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Seasonal fluctuation and efficacy of bio-chemicals against aphid infesting cabbage (*Brassica oleracea* var. *capitata* L.)

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Abstract
The present study was laid out on cabbage (*Brassica oleracea* var. *capitata* L.) in a randomized block design with three replications and eight treatments. The results obtained during the correlation studies of aphids with environmental factors revealed that significant negative correlation with maximum and minimum temperatures. Whereas, showed significant positive correlation with morning relative humidity and non-significant positive with evening relative humidity. Efficacy obtained against cabbage aphids (*Brevicoryne brassicae* L.) on one days before pre-treatment population (PTP) and 3, 7, 10 days after treatment (DAT) recorded during first and second spray showed that all the chemical and bio-pesticides treatments were found significantly superior in reducing the aphid population on cabbage as compared to control respectively 3, 7, 10 days after treatment (DAT) in both sprays. Both spraying indicated that Azadirachtin @ 1000 ml/ha was found most effective over other treatments followed by *Verticillium lecanii* @ 2000 ml/ha, Emamectin benzoate @ 150 gm/ha, Spinosad @ 750 ml/ha, *Metarhizium anisopliae* @ 2500 ml/ha, *Beauveria bassiana* @ 1500 ml/ha, while, treatment *Bacillus thuringiensis* (*kurstaki*) @ 1000 ml/ha was least effective against the aphid. However, untreated control recorded maximum aphids population.

Keywords: Aphid, cabbage, bio-pesticides and chemicals

Introduction
Cabbage (*Brassica oleracea* var. *capitata* L.) a member of Cruciferae family, is an important vegetable cole crop grown in all the states of India. It is the source of Fe, Ca and K and also contains Vitamin-C, B_1, B_2 and B_3 in considerable amount and it can gain as salad, boiled vegetables, in curries and pickles. In India, annual production of cabbage 9207 thousand MT (Metric tons) from 397 thousand ha of land with an average productivity is 23.19 MT/ ha, while Rajasthan contributes 12.74 thousand MT (Metric tons) production of cabbage with an area of 1.19 thousand ha and 10.64 MT/ha productivity (Anonymous, 2019-20) [1].

Insect-pests are one of the serious problems in the profitable cultivation of cabbage. These pests can cause damage to an extent of 80 to 100 per cent in the nurseries under favourable conditions and 10 to 25 per cent in the field condition. Maison (1965) [7] listed 51 insect-pests which damage cruciferous crops throughout the world. Lal (1975) [4] reported that in India, a total of 37 insect pests have been reported to feed on cabbage and among them the diamondback moth (DBM), *Plutella xylostella* is the most serious constraint in the profitable cultivation of cole crops wherever they are grown (Talekar *et al*., 1993) [13]. The severity of the incidence of pest is also greatly influenced by the prevailing climatic conditions which vary from region to region. Environmental factors also play an important role in determining the seasonal abundance and damage caused by insect-pests. Hence it is necessary to study the influence of various abiotic factors affecting the population fluctuation of major insect-pests on cabbage crop. The major insect-pests that infest cabbage crop are tobacco caterpillar (*Spodoptera litura* Fab.), diamondback moth (*Plutella xylostella* L.), cabbage semilooper (*Trichoplusia ni* Hubner), painted bug (*Bagrada cruciferarum* Kirk.), cabbage butterfly (*Pieris brassicae*), flea beetle (*Phyllotreta cruciferae* Goeze), cabbage aphid (*Brevicoryne brassicae* L.) and cabbage leaf webber (*Crocidolomia bionotalis* Zell). Among these, the estimated loss in yield due to aphid (*Lipaphis erysimi*) in cabbage crop was 47.1 to 96.0 per cent (Bakhetia, 1986) [2]. Aphids are attacked by many entomopathogens, predators and parasitoids (Skouras *et al*., 2015) [12]. Many entomopathogenic fungi like *Beauveria bassiana* (Balsamo) Vuillemin,

Metarhizium anisopliae (Metschnikoff) Sorokin, *Verticillium lecanii* (Zimm.) These microbial pesticides have been reported to be effective against aphids (Ujjan and Shahzad, 2012) [14].

Bio-control of insect-pest considered as a safe and effective method for management. Use of pesticides has become intensive and widespread in modern agriculture. 78.2% of farmers were aware of harmful effect of pesticides usage but not ready to adopt alternative of pesticides. This injudicious and indiscriminate application of pesticides is reported to effect adversely not only to human health and environment but also on the population of natural enemies *viz.* Lady bird beetle, spider, lace wing and honey bees. Therefore, an attempt is made to carry out an investigation to find out the environmental correlation and eco-friendly management of aphid infesting Cabbage (*Brassica oleracea* var. *capitata* L.).

Material and Methods

The experiment was conducted in Randomized Block Design (RBD) with three replications. Each treatment was applied two times at 15 days interval during study period. The observations will be recorded after transplanting from untreated plot and continue at weekly interval up to the pest infestation remains on crops in a zig - zag manner to leaving the boarder rows. The population of different insect-pest was recorded at weekly interval during morning hours without disturbing pest fauna. The estimation of aphid population was based on the numerical count method as described by Lal (1975) [4]. The five plants of cabbage were randomly selected from each plot and tagged. Total number of aphids on tagged plant three leaves from (upper, middle, lower) was counted visually with the help of magnifying lens at weekly interval.

Treatments details

Treatments	Formulated Dose (g or ml/ha)
T_1= Spinosad (45 SC)	750
T_2= *Metarhizium anisopliae* (1×10^8 cfu/ml)	2500
T_3= *Verticillium lecanii* (1×10^8 cfu/ml)	2000
T_4= Emamectin benzoate (5 SG)	150
T_5= *Beauveria bassiana* (1×10^8 cfu/ml)	1500
T_6= Azadirachtin (10000 ppm)	1000
T_7= *Bacillus thuringiensis* (*kurstaki*) (3.5% ES)	1000
T_8= Control	-

Treatments were applied in the form of foliar spray with the help of knapsack sprayer. Spray fluid was prepared by mixing of known quantity of insecticide with calculated water for spraying. All necessary care was taken to prevent the drift of insecticides to reach the adjacent plots. The first application was given on 31st December 2020 when the population of insect pests was sufficient and the second application was given on 15 days interval, *i.e*., on 15th January 2021.

The population of aphid was recorded one day before (PTP) and 3, 7, 10 days after the application of bio-chemicals in all the spray from randomly selected and tagged five plants in each plot. The population was counted early in the morning before 8:00 AM when the pests were not very active. The data mean population of aphid was transformed into angular values and subjected to analysis of variance. Randomized Block Design (RBD) was used for statistical analysis of experimental data. Critical difference (CD) values were analysed at 5 per cent level of significance. The data obtained were transformed using square root transformation.

Results and Discussion

Seasonal incidence of aphid in relation to weather parameters

The aphid population commenced in the first week of December (48th SMW) which gradually increased and reached to peak in the last week of January (4th SMW), (145.9 aphids/plant) at 24.24 °C maximum and 6.64 °C minimum temperatures, 99.57% morning and 68.14% evening relative humidity thereafter, population trends declined (Table-1).The correlation studies revealed that the aphid population had significant negative correlation with maximum and minimum temperatures (r = -0.771 and r = -0.779), whereas, showed significant positive correlation with morning relative humidity (r = 0.547) and non-significant positive with evening relative humidity (r = 0.282). The correlation studies indicate that the aphid population was affected significantly by temperature, rise in temperature after winter favours multiplication of aphid population and high temperature after second fortnight of February and onward reduced the aphid population. Morning humidity favours the more multiplication of aphids. Whereas, other weather parameters could not affect the incidence of aphid.

The results are in confirmation with the findings of earlier worker Sain *et al*. (2017) [11] conducted field experiment on incidence of aphid, *Lipaphis erysimi* (Kalt.) in two different *brassica* spp. *viz.*, *Brassica oleracea* and *Brassica juncea* during rabi season. The initial population of aphid appeared in first week of November (44 SMW) and reached its maximum during third week of December (50 SMW) when the temperature and relative humidity ranged from 20.57 °C to 11.21 °C and 73.71 to 37.42 per cent, respectively. Yadav and Agrawal (2018) [16] reported that the infestation of *Brevicoryne brassicae* first appeared in the 51th SMW in IPM field in the organic field and reached its peak in the 9th SMW.

Effect of different treatments on population of cabbage aphid (*Brevicoryne brassicae* L.)

The population of cabbage aphid (*Brevicoryne brassicae* L.) is presented (Table-2, Fig. 1 a & b) clearly indicated that the non-significant difference was observed among different treatments before spray, it means population was uniformly distributed in all the experimental plots.

After 3rd days of both sprays, all the treatments were found significantly superior in reducing the aphid population on cabbage as compared to control. The mean aphid population on cabbage ranged from 20.53 to 32.60 aphids/plant & 20.33 to 32.40 aphids/plant in different treatments as compared to control (37.93 aphids/plant & 71.73 aphids/plant), respectively. Among the treatments Azadirachtin @ 1000 ml/ha was found most effective over other treatments with minimum mean aphid population (20.53 & 20.33 aphids/plant) followed by *Verticillium lecanii* @ 2000 ml/ha (22.87 & 19.53 aphids/plant), Emamectin benzoate @ 150 gm/ha (24.47 & 24.33 aphids/plant), Spinosad @ 750 ml/ha (27.27 & 27.93 aphids/plant), *Metarhizium anisopliae* @ 2500 ml/ha (29.60 & 29.67 aphids/plant), *Beauveria bassiana* @ 1500 ml/ha (31.73 & 31.53 aphids/plant), while, treatment *Bacillus thuringiensis* (*kurstaki*) @ 1000 ml/ha was least effective with maximum mean aphid population (32.60 & 32.40 aphids/plant), respectively.

Population reduction was seen at 7th days after 1st & 2nd spray,

all the chemical and bio-pesticides treatments were found significantly superior in reducing the aphid population on cabbage as compared to control. Among, the treatments Azadirachtin @ 1000 ml/ha was found most effective among all the treatments with minimum mean aphid population (17.87 & 17.67 aphids/plant) followed by *Verticillium lecanii* @ 2000 ml/ha (19.53 & 20.33 aphids/plant), Emamectin benzoate @ 150 gm/ha (21.47 & 22.67 aphids/plant), Spinosad @ 750 ml/ha (22.60 & 26.27 aphids/plant), *Metarhizium anisopliae* @ 2500 ml/ha (24.60 & 28.00 aphids/plant), *Beauveria bassiana* @ 1500 ml/ha (26.40 & 29.87 aphids/plant) while, least effective treatment was *Bacillus thuringiensis* (*kurstaki*) @ 1000 ml/ha with maximum mean aphid population (27.13 & 30.73 aphids/plant), respectively.

At 10th days of both sprays, all the chemical and bio-pesticides treatments were found significantly superior in reducing the aphid population on cabbage as compared to control. Azadirachtin @ 1000 ml/ha was found significantly superior over other treatments with minimum mean aphid population (18.33 & 19.33 aphids/plant) followed by *Verticillium lecanii* @ 2000 ml/ha (20.00 & 21.33 aphids/plant), Emamectin benzoate @ 150 gm/ha (22.60 & 24.80 aphids/plant), Spinosad @ 750 ml/ha (26.07 & 27.40 aphids/plant), *Metarhizium anisopliae* @ 2500 ml/ha (28.07 & 31.00 aphids/plant), *Beauveria bassiana* @ 1500 ml/ha (29.20 & 31.53 aphids/plant) whereas, maximum mean aphid population was found in the treatment of *Bacillus thuringiensis* (*kurstaki*) @ 1000 ml/ha (30.40 32.53 aphids/plant), respectively.

Present findings are in confirmation with Rana and Singh (2002) [10] reported that application of *V. lecanii* @ 10^6 conidia/ml effectively reduced the population of aphid, *L. erysimi* on mustard. Parmar (2007) [9] found that azadirachtin significantly reduced the infestation of aphids on cabbage followed by *V. lecanii*. Nayak (2013) [8] reported that Nemazol, azadirachtin based formulations reduced the aphid population to the extent 50.8 percent. Neem products reduce the fecundity and fertility of adults, and moulting of nymphs (Lowery and Isman, 1996) [6], along with increasing development time of nymphs surviving to adulthood (Kraiss and Cullen, 2008) [3]. Neem based bio-pesticides destroy the reproductive potential of aphids by blocking the neurosecretory cells (Vimala *et al.*, 2010) [15]. Laxman *et al.* (2019) [5] field evaluation of biopesticides against diamondback moth (*Plutella xylostella*) and aphids (*Brevicoryne brassicae* and *Lipaphis erysimi*) on cabbage during *rabi* seasons 2016-17 and 2017-18 is reported. Nimbicidine resulted in the highest mean percent reduction over control of (60.19, 63.45) after first and second spray against aphids during 2016-17 and 2017-18, followed by neemban (54.90, 57.33), *V. lecanii* (45.87, 50.41), *B. bassiana* (37.83, 42.67) and *M. anisopliae* (32.96, 40.49).

Conclusion

The results obtained during the correlation studies of aphids with environmental factors revealed that significant negative correlation with maximum and minimum temperatures. Whereas, showed significant positive correlation with morning relative humidity and non-significant positive with evening relative humidity indicating the aphid population affect during high as well as low temperature and the humidity is not affecting the population growth of aphids.

Use of various pesticides against cabbage aphid (*Brevicoryne brassicae* L.) were significantly affecting in reducing pest population compare to untreated plot. Among the treatments Azadirachtin @ 1000 ml/ha was found most effective over other treatments with minimum mean aphid population followed by *Verticillium lecanii* @ 2000 ml/ha, Spinosad @ 750 ml/ha, Emamectin benzoate @ 150 ml/ha, *Beauveria bassiana* @ 1500 ml/ha, *Metarhizium anisopliae* @ 2500 ml/ha. While, treatment *Bacillus thuringiensis* (*kurstaki*) @ 1000 ml/ha was found least effective against cabbage aphids.

Conflict of interest: None

Authors' Contributions

Conceptualization and designing of the research work (BKP, NK); Execution of field experiments and data collection (NK, BKP): Analysis of data and interpretation (NK, SKJ, MSM); Preparation of original draft manuscript (NK, SKJ, LSS, MKL); Review & editing of manuscript (NK, BKP, SKJ)

Table 1: Seasonal incidence of cabbage aphid and their correlation with their weather parameters during *Rabi*-2020-21.

SMW	Duration of SMW	Temperature (°C)		Relative Humidity (%)		Mean population of cabbage aphid (aphids/plant) *
		Maximum	Minimum	Morning	Evening	
45th	05 Nov. 2020 – 11 Nov. 2020	31.96	15.30	89.57	67.29	0
46th	12 Nov. 2020 – 18 Nov. 2020	31.39	14.86	86.43	66.71	0
47th	19 Nov. 2020 – 25 Nov. 2020	30.81	14.00	89.71	70.00	0
48th	26 Nov. 2020 – 02 Dec. 2020	30.46	13.71	89.00	70.29	0.2
49th	03 Dec. 2020 – 09 Dec. 2020	29.24	12.00	89.00	76.14	0.6
50th	10 Dec. 2020 – 16 Dec. 2020	26.67	10.86	88.29	70.43	1.8
51th	17 Dec. 2020 – 23 Dec. 2020	25.60	8.71	87.43	59.14	5.2
52th	24 Dec. 2020 – 31 Dec. 2020	25.10	8.63	77.38	60.00	11.4
1st	01 Jan. 2021 – 07 Jan. 2021	24.60	9.00	76.00	66.00	45.6
2nd	08 Jan. 2021 – 14 Jan. 2021	23.39	10.14	99.86	80.14	96.8
3rd	15 Jan. 2021 – 21 Jan. 2021	23.89	6.36	99.71	78.00	126.8
4th	22 Jan. 2021 – 28 Jan. 2021	24.24	6.64	99.57	68.14	145.9
5th	29 Jan. 2021 – 04 Feb. 2021	22.6	6.5	87.7	65.3	125.2
6th	05 Feb. 2021 – 11 Feb. 2021	24.7	9.0	86.0	69.6	74.5
7th	12 Feb. 2021 – 18 Feb. 2021	26.8	10.3	85.0	63.0	40.8
8th	19 Feb. 2021 – 25 Feb. 2021	29.4	12.0	79.4	70.7	16.4
	Correlation	-0.771**	-0.779**	0.547*	0.282 NS	

*Average of 5 plants; *Significant at 5%, **Significant at 1%, NS- non significant

Table 2: Effect of chemical and bio-pesticides on the population of cabbage aphid (*Brevicoryne brassicae* L.) during *Rabi*-2020-21.

Treatments	Number of aphids/plant							
	Population after 1st spray				Population after 2nd spray			
	PTP	3 DAT	7 DAT	10 DAT	PTP	3 DAT	7 DAT	10 DAT
T_1 Spinosad (45 SC) @ 750 ml/ha	33.40 (5.82)*	27.27 (5.27)	22.60 (4.81)	26.07 (5.15)	29.40 (5.47)	27.93 (5.33)	26.27 (5.17)	27.40 (5.28)
T_2 *Metarhizium anisopliae* (1×10^8 cfu/ml) @ 2500 ml/ha	34.07 (5.88)	29.60 (5.49)	24.60 (5.01)	28.07 (5.34)	32.07 (5.71)	29.67 (5.49)	28.00 (5.34)	31.00 (5.61)
T_3 *Verticillium lecanii* (1×10^8 cfu/ml) @ 2000 ml/ha	32.80 (5.77)	22.87 (4.83)	19.53 (4.48)	20.00 (4.53)	22.87 (4.83)	22.00 (4.74)	20.33 (4.56)	21.33 (4.67)
T_4 Emamectin benzoate (5 SG) @ 150 gm/ha	34.07 (5.88)	24.47 (5.00)	21.47 (4.69)	22.60 (4.81)	26.40 (5.19)	24.33 (4.98)	22.67 (4.81)	24.80 (5.03)
T_5 *Beauveria bassiana* (1×10^8 cfu/ml) @ 1500 ml/ha	33.13 (5.80)	31.73 (5.68)	26.40 (5.19)	29.20 (5.45)	32.53 (5.75)	31.53 (5.66)	29.87 (5.51)	31.53 (5.66)
T_6 Azadirachtin (10000 ppm) @ 1000 ml/ha	32.60 (5.75)	20.53 (4.59)	17.87 (4.29)	18.33 (4.34)	21.33 (4.67)	20.33 (4.56)	17.67 (4.26)	19.33 (4.45)
T_7 *Bacillus thuringiensis* (*kurstaki*) (3.5% ES) @ 1000 ml/ha	33.53 (5.83)	32.60 (5.75)	27.13 (5.26)	30.40 (5.56)	33.07 (5.79)	32.40 (5.73)	30.73 (5.59)	32.53 (5.75)
T_8 Control	34.00 (5.87)	37.93 (6.20)	42.60 (6.56)	46.27 (6.84)	59.67 (7.76)	71.73 (8.50)	83.07 (9.14)	96.40 (9.84)
S Em ±	0.04	0.05	0.04	0.04	0.02	0.06	0.06	0.03
CD at 5%	NS	0.16	0.14	0.13	0.07	0.19	0.18	0.08

PTP= Pre-Treatment Population; DAT= Days after Treatment; *figure in parenthesis is square root transformation $\sqrt{X \pm 0.5}$

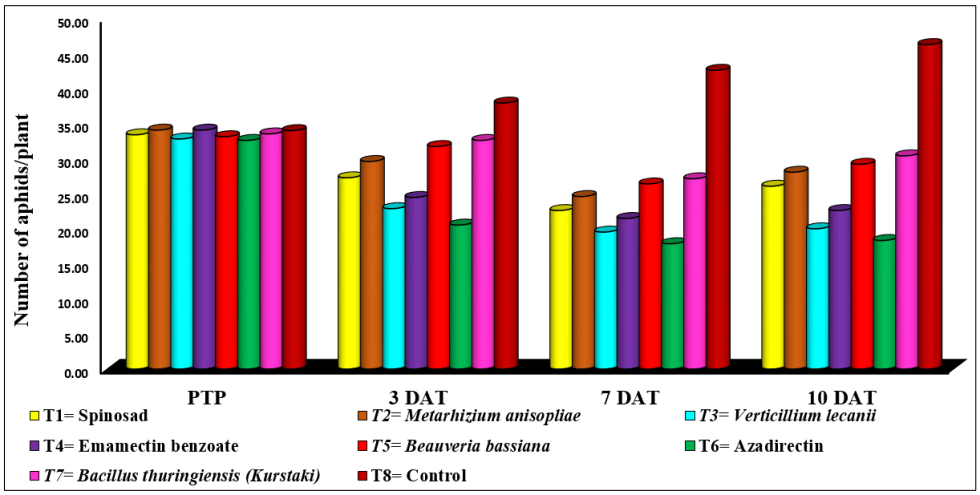

Fig 1(a): Effect of different chemical and bio-pesticides on the population of cabbage aphid (*Brevicoryne brassicae* L.) during *rabi*-2020-21 (population after 1st spray).

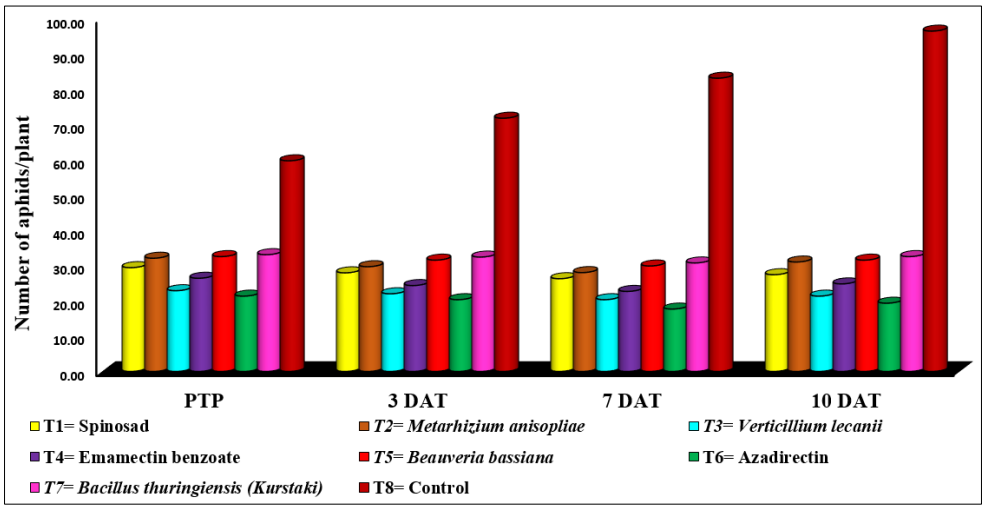

Fig 1(b): Effect of different chemical and bio-pesticides on the population of cabbage aphid (*Brevicoryne brassicae* L.) during *Rabi*-2020-21 (population after 2nd spray).

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