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Alcaeorrhynchus grandis and *Oomyzus scaposus*: Natural enemies of *Coccinella septumpunctata* in Bundelkhand

Sundar Pal, Sushil Kumar Chaturvedi, David Chella Baskar, Pradeep Kumar, Amit Kumar Patel, Arvind Parmar and Vishal Sarsiya

Abstract
In nature, *Coccinella septumpunctata* is a predator that deprives harmful insects of food and plays a significant role in crop protection; nevertheless, its end-parasites are also present in ecosystems, which are affecting its parasitic effect. *Oomyzus scaposus* and *Alcaeorrhynchus grandis* have been identified as pupal parasitoids and grub predators of *Coccinella septumpunctata* in Rani Lakshmi Bai Central Agricultural University, Jhansi, and Uttar Pradesh, India. In nature, *Oomyzus scaposus* is a parasite on a predator, *Coccinella septumpunctata*, thus being placed in the hyper parasitoid group. Observations show that the range of dead pupae of the ladybird beetle was 7.41-85.0 percent during that time when the degree of beetle pupae was 0.3±0.1-6.9±2.7 pupae plant^{-1} week^{-1}. *Alcaeorrhynchus grandis* caused 50 percent of the grub population and 100 percent of the pupae to die. As for beetle larvae and pupae, the ranges were 1.3±0.6 - 30.7±7.1 and 2.3±0.6 - 48.7±7.6, respectively, while for sting bugs, it ranged from 0.7±0.6 - 3.3±2.1adults annually. A high parasitism level has led to a contraction in predator communities, which has appeared to decline their natural biological control.

Keywords: *Alcaeorrhynchus grandis*, *Coccinella septumpunctata*, *Oomyzus scaposus*, Bundelkhand

Introduction
The Coccinellidae family belongs to the Coleoptera order, most of whose members are predators that are eaten soft body insects except for herbivorous Henosepilachna vigintioctopunctat that attacks brinjal. The *Coccinella septempuctata* is used as a biological control agent to eliminate harmful soft body insects. Natural factors are, including biotic and abiotic factors, affect the survival and predatory efficiency of the beetle. Predators are alert by nature and flee as soon as they get hurt, so cultural operations also reduce their perception of the surrounding environment. To protect itself from its natural enemies, the beetle uses defense reactions like flying away, running away, repeatedly wings spreading and shrinking, dropping from the plant. Other anti-predator adaptations (spiny projections or gin traps used primarily against ants during the pupal period). Among *Coccinella septempuctata*, the maximum number of aphids is consumed (Sundar and Bhatt, 2018) [9]. Numerous researchers have noted drastic variations in species diversity among the Coccinella. There were 78 species of Coccinella found in Poland, 71 species in Austria, and 67 species in Ukraine, reported by Hodek and Honek (1996) [2]. Based on Poorani (2002) [4] reports, about 400 species of Coccinella exist in India. In addition, there are also many secondary parasitoids and hyperparasitoids associated with the primary parasitoids. *Oomyzus scaposus* is first described as a larval and pupal parasite of *Coccinella septempunctata* in the Sargodha district of Punjab, Pakistan, by Ullah *et al.* (2020) [11]. Coccinella has about 160 parasitoids, of which 40 have hyperparasitoids, described in Piotr *et al.* (2012) [3]. This study only tried to identify what role natural enemies play in reducing the effects of the ladybird beetle in the environment.

Methods and Materials
Data was collected from the cafeterias of the Rani Lakshmi Bai Central Agricultural University in Jhansi (UP), India, during 2018-19 and 2019-20. The data on the wasp parasitic effects on beetle pupae were collected by randomly selecting five mustard plants in three different places within a field, from a cafeteria system, cereals, and oilseeds ecosystems, each at a weekly interval. The pupae from the whole plant were picked and counted, then placed in the rearing cage, and only those that died after parasitic emergence were counted.

The predatory effects of the stink bug were examined every week on five brinjal plants randomly selected from three different positions in the vegetable cafeteria crop. Collect beetle grubs and pupae from the entire plant, then place them in a rearing laboratory cage, counting and calculating death percentages. ICAR-National Bureau of Agricultural Insect Resources in Bangalore, India, received the specimen to identify the parasitic wasp emerging from the pupae.

Result and Discussions

Parasitoid wasps and *Coccinella septumpuncatata*

A study carried out in Bundelkhand discovered *Coccinella* pupae being parasitized by *Oomyzus scaposus* (Thomson). A population of adult Coccinella beetles was recorded at plants from 48th S.W. to 14th S.W. Its size range was 0.4±0.4 to 6.5±0.9 beetles plant^{-1} week^{-1}. During that period, the population of adult beetles peaked at 7th S.W. (Table 1). The highest population of adult beetles was recorded in 2009 and 2010 in the first week of August, according to Ali *et al.* (2018). Grubs' population increased from the 49th S.W. to the 8th S.W. and then decreased continuously until the end of the season. There were 8.9±2.3 grubs plant^{-1} week^{-1} at the peak population of 8th S.W. In the beginning, pupae were observed on the 52nd S.W., and its population was 0.5±0.2 pupae/plant/week, which was gradually increased until it reached the 10th S.W., at which point it had reached a peak. One of the earliest reports of the parasitized pupa of the Coccinella killed by the parasitic wasp *Oomyzus scaposus* was made on the 6th S.W., the last week of the season (plate 1). During that time, the parasitized pupae population was at its peak, with 3.3±0.6 pupae/plant/week and a parasitization percent range of 7.4-83.3.

In the cereal crop ecosystem, the peak population of the adult beetle was recorded at 7th S.W., with 6.5±0.8 adults plant^{-1} week^{-1} at that time, and it increased continuously from 48th S.W. Grubs were observed on the 48th to 14th S.W. between the research locations. At the 9th S.W., the population was a peak with 7.7±2.8 grubs plant^{-1} week^{-1}, starting with 0.4±0.4 grubs plant^{-1} week^{-1}. In the first SW, *Coccinella* pupae were spotted for the first time, increasing up to the fifth S.W., then decreasing for two weeks before returning to increasing order. As the season came to an end, the population was decreasing. *Coccinella* pupae were first parasitized during the 6th S.W. of the season. The pupil parasitism plant^{-1} week^{-1} values were 0.5±0.1, 0.7±0.5, 1.1±0.6, 1.2±0.4, 2.2±0.2, 2.4±0.4, 3.1±0.2, 3.5±1.0, and 2.8±0.8 while from the 6th to 14th SW its parasitization percentage was 17.0, 29.2, 31.3, 34.2, 51.1, 55.4, 60.7, 79.5, and 83.3. It was reported that *C. septempunctata* was attacked by three parasitic species and that high mortality was caused by *O. scaposus* (Won *et al.*, 1996) [12]. From 47th S.W. to 9th S.W., the adult and grub population of *Coccinella* had an increasing distribution, but after that, it declined. The grub density ranged between 0.3±0.2 and 7.5±0.5 grubs plant^{-1} week^{-1} for the whole season but peaked at 9th S.W.

Pupae population was tracked to be 0.7±0.6, 1.1±0.9, 2.7±0.8, 2.7±0.6, 2.7±1.2, 3.1±0.6, 3.6±0.2, 4.7±0.2, 5.7±0.8, 6.5±1.0, 6.9±2.7, 5.2±0.8 and 3.9±1.6 pupae plant^{-1} week^{-1}, respectively, from 2nd to 14th standard time. The peak of affected pupae by parasitoid wasps occurred at 11th S.W., which was on the point of peaking between 6th S.W. and 14th S.W. In the 6th, as mentioned earlier to 14th S.W. of the season, the parasitization percentages were 17.2, 26.4, 40.6, 65.9, 62.6, 65.7, 55.3, 61.3, and 85.0. Likewise, Likewise, Ullah *et al.* (2020) [11] reported that the same parasite parasitized 58.3% of pupae, while Shahadi *et al.* (2002) [6] reported 46.21%. Romanov (2018) presented the results of finding new occurrences of parasitism of the Crimean ladybird, *Harmonia axyridis* pupa, by Parasitoides *Omizus scaposus*. The *Colccinella septempunctata* L parasitized by *Oomyzus scaposus* has been reported by Triltsch (1996) [10].

Stink bug predation on *Coccinella*

The stinkbug population was reported in the 5th S.W. during the study for the first time from the vegetable cafeteria. Its population fluctuated by the middle of the season, but eventually, it began to decline. According to the record, bug populations ranged from 0.7±0.6 to 3.3±2.1 adults plant^{-1} week^{-1}, while the peak population was found in 10th S.W. (Table 2). In this study, the smelly bug population was estimated to prey on beetle grubs, pupae, and adult coccinella. 1.3*0.6-30.7*7.1 grubs plant-1 week-1 corresponds to its first grub population recorded in the 6th S.W. and its peak population at the 10th S.W. Hence, the grub population fluctuation was due to parasitism prevented the grub population from growing in the usual way. On the 10th S.W., observed a highly predatory effect of stink bugs on grub populations. At that time, the stink bugs killed 3.0±2.7 grubs plant^{-1} week^{-1} and followed throughout the season to be 0.7±0.6 to 3.0±2.7 grubs plant^{-1} week^{-1}. Percentage-wise, predatory effects were most pronounced in the last week of the season, when around 50 percent of the grub population was destroyed. Smith *et al.* (2009) [7] measured stink bugs density as 1.84±0.06 per 25 sweeps for the samples as a whole.

It was founded that ladybird beetle pupae range from 8.3±1.5 to 48.7±7.6 pupae per brinjal plant^{-1} week^{-1}. The pupae were found throughout the season, with their peak presence observed on 10th S.W., while their death rate peaked on 11th S.W. The reason was that this stink bug had been sucking the body sap from pupae using its stylets. The skeleton of the pupae body was entirely found stuck to the plant's leaves. It was evident that the stink bug had a predatory effect on pupae as the pupae died 100 percent during the last week of the study period; their mortality ranged from 18.7 to 100 percent during the study period. Essentially, the pupae stage cannot run away during the attack of a predator since it is immovable while at the same time attached to the plant, thereby resulting in its death. Thus, it uses the push-pool strategy to avoid the predator but fails. The predatory action of stink bugs on beetle pupae has always been more conspicuous than that of grubs during the study period. Similarly, Soni *et al.* (2013) [8] find supports our findings, and Ribeiro *et al.* (2010) [5] have reported that stinkbug predators are preying on caterpillars affecting their populations in palm plantations.

Table 1: The effect of a pupal parasitoid, *Oomyzus scaposus*, on *Coccinella septumpunctata*

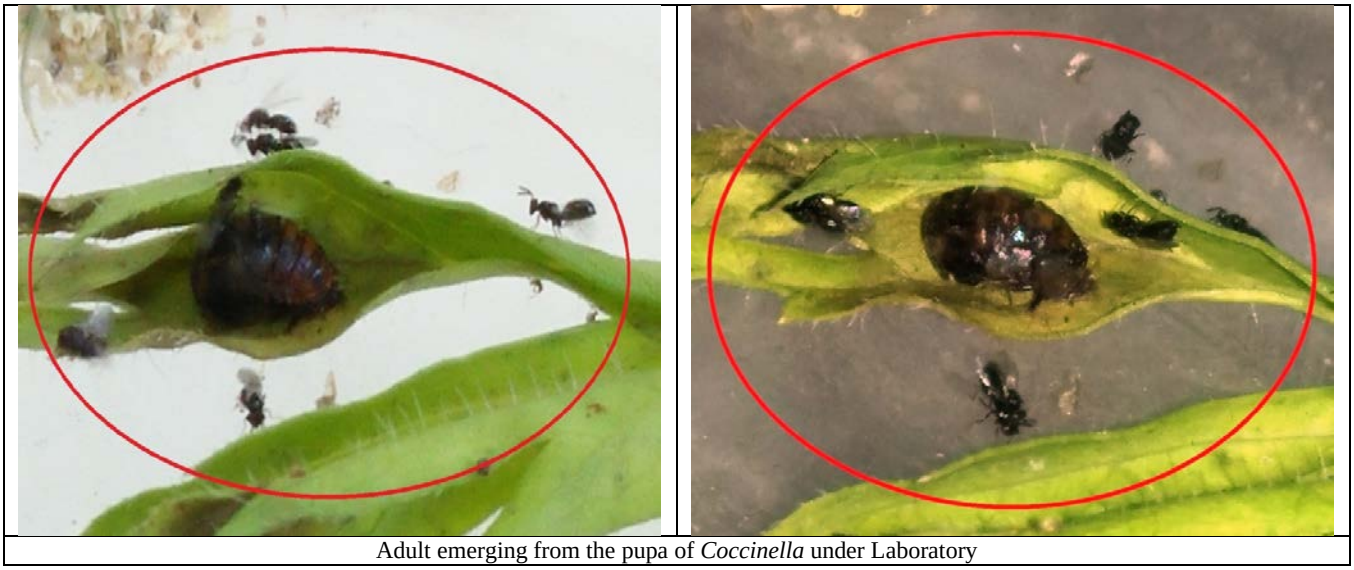
S.W.	Pooled population (Mean±SD$)														
	Crop cafeteria					Cereal crop ecosystem					Oilseed crop ecosystem				
	Adults	Grubs	Pupa	Parasitize pupas	Parasitization (%)	Adults	Grubs	Pupa	Parasitize pupas	Parasitization (%)	Adults	Grubs	Pupa	Parasitize pupas	Parasitization (%)
47	-	-	-	-	-	-	-	-	-	-	0.3±0.5	0.3±0.2	-	-	-
48	0.4±0.4	-	-	-	-	0.1±0.2	0.4±0.4	-	-	-	0.5±0.9	0.4±0.4	-	-	-
49	0.7±0.2	0.7±0.6	-	-	-	0.1±0.2	0.9±0.8	-	-	-	0.8±1.1	0.5±0.3	-	-	-
50	1.1±0.1	2.0±1.4	-	-	-	0.5±0.3	1.6±1.2	-	-	-	0.9±0.9	1.0±0.2	-	-	-
51	1.6±0.4	3.2±1.8	-	-	-	1.2±0.4	2.5±1.5	-	-	-	1.5±0.8	1.5±0.6	-	-	-
52	1.7±0.1	4.8±2.6	0.5±0.2	-	-	1.3±0.6	3.5±2.1	-	-	-	2.3±0.8	3.3±0.3	-	-	-
1	2.9±0.2	5.3±0.9	0.5±0.6	-	-	2.5±0.5	4.0±2.2	0.3±0.1	-	-	2.5±1.2	3.9±0.2	-	-	-
2	3.9±0.3	5.7±1.8	1.1±0.3	-	-	2.6±0.5	5.6±1.8	0.7±0.3	-	-	2.7±0.6	4.7±0.7	0.7±0.6	-	-
3	5.0±0.5	5.9±2.2	1.5±0.2	-	-	3.9±0.6	5.9±2.3	1.0±0.4	-	-	3.7±1.0	4.9±0.6	1.1±0.9	-	-
4	5.8±0.2	6.8±2.8	2.1±0.4	-	-	4.5±0.8	6.3±1.6	2.1±0.2	-	-	5.1±0.5	5.6±0.4	2.7±0.8	-	-
5	5.2±0.4	7.8±0.7	2.8±0.4	-	-	4.8±0.4	6.7±2.2	2.5±0.8	-	-	5.5±0.6	5.6±0.8	2.7±0.6	-	-
6	5.6±0.7	8.1±1.3	3.5±0.2	0.4±0.2	7.4	5.8±0.9	6.1±2.4	2.4±0.4	0.5±0.1	17.0	5.6±1.1	5.9±0.6	2.7±1.2	0.6±0.2	17.2
7	6.5±0.9	8.9±0.6	3.6±0.8	0.8±0.4	24.1	6.5±0.8	7.5±2.0	2.4±0.8	0.7±0.5	29.2	5.7±0.2	6.5±1.0	3.1±0.6	0.8±0.4	26.4
8	5.7±1.3	8.9±2.3	4.3±0.8	1.5±0.8	36.6	4.8±0.8	7.2±2.9	3.3±1.0	1.1±0.6	31.3	6.3±1.2	7.1±0.2	3.6±0.2	1.5±0.8	40.6
9	5.9±1.6	8.1±2.0	4.5±1.4	1.3±0.6	33.6	5.1±1.3	7.7±2.8	3.9±1.2	1.2±0.4	34.2	6.0±1.6	7.5±0.5	4.7±0.2	3.1±0.6	65.9
10	4.2±1.0	4.7±1.0	5.3±1.1	2.1±0.8	42.9	6.1±1.3	6.9±0.8	4.5±1.3	2.2±0.2	51.1	5.5±1.6	5.5±0.6	5.7±0.8	3.6±0.8	62.6
11	3.5±1.0	2.5±0.8	5.3±0.9	2.4±1.1	43.8	2.8±0.4	4.5±1.0	4.5±0.8	2.4±0.4	55.4	3.3±1.3	3.9±0.8	6.5±1.0	4.3±0.6	65.7
12	2.3±0.6	1.6±0.8	5.2±1.1	2.5±0.6	49.7	2.5±0.2	2.5±0.6	5.1±0.5	3.1±0.2	60.7	2.0±0.4	3.3±1.7	6.9±2.7	3.6±0.4	55.3
13	1.1±0.5	0.9±0.6	5.1±1.4	3.3±0.6	68.2	1.3±0.6	2.1±0.4	4.4±1.1	3.5±1.0	79.5	1.1±0.8	2.1±1.2	5.2±0.8	3.2±0.7	61.3
14	0.7±0.2	0.3±0.5	2.4±1.1	2.0±1.1	83.0	0.5±0.5	1.2±0.4	3.3±0.2	2.8±0.8	83.3	0.4±0.4	0.9±0.5	3.9±1.6	3.3±1.5	85.0

*Standard Week, $Standard deviation

Table 2: Hyper-predatory effect of *Alcaeorrhynchus grandis* on grub and pupae of *Coccinella septumpunctata*

S.W.*	Pooled population (Mean±SD$)							
	Coccinella septumpunctata			Stink Bug	Predatory effect of stink bug			
	Grub	Pupa	Adult		Grubs	Mortality (%)	Pupa	Mortality (%)
1.	6.0±1.0	9.7±2.1	4.0±1.0	1.3±0.6	0.7±0.6	11.8	3.3±2.1	34.4
2.	9.0±1.0	19.7±5.5	5.7±1.5	1.3±0.6	1.3±0.6	14.8	3.7±2.1	18.7
3.	15.7±1.5	36.0±5.0	8.3±1.2	2.0±1.0	1.7±0.6	10.7	8.7±4.5	24.1
4.	20.0±8.9	29.3±3.8	15.0±2.7	1.3±0.6	1.3±0.56	6.7	14.0±3.6	47.7
5.	15.7±5.1	26.0±1.7	12.7±1.5	2.3±1.5	1.3±0.6	8.5	11.7±2.1	44.9
6.	30.7±7.1	48.7±7.6	13.3±2.3	3.3±2.1	3.0±2.7	9.8	24.3±5.1	50.0
7.	22.3±8.5	43.7±3.2	12.7±4.0	2.7±0.6	2.7±1.2	12.0	27.7±2.5	63.4
8.	12.3±1.5	29.3±6.4	6.7±2.1	1.3±0.6	2.0±1.0	16.2	13.7±1.5	46.6
9.	9.0±1.0	15.7±1.5	3.0±1.0	1.3±0.6	1.3±0.6	14.8	8.3±2.1	53.2
10.	4.3±0.6	8.3±1.5	2.3±0.6	0.7±0.6	0.7±0.6	15.5	6. 0±1.7	72.0
11.	1.3±0.6	2.3±0.6	0.7±0.6	0.7±0.6	0.7±0.6	50.4	2.3±0.6	100.00

*Standard Week, $Standard deviation



Adult emerging from the pupa of *Coccinella* under Laboratory

Collection of infected pupae from agroecosystem

Adults after emergence in a petri dish

Stink bug stinking on *Coccinella* pupae

Stink bug stinking on *Coccinella* grub

Plate-I

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Conflict of interest
There is no conflict regarding the research work that is being published.

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