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Rahul Kumar
Department of Entomology, CS. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

RS Singh
Department of Entomology, CS. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Neelam Yadav
Department of Entomology, CS. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Awaneesh Chandra
Government Degree College, Jakhini, Varanasi, Uttar Pradesh, India

Corresponding Author:
Awaneesh Chandra
Government Degree College, Jakhini, Varanasi, Uttar Pradesh, India

Effect of different varieties and bio insecticide on natural enemy, *Coccinella septempunctata* of Indian mustard, *Brassica juncea* L.

Rahul Kumar, RS Singh, Neelam Yadav and Awaneesh Chandra

Abstract
A field study was conducted on effect of some varieties on the incidence of mustard aphid during *Rabi* 2010-11 and 2011-12 at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.). The predatory ladybird beetle, *Coccinella septempunctata* reached in (2.82-3.10 beetle/plant) number during first week of March (SW-09 & SW-09) during 2010-2011 and 2011-12, respectively. C. *septempunctata* increased gradually and its medium being 0.86-0.90, 1.04-1.02, 1.10-1.21, 1.46-1.30, 1.54-1.88, 1.90-1.49 and 0.86-1.04 beetle/plant in February 6th, 7th, 8th, 9th March 10th, 11th and 12th standard weeks. On the basis of toxicity against C*occinella septempunctata* the order was *Beauveria bassiana* > Neemarin > *Verticillum lecanii* > Dimethoate.

Keywords: Mustard, *Lipaphis erysimi*, *Coccinella septempunctata*, variety

Introduction
Rapeseed-mustard *Brassica juncea* (L.) is an important oilseed crop, which is a valuable source of edible oil. Mustard aphid (*Lipaphis erysimi* Kalt.) have been reported as a major constraint responsible for this low yield level, which causes average yield losses ranging 27.3-94.5% in Indian mustard due to aphid in U.P. [Singh and Malik, (1998) Singh *et al.*, (2000) and Malik *et al.*, (2003)] [17, 15, 6]. The infestation of aphid in rapeseed-mustard causes losses in seed yield along with the oil content in seeds. However, numbers of chemicals have been recommended for the management of this pest by several workers, but their indiscriminate use for suppressing the pest population increases the environmental hazards. Use of insecticides for the management of insect- pests in different crops is an integral part of integrated pest management, which should be eco-friendly, economically viable and socially acceptable. A number of newer chemicals have been registered in different groups for their better efficacy against different insect-pests. Thus, it is imperative to find out a selective molecule for the cost effective management of mustard aphid. Therefore, efforts were made to determine the efficacy and economics of some newer insecticides for the management of mustard aphid on Indian mustard in central Uttar Pradesh.

Oilseed *Brassicas* also referred to as rapeseed-mustard, an important group of oilseed crops in the world, comprise eight cultivated crops of tribe Brassicaceae within the family cruciferae (Brassicaceae). Uttar Pradesh is the second largest state of growing mustard in the country. The area, production and productivity of mustard in Uttar Pradesh were 6.63 lakh ha, 7.7 lakh tonnes and 1161 kg ha-1, respectively during the year 2013-14.

A number of insect-pests are found to be associated with rapeseed-mustard crops in India, which include mustard aphid, *Lipaphis erysim* Kaltenbach (Homoptera : Aphididae), sawfly, *Athalia lugens* Klug (Hymenoptera : Tenthredinidae), painted bug, *Bagrada hilaris* Burmeister (Hemiptera : Pentatomidae), diamond back moth (*Plutella xylostella* Linnaeus), cabbage butterfly (*Pieris brassicae* Linnaeus), larger moth (*Crocidolomia binotalis* Zeller), green peach aphid (*Myzus persicae* Sulzer) etc. (Dhaliwal and Arora, 2006) [3] but mustard aphid is very important among them which may alone prove as limiting factor in the production of mustard. However, this insect-pest can be managed through chemicals, which have been found detrimental for their natural enemies as well as to human health and also posing the problems of resistance in some of the pests. Therefore, development of eco-friendly techniques in pest management may provide the solution of these problems.

Materials and methods

The field experiments were carried out during winter seasons of 2010-11 and 2011-12. The field experiment was conducted at Student's Instructional Farm**,** C.S. Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh. Experimental field was well leveled and had assured irrigation facilities. The experimental soil was sandy loam in texture and slightly alkaline in nature. The required seeds of all the mustard were obtained from oilseeds section of university during each year of experiment. All 4 treatment combinations (irrigation x genotypes) were tested in a factorial randomized block design with three replications. All treatments were allocated to different plots randomly in each replication.

A field experiment was conducted at Student's Instructional Farm during Rabi season of 2010-11. The experiment was laid out in Split Plot Design (SPD). The experiment included four treatments replicated three times. The plot size of each treatment was 2.8 m x 5.0 m (14 m^2). Urvashi, Vardan, Varuna and Rohini variety of rapeseed was sown @ 6kg/ha on second week of November, 2010 maintaining 30 cm RR and 5 cm PP. Each plot consisted six rows with 40 plants in each row i.e. 360 plants/plot with 12 t/ha compost and 60:40:20 kg NPK/ha as basal dose of plant nutrients. The treatments were: i) *Beauveria bassiana* @ 5gm/L of water; ii) *Verticillilum lecanii* @ 2ml/L of water; iii) Margosom @ 5ml/L of water; iv) Dimethoate @2ml/L of water; and vi) Untreated control. Observations were taken from 10cm apical central shoot of inflorescence from 10 randomly selected plants of each plot. Both pretreatment and post-treatment observations were taken for mustard aphid. Post-treatment observations were recorded after 3, 6, and 9 days of spray. In case of pre-treatment observation, it was taken 24 hours before spraying in case of 1st spray. However, in case of 2nd and 3rd spray, count taken at 9 days after each spray observation was taken as the pre-treatment population for succeeding spray

Population dynamics of mustard aphid and its natural enemies on different varieties of mustard Indian mustard, *Brassica juncea* L.

The population of grubs and adult of different species of ladybird beetle, C*occinella septempunctata* predators were recorded on selected plants separately (grubs and beetle) at weekly intervals on different varieties. To determine the population dynamics of aphid in relation to prevailing weather parameters, the population along with natural enemies, ladybird beetle, C*occinella septempunctata* was recorded at weekly intervals on 10 randomly selected plants on 10 cm top shoots of mustard varieties Varuna, Vardan, rohini and Urvashi in three replication under field conditions. The meteorological data was obtained from the university observatory to correlate with pest population.

Effect of bio-insecticides on natural enemies of mustard aphid

To determine the toxicity of different bio-insecticides application on mustard aphid, treated mustard aphid was fed to natural enemies, ladybird beetle, C*occinella septempunctata* of mustard aphid. The observation was made after 5 days exposes of treated aphid to the natural enemies.

Meteorological observations

The weather data on meteorological parameters *viz*., minimum and maximum Temperature (^{0}C), Relative humidity (%), Rain fall (mm), and Wind speed (km/h) of study period, collected from Department of Agronomy of the University, (Table: 1&2).

Table 1: Meteorological conditions prevailing during year 2010-11 & 2011-12.

Year 2010-11							Year 2011-12					
Standard Weeks	Temperture^{0}C		Relative Humidity		Rainfall Average (mm)	Wind Speed (km/h)	Temperture^{0}C		Relative Humidity		Rainfall Average (mm)	Wind Speed (km/h)
	Max. ^{0}C	Min. ^{0}C	Max. (%)	Min. (%)			Max. ^{0}C	Min. ^{0}C	Max. (%)	Min. (%)		
1	12.9	5.4	95	71	0.0	4.8	19.1	11.1	98	82	4.5	1.8
2	12.7	5.1	94	59	0.0	2.0	18.0	7.3	89	75	0.0	2.1
3	21.9	7.1	83	35	0.0	4.6	19.3	7.5	91	59	0.0	4.1
4	24.0	8.8	84	43	0.0	2.5	21.9	5.8	91	56	0.0	3.7
5	23.6	8.9	88	44	0.0	3.0	22.4	5.6	90	53	0.0	1.9
6	20.9	11.4	89	41	0.0	2.9	21.3	8.3	87	51	7.2	3.3
7	24.5	12.9	88	54	6.2	4.0	23.8	8.8	85	46	0.0	2.3
8	25.0	10.4	89	44	0.0	2.0	28.4	11.5	88	45	0.0	4.9
9	26.9	13.5	83	49	1.8	2.2	27.4	10.3	78	47	1.8	6.4
10	29.1	14.9	73	36	0.0	4.9	28.4	11.5	73	34	0.0	3.9
11	31.9	15.4	78	40	00	3.4	29.1	12.5	72	44	0.0	5.9
12	30.9	16.9	71	42	00	3.9	32.1	15.9	63	33	0.0	7.9
13.	39.9	18.8	80	60	00	3.5	35.7	16.9	68	32	0.0	5.4

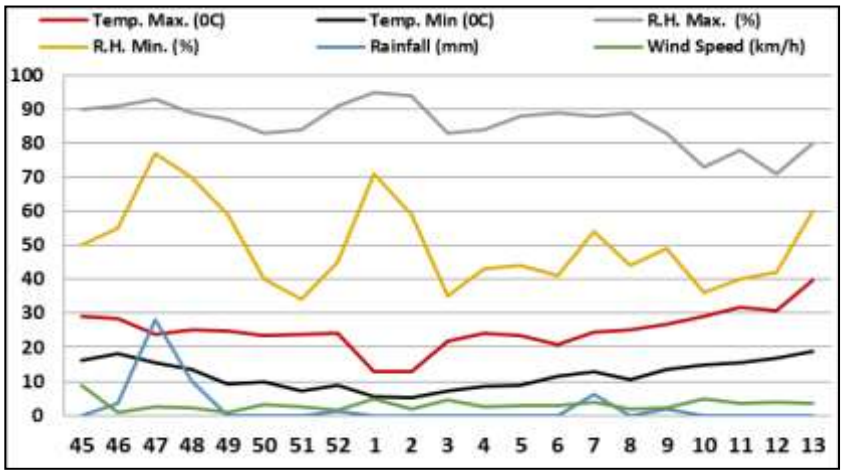

Fig 1: Meteorological conditions prevailing during 2010-11

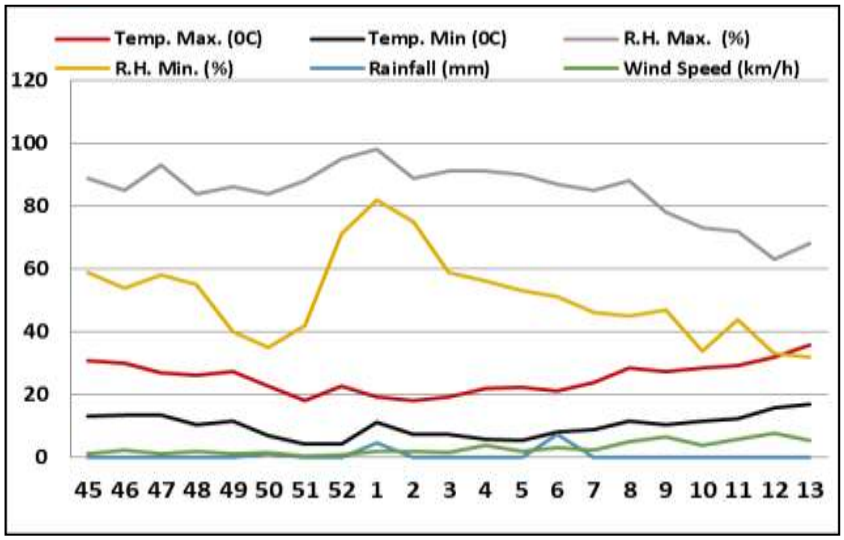

Fig 2: Meteorological conditions prevailing during 2011-12

Table 2: Effect of different varieties and bio-insecticide on natural enemies, C*occinella septempunctata* of mustard aphid

	2010-11 Average no. of C*occinella septempunctata*/plant							**2011-12 Average no. of C*occinella septempunctata*/plant**						
	SW-06	**SW-07**	**SW-08**	**SW-09**	**SW-10**	**SW-11**	**SW-12**	**SW-06**	**SW-07**	**SW-08**	**SW-09**	**SW-10**	**SW-11**	**SW-12**
Urvashi	1.72 (1.31)	2.13 (1.46)	1.96 (1.40)	2.82 (1.68)	1.28 (1.13)	1.06 (1.03)	0.94 (0.97)	1.88 (1.37)	2.22 (1.49)	2.82 (1.68)	3.10 (1.76)	2.25 (1.50)	1.66 (1.29)	1.19 (1.09)
Vardan	1.21 (1.10)	1.59 (1.26)	1.80 (1.34)	2.02 (1.42)	1.19 (1.09)	0.94 (0.97)	0.83 (0.91)	1.59 (1.26)	1.90 (1.38)	2.16 (1.47)	2.43 (1.56)	1.90 (1.38)	1.28 (1.13)	0.98 (0.99)
Varuna	0.98 (0.99)	1.25 (1.12)	1.56 (1.25)	1.42 (1.19)	1.14 (1.07)	0.90 (0.95)	0.83 (0.91)	1.28 (1.13)	1.46 (1.21)	1.72 (1.31)	2.07 (1.44)	1.54 (1.24)	1.10 (1.05)	0.94 (0.97)
Rohini	0.90 (0.95)	0.98 (0.99)	1.30 (1.14)	1.06 (1.03)	1.25 (1.12)	0.94 (0.97)	0.77 (0.88)	0.98 (0.99)	1.14 (1.07)	1.39 (1.18)	1.85 (1.36)	1.23 (1.11)	0.98 (0.99)	0.86 (0.93)
SE(d)	0.05	0.07	0.05	0.06	0.03	0.02	0.02	0.05	0.05	0.07	0.08	0.05	0.05	0.02
CD P(0.05)	0.11	0.14	0.10	0.13	N.S.	0.04	0.04	0.10	0.11	0.14	0.17	0.12	0.10	0.05
Beauveria bassiana	0.90 (0.95)	1.17 (1.08)	1.30 (1.14)	1.49 (1.22)	1.56 (1.25)	1.02 (1.01)	0.92 (0.97)	1.06 (1.03)	1.23 (1.11)	1.49 (1.22)	1.64 (1.28)	1.93 (1.39)	1.82 (1.35)	1.25 (1.12)
Verticillum lecanii	0.83 (0.91)	0.86 (0.93)	0.94 (0.97)	1.00 (1.00)	1.04 (1.02)	0.83 (0.91)	0.83 (0.91)	0.86 (0.93)	0.86 (0.93)	1.02 (1.01)	1.10 (1.05)	1.25 (1.12)	1.25 (1.12)	0.94 (0.97)
Neemarin	0.86 (0.93)	1.04 (1.02)	1.10 (1.05)	1.46 (1.21)	1.30 (1.14)	0.90 (0.95)	0.86 (0.93)	0.90 (0.95)	1.02 (1.01)	1.21 (1.10)	1.30 (1.14)	1.54 (1.24)	1.49 (1.22)	1.04 (1.02)
Dimethoate	0.77 (0.88)	0.83 (0.91)	0.90 (0.95)	1.00 (1.00)	0.98 (0.99)	0.83 (0.91)	0.77 (0.88)	0.83 (0.91)	0.86 (0.93)	0.98 (0.99)	0.98 (0.99)	1.17 (1.08)	1.10 (1.05)	0.86 (0.93)
Control (Untreated)	1.80 (1.34)	2.34 (1.53)	2.99 (1.73)	3.06 (1.75)	3.57 (1.89)	4.00 (2.00)	4.54 (2.13)	1.90 (1.38)	2.99 (1.73)	3.28 (1.81)	3.57 (1.89)	4.20 (2.05)	4.58 (2.14)	4.88 (2.21)
SE(d)	0.02	0.02	0.03	0.05	0.03	0.03	0.03	0.02	0.03	0.05	0.05	0.06	0.05	0.04
CD P(0.05)	0.04	0.04	0.07	0.10	0.06	0.05	0.06	0.05	0.06	0.10	0.10	0.13	0.09	0.08

NB: Figures in parentheses are square root transformed values $\sqrt{x} + 0.5$ NB: T_1– *Beauveria bassiana* 2g/l, T_2– *Verticillum lecanii* 5g/l,T_3– Neemarin, 3ml/l, T_4– Dimethoate 2ml/l

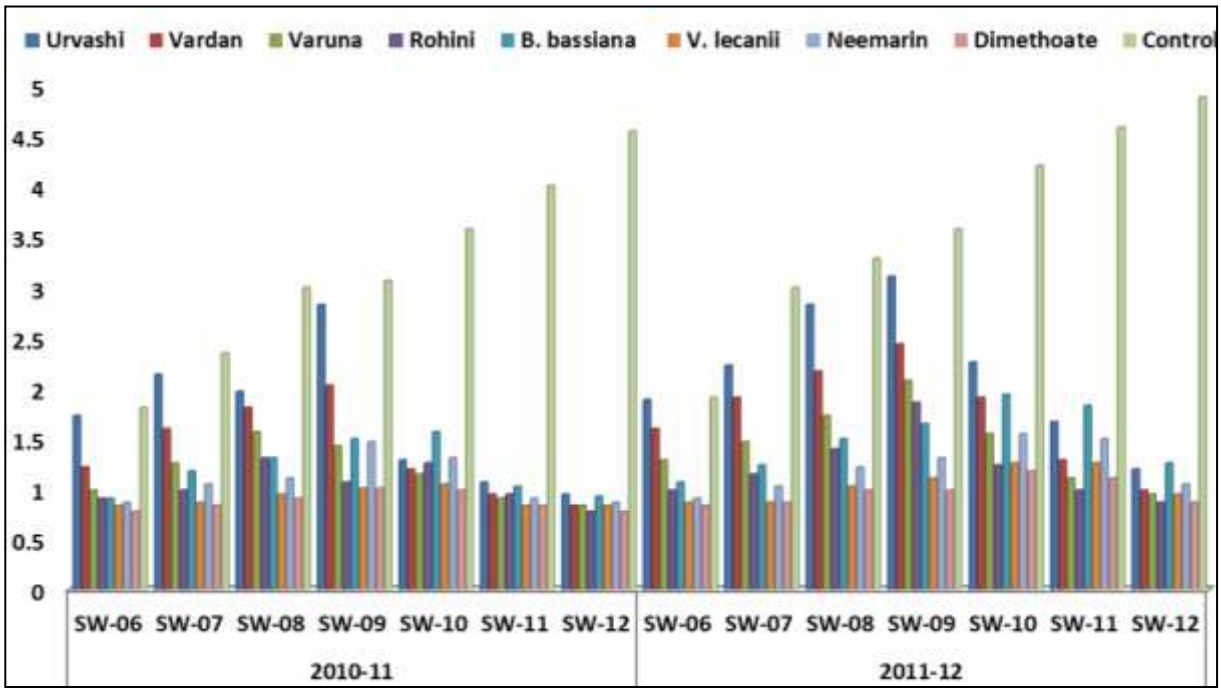

Fig 3: Effect of bio-insecticides on natural enemies of mustard aphid

Results and discussion

Effect of natural enemies (ladybird beetle) on mustard aphid (*L. erysimi* Kalt.) in different mustard crops, during *Rabi* session 2010-11 and 2011-12

The perusal of different natural enemies of mustard aphid was observed on different *Brassica* spp. and recorded predators like *Coccinella spp.* and *Syrphid species*. Coccinellid, C*occinella septempunctata* appeared during second and third week of February with their initial population of aphid was quite high. Ladybird beetle (C*occinella septempunctata*) reached its peak level during mid-February (2.82-3.10 beetles/plant) when the aphid population was highest The population of *C. septempunctata* increased gradually and reached at(2.82-3.10, 2.02-2.43, 1.42-2.07 and 1.06-1.85) on Urvashi, Vradan, Varuna and Rohini, varieties both year, respectively, in the first week of March, when the aphid population are started to decline.

Effect of different varieties on natural enemies, C. *septempunctata* of mustard crop

Maximum population of ladybird beetle C. *septempunctata* as a predator of mustard aphid was observed on different mustard varieties which was found actively predating on mustard aphid from 6th standard week (Table: 2 & Fig. 2.1). The population of predator (*Coccinellidae spp.*) appeared was1.72, 1.21, 0.98 and 0.90 beetle/plant, respectively on mustard varieties *viz*., Urvashi, Vardan, Varuna and Rohini with 24.5^{0}C maximum and 12.9^{0}C minimum temperature and 88.0 maximum and 54.0 minimum percent relative humidity during 2010-11 and 1.88, 1.59, 1.28 and 0.98 beetle/plant, respectively on mustard varieties *viz*., Urvashi, Vardan, Varuna and Rohini with 23.8^{0}C maximum and 8.8^{0}C minimum temperature and 85.0 maximum and 46.0 minimum percent relative humidity during 2011-12.

The ladybird beetle C*occinella septempunctata* population recorded in fist year during 7th standard week was 2.13, 1.59, 1.25 and 0.98 beetle/plant on Urvashi, Vardan, Varuna, and Rohini with 25.0^{0}C maximum and 10.4^{0}C minimum temperature and 89.0 maximum and 44.0 minimum percent relative humidity in year 2010-11, second year during 8th standard week was 2.22, 1.90, 1.46 and 1.14 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 28.4^{0}C maximum and 11.5^{0}C minimum temperature and 88.0 maximum and 45.0 minimum percent relative humidity. And ladybird beetle C*occinella septempunctata* population recorded in fist year 9th standard week 1.96, 1.80, 1.56 and 1.30 beetle/plant on Urvashi, Vardan, Varuna, and Rohini with 26.9^{0}C maximum and 12.8^{0}C minimum temperature and 83.0 maximum and 49.0 minimum percent relative humidity in the year during 2010-11 and second year 8th standard week predator population was 2.82, 2.16, 1.72 and 1.39 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 27.04^{0}C maximum and 10.3^{0}C minimum temperature and 78.0 maximum and 47.0 minimum percent relative humidity.

Among the ladybird beetles C*occinella septempunctata* population gradually increased and reached at its maximum on Urvashi, Vardan, Varuna and Rohini in the first year 9th standard weeks 2.82, 2.02, 1.42 and 1.06 beetle/plant because of 29.6^{0}C maximum and 14.7^{0}C minimum temperature associated with 83.0 maximum and 49.0 minimum percent relative humidity in the year during 2010-11 and second year during 9th standard weeks it was 3.10, 2.43, 2.07 and 1.85 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 28.4^{0}C maximum and 11.5^{0}C minimum temperature and 73.0 maximum and 34.0 minimum percent relative humidity in the year during 2011-12. The population of ladybird beetles recorded in 10th standard weeks its population 1.28, 1.19, 1.14 and 1.25 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 31.9^{0}C maximum and 15.4^{0}C minimum temperature, 78.0 maximum and 40.0 minimum percent relative humidity in the year during 2010-11 (Table: 2 & Fig. 2.1) and second year 10th standard week 2.25, 1.90, 1.54 and 1.23 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 29.1^{0}C maximum and 12.5^{0}C minimum temperature, 72.0 maximum and 44.0 minimum percent relative humidity in year 2011-12 (Table: 1) (Fig 1.1&1.2)

Ladybird beetle C*occinella septempunctata* recorded in first year during 11th standard week on Urvashi, Vardan, Varuna, and Rohini, 1.06, 0.94, 0.90 and 0.94 beetle/plant with 34.9^{0}C maximum and 16.9^{0}C minimum temperature, 71.0 maximum

and 42.0 minimum percent relative humidity and second year during 11th standard week its population was 1.66, 1.28, 1.10 and 0.98 beetle/plant on Urvashi, Vardan, Varuna, and Rohini with 32.1^{0}C maximum and 15.9^{0}C minimum temperature, 63.0 maximum and 33.0 minimum percent relative humidity in year 2011-12. The data recorded in fist year during 12th standard week the ladybird beetle population was 0.94, 0.83, 0.83 and 0.77 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 34.1^{0}C maximum and 18.4^{0}C minimum temperature, 80.0 maximum and 60.0 minimum percent relative humidity in 2010-11 (Table: 2) and in second year during 12th standard week predator population was 1.19, 0.98, 0.94 and 0.86 beetle/plant on Urvashi, Vardan, Varuna and Rohini with 35.7^{0}C maximum and 16.9^{0}C minimum temperature, 68.0 maximum and 32.0 minimum percent relative humidity during 2011-12.

Effect of bio-insecticides on natural enemies (ladybird beetle, *Coccinellidae spp.*) of mustard aphid

The ladybird beetle *Coccinella septempunctata* was found to predator on aphid feeding on different varieties of most crops starting from second week of February. The population of ladybird beetle C*occinella septempunctata* increased gradually and its maximum being 0.90-1.06, 1.17-1.23, 1.30-1.49, 1.49-1.64, 1.93-2.19, 1.02-1.82 and 0.92-1.25 beetle/plant in February 6th, 7th, 8th, 9th March 10th, 11th, and 12th standard weeks, respectively in these year on the bio-insecticides of *Beauveria bassiana* 2g/litre in the fourth week of February from the first week of March, started to decline while ladybird beetle *Coccinella septempunctata* started to increase due to increase in temperature. C. *septempunctata* increased gradually and its medium being 0.86-0.90, 1.04-1.02, 1.10-1.21, 1.46-1.30, 1.54-1.88, 1.90-1.49 and 0.86-1.04 beetle/plant in February 6th, 7th, 8th, 9th March 10th, 11th and 12th standard weeks, respectively in these year on the bio-insecticides of Neemarin (neem oil) 3g/litre in respectively on the fourth week of February from the first week of March. Dimethoate 2ml/litre of water having lowest mean population received with 0.77-0.83, 0.83-0.86, 0.90-0.98, 1.00-0.98, 1.17-1.51, 0.83-1.10 and 0.77-0.86 beetle/plant than other bio-insecticides followed by *Verticillilum lecanii* 5g/litre of water having found mean population with 0.83-0.86, 0.86-0.86, 0.94-1.02, 1.00-1.10, 1.25-1.59, 0.83-1.25 and 0.83-0.94 beetle/plant as compared to control 1.80-1.90, 2.34-2.99, 2.99-3.28, 3.06-3.57, 3.57-4.20, 4.00-4.58 and 4.54-4.88 beetle/plant in February 6th, 7th, 8th, 9th March 10th, 11th and 12th standard weeks during 2010-2011 and 2011-12, respectively.

Regarding the appearance of aphid during January, these results are in corroboration with those of Chandra and Kushwaha (1986) [2], Mathur and Singh (1986 b) [7], Sinha *et al*. (1990) [14], and Rana *et al*. (1993) [9], who also noticed the appearance of aphid population at following stage during January. As regards the appearance of *Coccinellids* during late February, these findings confirm the views of Bakhetia and Sekhon (1989) [1], during late February. The weather conditions, which favoured the fast multiplication of the aphids, proved detrimental of the predatory *Coccinellids.* Vekaria and Patel (2000) [20] reported that the efficacy of 2 plant products (Neemol and nicotine sulfate [nicotine]), applied alone or in combination with chemical insecticides. Evaluation of the effects of the different treatments on the natural enemies of *L. erysimi* showed that both plant products were less toxic to *Diaeretiella rapae* and *Coccinella septempunctata* than the chemical insecticides. Gupta *et al.* (2001) [4] reported the efficiency of seven neem based formulations (neenarin, neemazal, bioneem, nimbicide, achook, econeem and neemgold) in controlling the *L. erysimi* infesting mustard which were evaluated in field experiments. Sanjeev and Singh (2008) [12] reported that the recommended NSKE 5% for aphid management which is safe eco-friendly botanical equally effective as endosulfan. Rana and Singh (2002) [10] reported that a significant reduction in aphid at 10 DAS, thus *Verticillilum lecanii* could be effective as an IPM tool. Kular *et al.* (2001) [5] reported that the effect of aphid management practices, such as cultural methods, use of resistant varieties, biological control agents (*Verticillilum lecanii*) and neem (*Azadirachta indica*) based applications of insecticides compared to treated crops. S.S. Dhaka *et al.* (2009) [19] reported that the efficacy of newer insecticides was studied against mustard aphid, *Lipaphis erysimi* (Kalt.) and their effect on *Coccinella septumpunctata* was also recorded at Pilibhit (UP) during 2007-08 on Indian mustard. The insecticides used are acetamiprid 20 SP (125 g/ha) and imidachloprid 17.8 SL (150 ml/ha). Acetamiprid 20 SP (125 g/ha) proved as the best insecticide followed by acephate, thiamethoxam, imidacloprid, profenofos, dimethoate and oxydemeton methyl for the management of aphids. Thiamethoxam was found as the safer insecticide to the coccinellids. Sanjeev Rai *et al.* (2010) [11] reported that the effect of different prey (aphid) densities (functional response) of second, third, fourth instars of grub and adult of two important aphidophagous *coccinellids*, *Coccinella septempunctata* (L.) and *Coccinella transversalis* (Fabr.) i.e. 20, 40, 80, 100, 200, 400 and 800, during 2003 and 2004. The present study revealed that the prey density has significant influence on the preying capacity of the grub and adult of both species. Prey consumption by the second, third, fourth instars of grub and adult of *Coccinella septempunctata* (L.) and *Coccinella transversalis* (Fabr.) followed an increasing trend from lower prey density (20) to higher prey densities i.e. 40, 80, 100, 200, 400 and 800, while the percentage of prey consumption decreased with increasing prey (aphid) densities. It was also observed that functional response of fourth instar grub was found to be maximum (287.7 ± 2.87) (187.7 ± 2.56) followed by third instars, adult and second instar grub of *C. septempunctata* and *C. transversalis* on prey density of 800, respectively. The determination factor (R) was found to be significant. Singh *et al.* (2009) [18] reported that four bioagents, *viz., Coccinella septempunctata* L., *Menochilus sexmaculatus* (F.), *Chrysoperla carnea* (Stephens) and *Verticillium lecanii* (Zimmerman), were evaluated against mustard aphid, *Lipaphis erysimi* (Kaltenbach), on single plants covered with muslin cloth in the field at National Research Centre on Rapeseed-Mustard, Sewar, Bharatpur (Rajasthan) during 2005-06 and 2006-07. *C. septempunctata* @ two adults/plant was found to be the most effective, reducing 96.19% of the aphid population in 10 days followed by *C. septempunctata* @ two larvae per plant (93.42%), *V. lecanii* @ 108 spores-ml (84.90%), *M. sexmaculatus* @ two adults (84.62%) and *C. carnea* @ four larvae-plant (82.98%). *C. septempunctata* @ one adult per plant reduced the aphid population by 77.49% and *M. sexmaculatus* by 69.08%. P. P. Pradhan *et al.* (2020) [8] reported that the insect pests and natural enemies of mustard. During the period of present investigation, a total number of four insect pests from four different families *viz*, mustard aphid, *Lipaphis erysimi* (Kalt.); mustard sawfly, *Athalialugens proxima* (Klug); Flea beetle, *Phyllotreta Cruciferae* (Goeze); cabbage butterfly, *Pieris brassicae* (Linn.) were recorded at different stages of mustard crop. On the other hand, total three predators *viz*, coccinellid beetle (*Coccinella transversalis* (Fab.) and *Harmonia axyridis* (Fab.), green lacewing, *Chrysoperla carnea* (Stephens);

syrphid fly, *Xanthogrammas cutellaris* (Fab.) and one aphid parasitoid, *Diaeretiella rapae* (M'lntosh) were recorded as major natural enemies on insect pests of mustard. However, out of both coccinellids *C. transversalis* was dominant and considered as major predator of aphids. Singh, N. N., *et al. (*2000) [13] reported that the the coccinellid predators associated with the mustard aphid, *Lipaphis erysimi* (Kalt), infesting mustard crops during 1992-93 and 1993-94 at B.H.U. research farm and in farmers' fields of six selected villages around the campus. This study revealed that four species of coccinellids (*Coccinella. Septempunctata* (Linn), *C.transversalis* (Fab.), *M. sexmaculatus* [*Cheilomenes sexmaculata*] and *Brumoides suturalis*) were present. Among these, *C. septempunctata* and *C. transversalis* were important aphidophagous coccinellid predators of the mustard aphid. Singh Deepak Pal, *et al. (*2000) [16] reported that the effect of Bio rational approaches for management of mustard aphid, (*Lipaphis erysimi* Kalt.) on seed yield and its economics was conducted on the Oilseed Farm Kalyanpur, Kanpur during rabi, 2018-19. The treatments were: T1: Azadirachtin@ 5ml/L followed by its second spray after 15 days, T2: Azadirachtin followed by *Beauveria bassiana*@2g/L after 15 days, T3: *Beauveria bassiana* followed by its second spray after 15 days, T4 : Azadirachtin followed by *Verticillium laccani* @2g/L after 15 days, T5: *Verticillium leccani* followed by its second spray after 15 days, T6 : Dimethoate 30EC@ 1ml/L followed by its second spray after 15 days and T7 : Control. Out of which Dimethoate 30EC@ 1ml/L followed by its second spray after 15 days provided highest seed yield which was higher than Azadirachtin followed by *Verticillium leccani* after 15 days. Dimethoate followed by its second spray after 15 days was found most economic with highest IBCR as it gave the maximum benefit (1:37.6) which is very large as compared to remaining treatments and the next effective treatment was Azadirachtin followed by *Verticillium leccani* after 15 days (1:12.5).

Conclusion

The different natural enemies of mustard aphid were observed on different *Brassica* spp. and recorded predator *viz*., C*occinella septempunctata* which appeared during second and third week of February (SW-09 & SW-09) with their initial population of aphid. Other predators of mustard aphid were also noticed as the population of aphid increased. Lady bird beetle (C*occinella septempunctata*) reached its peak level (2.82-3.10 beetle/plant) during 2010-11 and 2011-12, respectively mid-February when the aphid population was highest. The order toxicity on the basis against *C. septempunctata* was *Beauveria bassiana* > Neemarin > *Verticillilum lecanii* > Dimethoate. It may be concluded that the expression of growth, yield and net profit of mustard under the agro-climatic conditions of central plain zone of U.P. can be enhanced by application of bio-insecticides *Verticillilum lecanii* and balanced dosage of nutrients at timely application.

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