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Research Article

Testing of bio-rational and synthetic pesticides to manage cabbage aphid (*Brevicoryne brassicae* L.) in cabbage field at Rampur, Chitwan, Nepal

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ABSTRACT
Cabbage aphid (*Brevicoryne brassicae* L.) is an important pest of cabbage which reduces the yield and quality of the cabbage head. Farmers haven been using chemical pesticides to manage them but unfortunately these practices are toxic for human health, biodiversity and the environment. The study was conducted to test the efficacy of different bio-rational insecticides along with the chemical insecticide. 'Green Coronet' cabbage variety was used and the field experiment was laid out in the experimental farm of Agriculture and Forestry University (AFU), Rampur, Chitwan during the winter season of 2014. The Experiment was designed in randomized complete block design with having 7 treatments (bio-rational insecticides with chemical and control) and 3 replications. Plot size was 5.76 m^2 (2.4m×2.4m) and spacing of 1 m was maintained between each blocks and plots. Field experiment showed that the highest reduction of cabbage aphid was obtained in Dimethoate (30 EC) treated plot followed by Derisom treated plot. The highest yield of cabbage head was obtained in Dimethoate treated plots (66.47 mt/ha) which was significantly at par with the Derisom (58.79 mt/ ha) treated plots. The yield for other treated plots were 47.60 mt/ha for Margosom, 43.77 mt/ha for *Verticillium*, 41.63 mt/ ha for Cow urine, 36.77 mt/ ha for Spinosad and control (33.45 mt/ ha) in terms of cabbage head yield. And, at the same time, natural enemies' population was significantly lower to Dimethoate treated plots compared to bio-rational insecticides. Thus, Derisom (Derris based botanical) might be the best viable alternative in eco-friendly management of cabbage aphid considering cabbage head yield and protection of natural enemies. It was also evident from the research that Margosom (Neem based botanical) was found beneficial not only to conserve natural enemies in the cabbage field but also to minimize cabbage aphid population.
Keywords: Cabbage aphid, bio-rational, cabbage head, Derisom, eco-friendly

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INTRODUCTION
Cabbage is one of the most important consumed vegetables worldwide along with Nepal (Shrestha, 2019; Talekar, 2000). In Nepal, Cabbage is cultivated in 28071.4 hectares with

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average productivity of 17.2 Mt/ha (ABPSD, 2016). This crop is mainly grown during the winter season in the plain region but could be produced year round in the cooler region of Nepal. Nutritionally, cabbage is a good source of vitamin C and sulfur (Shrestha, 2019).

Cabbage is infested by many insects such as cabbage butterfly, diamondback moth, tobacco caterpillar, soybean hairy caterpillar, cabbage looper, semilooper, cutworm, flea beetle, aphid, painted bug, etc. (Thapa, 1986-87; Sachan and Gangwar, 1990; NARC, 1998; Neupane, 2000). Among above mentioned ones, cabbage aphid (*Brevicoryne brassicae* L.) is one of the major pests of cabbage in Nepal (Joshi, 1994; Neupane, 2000). Cabbage aphid (*B. brassicae*) reduces the yield of cabbage significantly and also reduces the market price due to deterioration in quality (Costello, 1995). This pest feeds the plant by sucking sap from the cabbage. Infested seedlings become stunted and deformed. Their leaves become curled and yellowed (Metcalf, 1962).

The worldwide control and management of aphids in cruciferous crops is primarily based upon the use of insecticides (Nunnenmacher and Goldbach, 1996). Farmers in Nepal have been using different chemical pesticides as per their knowledge, which oftentimes do not match with the scientific basis of usage of pesticides. Irrational use of pesticides causes economic losses to the farmers, pollution, health hazards and also pest resistance (G.C. and Keller, 2005; Upadhyaya, 2003). Twenty aphid species are now resistant to the insecticides like Organophosphate, Carbamate and Pyrethroid (Minks and Harrewijn, 1989). The green peach aphid; *M. persicae* (Sulzer) has become resistant to various chemical insecticides (Taniguchi, 1987; Hockland *et al.*, 1992). Therefore, it is urgent to develop eco-friendly measures for controlling various insect pests (Joshi *et al*., 1991; Palikhe *et al*., 2003) such as cabbage aphid.

There are many alternative control options to manage the insect pests by use of biocontrol agents, microbials, and botanicals (Lowery and Isman, 1994; Milner, 1997; Singh *et al*., 2007; Bugg *et al*., 2008). These bio-rational or low risk pesticides are being used to replace the conventional ones. Bio-rational insecticides are synthetic or natural substances that are more effective to control insect pests with having low toxicity to non-target organisms and the environment (Hara, 2000). These are being developed by the agro-chemical companies and due to the reasons of being more selective in nature, these fit well in Integrated Pest Management (IPM) programs (Casida and Quistad, 1998; Horowitz *et al*., 2004). Various bio-rational insecticides' efficacy for managing cabbage aphid is not tested sufficiently in the condition of Nepal. Hence, this experiment was designed to evaluate the different bio-rational and synthetic insecticides against cabbage aphid management. Additionally, effect of those insecticides on natural enemies' population was also studied.

MATERIALS AND METHODS

Field experiment was carried out to test the efficacy of different bio-rational and synthetic insecticides against cabbage aphid of cabbage under field conditions. The field experiment was laid out in the experimental farm of Department of Entomology, AFU, Rampur, Chitwan during winter season of 2014. The experiment consisted of 7 treatments with 3 replications by following randomized complete block design. Plot size was 5.76 m^2 (2.4m×2.4m) and spacing between two blocks and two plots within blocks was 1m. Land preparation was done by conventional tillage and harrowing. At the time of land preparation, compost was

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incorporated at the rate of 20 mt/ha and NPK at the rate of 240:180:80 kg/ha. The cabbage variety selected for field experimentation was Green Coronet and seeds were sown in nursery in December and covered by plastic tunnel after light irrigation. 32 days of old seedling of Green Coronet variety of cabbage was transplanted in the field with spacing of 40 cm×40 cm on 3rd week of January. All the insecticide treatments (described in Table 1) were sprayed on cabbage plants using a hand compression sprayer of 8 liters' capacity, working at the rate of 500-700 L/ha. Pesticides were applied with onset of infestation of cabbage aphid and spraying was done thrice at 10 days interval. Cabbage aphid number was recorded from randomly selected 10 cabbage plants per plot. Pre- treatment and post-treatment cabbage aphid populations were recorded for the experiment. In case of pre-treatment, data was taken 24 hours prior to spraying in case of first spray. But, thereafter for pre-treatment data for succeeding spray, cabbage aphid population recorded at 9 days of spraying was considered. Post-treatment cabbage aphid number was recorded at 3, 6 and 9 days after spraying. For the natural enemies' population, the same procedure as done for the cabbage aphid population was done and a total number of natural enemies were considered for the experiment.

Table1. Treatment description

Treatments	Chemical/Scientific Name	Trade Name	Formulation	Dose
Entomopathogenic fungus *Verticillium lecanii* (S.P.)	*Verticillium lecanii* (T_1)	Mealikil	1.15 % WP	1 g/L of water
Synthetic Insecticide	Dimethoate (T_2)	Rogohit	30 EC	2 mL/L of water
Botanical insecticide	Fractions of *Derris indica* (T_3)	Derisom	20,000 ppm	2mL/L of water
Botanical insecticide	Azadirachtin (T_4)	Margosom	0.15 EC	5 mL/L of water
Bioinsecticide	Spinosad (T_5)	Tracer	45 % SC	0.7 mL/L of water
Cow urine	Cow urine (T_6)	Locally collected		1:10 of water
Control	Water spray			

After collection and summarization, data was tabulated by using Microsoft Excel (MS-Excel). The data of insects were statistically analyzed by converting them into $(x+0.5)^{1/2}$ as suggested by Gomez and Gomez (1984) and analyzed by using MSTAT. The treatment means were compared by the Least Significant Difference (LSD) test at 5% and 1% level (Gomez & Gomez, 1984; Shrestha, 2019).Yield comparison between different treatments was done by using the increase in yield over control as follows.

Increase in yield over control (%) = [(T-C)/C] ×100
Where,
T = yield from treatment plot, and
C = yield from control plot

RESULTS AND DISCUSSION

The results showing the reduction of cabbage aphid number is depicted in Table 2, 3 and 4. From the experiment, it was observed that all the insecticides tested were effective to control the cabbage aphid in the cabbage compared to control. Among different treatments of insecticides, Dimethoate was found effective compared to other insecticides, except at 9 days after first spray (Table 2). At 3 days after first spray, Derisom was found superior to *Verticillium*, Margosom, Spinosad, cow urine and control (Table 2). At 6 days after first

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spray, Derisom and *Verticillium* were effective compared to Spinosad, cow urine and control and at 9 days after first spray, Dimethoate and *Verticillium* were more effective to cow urine and control (Table 2).

Table 2. Population of cabbage aphid after first spray, Rampur, 2015

Treatments	Pre treatment	3 DAS	6 DAS	9 DAS
Verticillium	28.00±2.78 (6.11)	30.80^{bc} ± 1.49 (5.59)	21.65^{de} ± 5.10 (4.59)	25.36^{c}± 1.16 (5.08)
Dimethoate	33.90 ± 4.27 (6.69)	10.33^{e} ± 0.92 (3.28)	16.64^{e} ± 1.29 (4.13)	21.00^{c} ± 1.67 (4.63)
Margosom	31.82 ± 3.05 (6.46)	29.60^{c} ± 2.17 (5.47)	28.43^{cd} ± 2.11 (5.37)	32.16^{bc} ± 2.19 (5.70)
Derisom	30.92 ± 2.39 (6.35)	18.72^{d} ± 1.51 (4.37)	23.21^{de} ±0.71 (4.87)	26.87^{bc} ± 0.90 (5.23)
Spinosad	31.83 ± 0.71 (6.42)	33.23^{bc} ± 0.99 (5.81)	37.90^{bc} ± 1.68 (6.19)	30.25^{bc} ± 6.22 (5.45)
Cow urine	33.69 ± 2.33 (6.58)	38.05^{b} ± 3.32 (6.19)	46.27^{b} ± 2.94 (6.83)	41.66^{b} ± 6.15 (6.44)
Control	34.80 ± 4.87 (6.65)	59.32^{a} ± 2.01 (7.73)	72.12^{a} ± 2.68 (8.52)	77.85^{a} ± 1.72 (8.85)
CV	7.38%	6.23%	9.79%	10.82%
LSD	0.8495	0.6085	1.008	0.138
F test (α=0.05)		**	**	**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation (x+0.5) ½. (*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.

Table 3. Population of cabbage aphid after second spray, Rampur, 2015

Treatments	Pre treatment	3 DAS	6 DAS	9 DAS
Verticillium	25.36^{c}±1.16 (5.08)	20.37^{d} ± 1.74 (4.56)	16.75^{de} ± 1.14 (4.15)	21.66^{de}± 1.36 (4.70)
Dimethoate	21.00^{c} ± 1.67 (4.63)	12.86^{e} ± 0.72 (3.65)	9.90^{f} ± 0.62 (3.22)	12.31^{f} ± 0.33 (3.58)
Margosom	32.16^{bc} ± 2.19 (5.70)	23.43^{cd} ± 1.08 (4.89)	19.50^{cd} ± 0.68 (4.47)	24.72^{cd} ± 0.52 (5.02)
Derisom	26.87^{bc} ± 0.90 (5.23)	17.73^{d} ± 0.65 (4.27)	14.70^{e} ±0.56 (3.90)	18.95^{e} ± 0.58 (4.41)
Spinosad	30.25^{bc} ± 6.22 (5.45)	29.20^{c} ± 3.21 (5.43)	21.65^{c} ± 1.29 (4.70)	28.27^{c} ± 1.86 (5.36)
Cow urine	41.66^{b} ± 6.15 (6.44)	39.42^{b} ± 0.91 (6.32)	28.48^{b} ± 0.29 (5.38)	37.59^{b} ± 0.99 (6.17)
Control	77.85^{a} ± 1.72 (8.85)	89.64^{a} ± 1.52 (9.49)	97.97^{a} ± 1.41 (9.92)	116.22^{a} ± 2.73 (10.8)
CV	10.82%	6.25%	4.21%	4.31%
LSD	0.138	0.6137	0.3816	0.4394
F test (α=0.05)	**	**	**	**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation (x+0.5) ½. (*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.

At 3 days after the second spray, Derisom and *Verticillium* were superior to Spinosad, cow urine and control (Table 3). Additionally, at 6 days after the second spray, it was observed

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that Derisom was superior to Margosom, Spinosad, cow urine and control and at the same time, Derisom was significantly at par to *Verticillium* (Table 3). Moreover, at 9 days after the second spray, Deriosm was found to be superior to Margosom, Spinosad, cow urine and control and significantly at par with the *Verticillium* (Table 3). Last but not the least, at 3, 6 and 9 days after the third spray, Derisom, *Verticillium* and Margosom were found superior to Spinosad, cow urine and control. Additionally, Spinosad and cow urine were found effective compared to control (Table 4).

Table 4. Population of cabbage aphid after third spray, Rampur, 2015

Treatments	Pre treatment	3 DAS	6 DAS	9 DAS
Verticillium	21.66^{de}±1.36 (4.70)	15.24^{c} ± 0.66 (3.97)	17.32^{c} ± 1.28 (4.21)	9.49^{c}± 0.73 (3.15)
Dimethoate	12.31^{f} ± 0.33 (3.58)	5.92^{d} ± 0.75 (2.52)	6.49^{d} ± 0.72 (2.63)	2.54^{d} ± 0.61 (1.72)
T_3 Margosom	24.72^{cd} ± 0.52 (5.02)	13.91^{c} ± 1.27 (3.78)	16.18^{c} ± 0.91 (4.08)	9.82^{c} ± 0.66 (3.21)
Derisom	18.95^{e} ± 0.58 (4.41)	10.91^{c} ± 0.76 (3.37)	11.92^{c} ±1.04 (3.51)	6.52^{c} ± 1.07 (2.63)
Spinosad	28.27^{c} ± 1.86 (5.36)	22.69^{b} ± 2.34 (4.80)	26.08^{b} ± 2.84 (5.13)	16.79^{b} ± 0.85 (4.15)
Cow urine	37.59^{b} ± 0.99 (6.17)	27.06^{b} ± 1.07 (5.25)	30.66^{b} ± 2.25 (5.57)	18.55^{b} ± 1.57 (4.35)
Control	116.22^{a} ± 2.73 (10.8)	128.1^{a} ± 4.55 (11.34)	147.80^{a} ± 4.70 (12.17)	126.43^{a} ± 3.51 (11.26)
CV	4.31%	6.94%	7.68%	7.51%
LSD	0.4394	0.6163	0.7292	0.5819
F test (α=0.05)	**	**	**	**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation (x+0.5) ^{½}. *(*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.*

For natural enemies population at different treatments, Margosom and control had significantly more natural enemies than Dimethoate, *Verticillium*, Derisom and Spinosad at 3 days after spraying the first spray. And, it was also observed that natural enemies' populations were significantly at par for control, cow urine and Margosom (Table 5). At 6 days after first spray, Margosom and control has more natural enemies than Dimethoate and *Verticillium* (Table 5). And, at 9 days after first spray, Margosom and control has more natural enemies to Dimethoate, Derisom and Spinosad (Table 5). For the second spray, at 3 days after second spray, Margosom has more natural enemies than Dimethoate, *Verticillium*, Derisom and Spinosad (Table 6). At 6 days after second spray, Margosom, *Verticillium*, Spinosad, cow urine and control has more natural enemies than Dimethoate and at 9 days after the second spray, *Verticillium*, Margosom, Derisom, cow urine and control has more natural enemies than Dimethoate (Table 6). For the third spray of insecticides, at 3 days after the spray, Margosom has more natural enemies than *Verticillium*, Dimethoate, Derisom and Spinosad (Table 7). At 6 days after spraying, Dimethoate has less number of natural enemies compared to other insecticides (Table 7). And, at 9 days after spraying, cow urine has more natural enemies compared to Dimethoate, Spinosad and Derisom (Table 7).

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Table 5. Prevalence of natural enemies after first spray, Rampur, 2015

Treatments	Pre treatment	3 DAS	6 DAS	9 DAS
Verticillium	9.33 ± 0.72	9.33^{e} ± 0.72	12.67^{c} ± 0.72	15^{bcd} ± 1.25
	(3.13)	(3.13)	(3.62)	(3.93)
Dimethoate	9.00 ± 0.4	10.67^{de} ± 0.72	12.67^{c} ± 0.98	10^{d} ± 0.94
	(3.08)	(3.34)	(3.62)	(3.23)
Margosom	10.33 ± 0.98	16.33^{a} ± 0.72	18.67^{ab} ± 0.98	20^{ab} ± 1.25
	(3.28)	(4.10)	(4.37)	(4.52)
Derisom	8.67 ± 0.72	13.00^{bcd} ± 0.94	15.33^{bc} ± 1.44	15^{bcd} ± 1.25
	(3.02)	(3.67)	(3.97)	(3.93)
Spinosad	8.00 ± 0.94	12.33^{cd} ± 0.72	14.33^{bc} ± 0.72	13^{cd} ± 1.89
	(2.90)	(3.58)	(3.85)	(3.65)
Cow urine	8.67 ± 0.98	14.00^{abc} ± 0.47	16.67^{abc} ± 0.98	18^{abc} ± 2.16
	(3.02)	(3.81)	(4.14)	(4.28)
Control	10.33 ± 1.91	15.67^{ab} ± 0.98	21.33^{a} ± 1.19	23^{a} ± 1.70
	(3.25)	(4.02)	(4.67)	(4.84)
CV	12.14%	6.05%	7.11%	10.15%
LSD	0.668	0.3938	0.5094	0.7313
F test (α=0.05)		**	**	**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation (x+0.5) ½. (*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.

Table 6. Prevalence of natural enemies after second spray, Rampur, 2015

Treatments	Pre treatment	3 DAS	6 DAS	9 DAS
Verticillium	15^{bcd} ± 1.2	12.67^{bcd} ± 0.98	15.00^{ab} ± 1.25	17.33^{ab} ± 0.72
	(3.93)	(3.62)	(3.93)	(4.22)
Dimethoate	10^{d} ± 0.94	7.67^{d} ± 0.98	7.33^{c} ± 1.96	8.67^{c} ± 0.98
	(3.23)	(2.84)	(2.74)	(3.02)
Margosom	20^{ab} ±1.25	18.67^{ab} ± 2.23	19.00^{ab} ± 1.41	21.00^{ab} ± 1.41
	(4.52)	(4.36)	(4.41)	(4.63)
Derisom	15^{bcd} ± 1.25	11.33^{cd} ± 1.44	12.33^{bc} ± 1.19	15.33^{ab} ± 1.91
	(3.93)	(3.42)	(3.57)	(3.96)
Spinosad	13^{cd} ± 1.89	11^{cd} ± 1.89	13.00^{b} ± 0.47	13.67^{bc} ± 0.98
	(3.65)	(3.36)	(3.67)	(3.76)
Cow urine	18^{abc} ±2.16	17^{abc} ± 2.16	17.00^{ab} ± 2.16	20.67^{ab} ± 1.66
	(4.28)	(4.16)	(4.16)	(4.59)
Control	23^{a} ± 1.70	24^{a} ± 1.41	22.67^{a} ± 2.23	23.00^{a} ± 3.77
	(4.84)	(4.94)	(4.80)	(4.80)
CV	10.15%	12.09%	12.17%	11.02%
LSD	0.7313	0.821	0.8439	0.8113
F test (α=0.05)	**	**	**	**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation (x+0.5) ½. (*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.

The highest yield (66.47 mt/ ha) of cabbage head was obtained in Dimethoate treated plots which was significantly at par with the Derisom (58.79 mt/ ha) treated plots. Dimethoate and Derisom were followed by Margosom (47.60 mt/ha), *Verticillium* (43.77 mt/ha), Cow urine (41.63 mt/ ha), Spinosad (36.77 mt/ ha) and control. The lowest yield was obtained in untreated control plot with average cabbage head yield of only 33.45 mt/ ha due to severe infestation of cabbage aphid, *Brevicoryne brassicae* L. Dimethoate had of 98.72 % increase

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in head yield over control while Derisom had 75.77% increase in yield over control which is followed by Margosom (42.31%), *Verticillium* (30.86%), Cow urine (24.45%) and Spinosad (9.92%) respectively (Table 8). Thus, we can say that Dimethoate was found very effective for minimizing the aphid population in the cabbage crop. This is strongly supported by the experiment conducted by Jana *et al.* (1997) in which reduction of aphid species with application of Dimethoate by 83.7 % over untreated check. Similar result was also obtained among various treatments for managing mustard aphid (Kafle, 2015).

Table 7. Prevalence of natural enemies after third spray, Rampur, 2015

Treatments	Pre treatment	3 DAS	6 DAS	9 DAS
Verticillium	17.33 ^{ab} ± 0.72 (4.22)	11.33 ^{bc} ±1.19 (3.43)	7.33 ^{b} ± 1.52 (2.76)	4.33 ^{abc} ± 1.19 (2.15)
Dimethoate	8.67 ^{c} ± 0.98 (3.02)	4.67 ^{d} ± 0.98 (2.24)	3.00 ^{c} ± 0.47 (1.86)	1.00 ^{d} ± 0.47 (1.17)
Margosom	21.00 ^{ab} ± 1.41 (4.63)	14.33 ^{ab} ± 1.19 (3.84)	8.33 ^{b} ± 1.19 (2.95)	3.33 ^{bcd} ± 0.72 (1.93)
Derisom	15.33 ^{ab} ± 1.91 (3.96)	10.33 ^{bc} ± 0.98 (3.28)	5.33 ^{bc} ± 0.72 (2.40)	1.67 ^{cd} ± 0.72 (1.39)
Spinosad	13.67 ^{bc} ± 0.98 (3.76)	8.67 ^{c} ± 1.44 (3.00)	5.00 ^{bc} ± 0.94 (2.32)	1.33 ^{cd} ± 0.54 (1.29)
Cow urine	20.67 ^{ab} ± 1.66 (4.59)	15.33 ^{ab} ± 1.44 (3.97)	13.33 ^{a} ± 0.72 (3.72)	5.67 ^{ab} ± 0.72 (2.47)
Control	23.00 ^{a} ± 3.77 (4.80)	21.00 ^{a} ± 2.05 (4.62)	16.00 ^{a} ± 1.41 (4.05)	8.33 ^{a} ± 1.19 (2.95)
CV	11.02%	12.12%	11.65%	24.37%
LSD	0.8113	0.7506	0.5927	0.8268
F test (α=0.05)	**	**	**	**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation $(x+0.5)^{½}$. (*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.

It has also found that the natural enemies' population was reduced drastically with Dimethoate but its population maintained with the application of botanical pesticides like Derisom, Margosom and with bio-rational pesticides like cow urine, *Verticillium* and Spinosad. Derisom was also found equally effective for the management of the cabbage aphid population. However, its effectiveness is quite lower than that of the Dimethoate. This result was supported by Moyo *et al.* (2006) where they have observed a significantly higher percentage of aphid reduction with the extraction of three species, *Derris elliptica* (Wall.) Benth., *Capsicum frutescens* L., *Tagetes minuta* L. on vegetables. Neem product, Azadirachtin (Margosom) and Verticillium was also found effective for the management of cabbage aphid (Dhaliwal *et al.* 1998, Rawat, 2006). Adhikari (2011) also reported that Neem product, i.e. Nimbecidine was also effective in reducing aphid population. It showed an average control up to 48.22% in different sprays. Rawat (2006) stated that the population reduction over control of *Verticillium lecanii* to mustard aphid was 40.80-51.60% during the month of October to January.

Cow urine, the locally prepared treatment was also found effective for the management of cabbage aphid and this implied the one alternative for chemical pesticide. Cow urine is insect repellent due to its foul order so the action of aphid gets hampered and infestation on plants declines (Kumawat *et al.,* 2014). Spinosad was found to be the least effective applied

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treatments used in the management of cabbage aphid. The low efficacy of Spinosad compared to other treatments was supported by the research conducted in Pakistan (Akbar *et al.*, 2010). According to that research, the Spinosad has low efficacy on cabbage aphid i.e. 11.26%. Dimethoate (3.18) resulted higher benefit: cost ratio as compared to the rest of other treatments followed by Derisom (2.63), Margosom (2.21), *Verticillium* (2.05), Cow urine (2.04), Control (1.67) and Spinosad (1.26) respectively (Table 9). Even though the treatment Dimethoate gave high productivity and cost benefit ratio, but the but ecofriendly treatments like Derisom, Margosom, etc. are equally viable and sustainable options to chemical insecticides. Similar findings have been reported by Rawat (2006) in which chemicals showed the higher cost: benefit ratio which was followed by botanicals.

Table 8. Yield of Cabbage in different treatments harvested at Rampur, 2015

Treatments	Biomass (mt/Ha)	Increase in yield over control (%)	Head Weight (mt/Ha)	Increase in yield over control (%)	Head Diameter (cm)
Verticillium	82.06^{ab}	37.68	43.77^{bc}	30.86	15.100^{bc}
Dimethoate	89.48^{a}	50.12	66.47^{a}	98.72	12.700^{d}
Margosom	86.44^{ab}	45.02	47.60^{b}	42.31	13.200^{cd}
Derisom	87.60^{a}	46.98	58.79^{a}	75.77	13.683^{cd}
Spinosad	68.46^{cd}	14.85	36.77^{cd}	9.92	16.467^{ab}
Cow urine	73.10^{bc}	22.65	41.63^{bcd}	24.45	17.483^{a}
Control	59.60^{d}	0	33.45^{d}	0	10.150^{e}
CV	9.23%		10.13%		7.4
LSD	12.82		8.457		1.858
SEM	4.1614		2.7446		0.603
F test(α=0.05)	**		**		**

DAS: Days after spraying, CV: Coefficient of variation, LSD: Least significant difference. Values with the same letters in a column are not significantly different at 5% by DMRT and figures after ± indicate standard error. The figure in parenthesis is square root transformation $(x+0.5)^{½}$. (*) indicates significant at 5 % level of significance while (**) denotes significant at 1 % level of significance.

Table 9. Benefit- Cost ratio of different treatments for cabbage aphid, Rampur, 2015

Treatments	Head wt. (mt/ha)	Total return (NRs/ha)*	Cost of cultivation	Net profit (NRs/ ha)	Benefit cost ratio (B:C)
Verticillium	43.77	437,700	213910	223,790	2.05
Dimethoate	66.47	664,700	209110	455,590	3.18
Margosom	47.6	476,000	215,410	260,590	2.21
Derisom	58.79	587,900	223510	364,390	2.63
Spinosad	36.77	367,700	291,910	75,790	1.26
Cow urine	41.63	416,300	203710	212,590	2.04
Control	33.45	334,500	200,160	134,340	1.67

The selling price in rupees of cabbage head at farm gate price was NRs. 10 per kg in Chitwan.

Chemical had always a detrimental effect on the natural enemies that is why less number of natural enemies has been found in the Dimethoate treated plots. The natural enemies exposed to insecticide residues on plant surfaces resulted in mortality or sub-lethal effects and decreased in searching ability for predation. The same research showed that the predatory capacity of larvae and adult lady bird beetle deteriorates due to infestation upon Dimethoate treated aphid and subsequently, they prefer to attack untreated ones (Singh *et al.*, 2004). Fadare and Amusa (2003) stated that the microbial pesticides caused the mortalities of pests but allowed the survival of their natural enemies, but on the other side, chemical pesticides

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caused the mortalities of both harmful and beneficial insect species and pests develops resistance to pesticides overtime (Dingha *et al*., 2020). Along with resistance problems, there are many problems caused by the chemicals such as health hazards, environmental effects, adverse effects on non-target organisms and destruction of natural enemies (Subedi and Vaidya, 2003).

CONCLUSION

Cabbage aphid (*Brevicoryne brassciae* L.) is one of the major pest of the cabbage and it significantly reduces the cabbage yield in the cabbage growing areas. *Brevicoryne brassicae* appear each year at damaging levels and farmers use mainly chemical insecticides for the management which has been creating many problems in soil, plant and human health. At the same time the use of bio-rational pesticides would be an eco-friendly technique for pest management. In spite of effectiveness of Dimethoate over the cabbage aphid management, high productivity and benefit cost ratio but the eco-friendly treatments could be viable alternative to chemical insecticide and these treatments have also less mortality on natural enemies than chemical pesticide i.e. Dimethoate. Since the cabbage head yield was significantly at par for the Dimethoate and Derisom treated plots, Derisom could be the best alternative for cabbage aphid management. This could be due to the conservation of natural enemies due to Derisom application compared to high mortality of natural enemies in case of Dimethoate treated plots. It was also observed that natural enemies' population was higher for Margosom treated plots compared to Dimethoate and some other insecticides too, with also being effective for cabbage aphid management. Spinosad was not found effective and cost effective for the cabbage aphid management as other applied treatments. From this research, we have noticed that the natural enemies exposed to the chemical insecticides, leads to the substantial decrease of natural enemies population in the field while the bio-rational pesticides had no harm to those beneficial species of insects. The experiment we have conducted illustrated that use of bio-rational pesticides is must to keep the natural enemies in the growers' field. This information will help to reduce the application of conventional pesticides and several negative consequences to the humans and environment.

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Authors' contributions

S. Nyaupane collected all the information from fields and extracted information from literature, analyzed data and wrote the manuscript, S. Tiwari and R.B. Thapa, were involved to guide and monitor the research activities and also the preparation of manuscript and S. Jaishi was involved to compile the literature for the manuscript.

Conflict of interest

The authors declare no conflicts of interest regarding publication of this manuscript.

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