subduing and consuming prey, and consequently being more voracious was able to eat a large amount of aphid compared to *Adalia tetraspilota*, *Hippodamia verigata and* chrysopid *(Chrysoperla z. sillemi*. Also the number of aphids engrossed by 2nd and 3rd instar larvae showed significant difference. The third instar larvae are showed better predatory activity and faster response. The higher voracity of later instar larvae is possibly due to higher energy intake for growth and to attain critical weight for pupation [38]. The recovery of 3rd instar grub wasalso more as compared to the grubs recovered by releasing the 2nd instar. The number of prey items attacked also increase with the total time, prey density and attack rate [39]. The increase in number of aphid killed with the increasing density may be explained by the fact that at higher prey densities, encounter rates are more frequent and consequently predators consume considerably more than the minimum required [38, 40].

Table 1: Evaluation of efficacy of predators against green apple aphid *Aphis pomi* in apple orchard of Kashmir

Treatment	Number of aphids/10cm of twigs before treatment	Number of aphids/10 cm twig after treatment*				Mean	Recovery of Natural enemies**	
		1st weekly release	2nd weekly release	3rd weekly release	4th weekly release		Before treatment	After treatment (30 days after 4th weekly release)
2nd instar grub of Cs@30/ tree	78.2	41.24 (47.26)	39.60 (49.36)	36.98 (52.71)	32.90 (57.92)	37.68 (51.81)	1.4	2.3 (37.50)
3rd instar grub of Cs@30/ tree	74.8	33.10 (55.75)	30.20 (59.62)	26.65 (64.37)	23.74 (68.26)	28.42 (62.00)	1.2	2.5 (52.00)
2nd instar larva of Czs@30/ tree	80.4	46.62 (42.00)	43.53 (45.86)	40.06 (50.17)	35.84 (55.42)	41.51 (48.37)	0.8	1.3 (38.46)

3rd instar larva of @30/ tree	81.6	45.64 (44.06)	40.12 (50.88)	34.04 (58.28)	26.72 (67.25)	36.63 (55.11)	0.9	1.5 (40.00)
2nd instar grub of At30@30/ tree	76.6	45.39 (44.42)	42.61 (44.37)	39.05 (49.02)	34.02 (55.59)	40.26 (36.34)	1.2	1.6 (25.00)
3rd instar grub of At@30/ tree	79.4	44.42 (44.05)	42.73 (46.18)	38.19 (51.90)	33.61 (57.67)	39.73 (50.21)	0.9	1.4 (35.71)
2nd instar grub of Hv@30/ tree	80.2	43.29 (46.02)	41.94 (47.70)	37.62 (53.09)	30.69 (61.17)	38.38 (52.14)	1.5	1.9 (21.05)
3rd instar grub of Hv@30/ tree	82.0	42.92 (47.65)	40.12 (51.07)	36.34 (55.68)	30.29 (63.30)	37.41 (54.37)	1.2	1.8 (33.33)
Treated check (Imdaclorpid 17.8SL @ 0.28ml/liter of water)	79.8	18.62 (76.66)	17.24 (78.39)	19.20 (75.44)	25.19 (68.43)	20.06 (74.86)	1.6	0.7 (-56.25)
Untreated check (Use water only)	80.4	82.80 (-2.98)	91.62 (-13.95)	94.78 (-14.38)	98.42 (-22.41)	91.90 (-14.31)	1.6	1.8 (11.11)
CD(P=0.05)	4.20	4.39	3.36	4.42	4.18	-	-	-

Replication: 5, Figure in parenthesis indicates mean % reduction of aphids, Cs = *Coccinella septempunctata*, Czs = *Chrysoperla z.sillemi*, At = *Adalia tetraspilota*, Hv = *Hippodamia verigata*, *Natural enemies count on the basis of 10 twigs.
**Figure in parenthesis indicates mean % Recovery of Natural enemies.

Table 2: Evaluation of efficacy of predators against cabbage aphid *Brevicoryne brassicae* in Cabbage field of Kashmir

Treatment	Number of aphids/ leaf before treatment	Number of aphids/ leaf after treatment				Mean	Recovery of Natural enemies*	
		1st weekly release	2nd weekly release	3rd weekly release	4th weekly release		Before treatment/10 leaves	After treatment (30 days after 4th weekly release/ 10 leaves)
2nd instar grub of Cs@ 5/Plant	80.25	42.30 (47.28)	40.50 (49.53)	36.25 (54.82)	30.15 (62.42)	37.30 (53.51)	1.2	2.4 (50.00)
3rd instar grub of Cs@ 5/ Plant	75.65	32.25 (57.36)	28.60 (62.19)	25.45 (66.35)	22.65 (70.05)	27.23 (63.98)	1.0	2.2 (54.54)
2nd instar larva of Czs@ 5/Plant	92.25	56.25 (39.02)	47.35 (48.67)	43.65 (52.68)	38.25 (58.53)	46.32 (49.78)	0.8	1.4 (42.85)
3rd instar larva of Czs@ 5/ Plant	90.85	52.15 (42.59)	45.65 (49.75)	41.25 (54.59)	36.75 (59.54)	43.95 (51.61)	0.6	1.4 (57.14)
2nd instar grub of At@ 5/ Plant	94.25	62.45 (33.74)	56.70 (39.84)	50.65 (46.25)	44.25 (53.05)	53.51 (43.25)	1.2	2.0 (40.00)
3rd instar grub of At@ 5/ Plant	85.65	47.65 (44.36)	43.25 (49.50)	38.65 (54.87)	34.25 (60.01)	40.95 (52.18)	0.8	1.6 (50.00)
2nd instar grub of Hv@ 5/ Plant	90.65	58.25 (35.69)	54.20 (40.20)	48.10 (46.93)	42.40 (53.22)	50.73 (44.01)	1.6	2.4 (33.33)
3rd instar grub of Hv@ 5/ Plant	82.25	45.50 (44.68)	42.25 (48.63)	36.20 (55.98)	32.45 (60.54)	39.10 (52.46)	1.4	2.4 (41.66)
Treated check(Imdaclorpid 17.8SL @ 0.28ml/liter of water)	95.25	20.45 (78.32)	24.65 (74.12)	25.50 (73.22)	26.75 (72.24)	24.33 (74.52)	1.6	0.8 (-50.00)
Untreated check (use water ony)	89.15	90.25 (-1.23)	90.76 (-1.81)	92.30 (-3.53)	94.65 (-6.17)	91.44 (-2.57)	1.8	2.2 (18.18)
CD(P=0.05)	4.67	3.66	4.01	3.19	2.94	3.08	-	-

Replication: 5, Figure in parenthesis indicates mean % reduction of aphids
Cs = *Coccinella septempunctata*, Czs = *Chrysoperla z.sillemi*, At = *Adalia tetraspilota*, Hv = *Hippodamia verigata*
*Figure in parenthesis indicates mean % Recovery of Natural enemies

4. Acknowledgements
This research has been funded by Department of Science and Technology (DST), Ministry of Science; New Delhi, India entitled "Biodiversity and management of aphid fauna of temperate horticulture ecosystem of Kashmir". The authors are thankful to DST for the financial assistance.

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