Research Article

EFFICACY OF BIOLOGICAL AND CHEMICAL INSECTICIDES AGAINST DIAMONDBACK MOTH (*Plutella xylostella* L.) ON CABBAGE (*Brassica oleracea* var. *capitata* L.)

B. Sapkota*, R. Regmi, S. Tiwari, and R. B. Thapa
Agriculture and Forestry University, Rampur, Chitwan, Nepal

*Corresponding author: bijaysapkota25@gmail.com
Received date: 29 December 2021, Accepted date: 20 March 2022

ABSTRACT

Diamondback moth, *Plutella xylostella* (L.) is the most devastating pest in late winter in cabbage (*Brassica oleracea* var. *capitata* L.). Pesticides are the common pest management practices to manage the crucifer pests. These practices are not sustainable and ecofriendly. Hence, a field experiment was conducted to evaluate the efficacy of chemical, botanicals and biological insecticides todevelop safer and more effective insecticides for the diamondback moth, in cabbage during winter season 2018-19. The experiment was laid in a randomized block design (RCBD) with four replication and five treatments viz. i) Emamectin benzoate 5SG @ 0.4 gm/l, ii) Neemix (Azadirachtin 300 ppm) @ 2 ml/l, iii) *Metarhizium anisopliae* @ 2 ml/l, iv) *Beauveri abassiana* @ 2 ml/l and v) control (untreated). Standard recommended agronomic practices were followed in field to ensure better crop growth. The maximum reduction of *P. xylostella* larval population over untreated control was recorded in Emamectin benzoate 5 SG (95%) andNeemix(95%) sprayed field. Bio-pesticides such as*M. anisopliae* and *B. bassiana* were effective only after the first spray with maximum efficacy of (76%) and (65%), respectively, and decreased efficacy in the second and third sprays. Both yields with the least number of damaged leaves and maximum net profit was recorded in Emamectin benzoate sprayed plots with a higher benefit-cost ratio of (3.47), which was followed by *M. anisopliae*(2.96) and Neemix (2.92) treatments, respectively. Emamectin benzoate 5 SG and Neemix are effective and safe insecticides in controlling diamondback moth in cabbage crops and are viable options for integrated management of *P. xylostella*.

Keywords: Bio-pesticides, cabbage, *P. xylostella*, management, emamectin benzoate, neemix

INTRODUCTION

Cabbage (*Brassica oleracea*. var. *capitata* L.) is one of the most important palatable leafy vegetable grown all around world. It is one of the major vegetable grown during cool season in Nepal. In Chitwan district, the area under cabbage production is 340 ha with productivity of 15.53 mt/ha and national productivity of16.46 mt/ha (MoAD,2019).Cabbage has capacity to absorb large amount of nutrient from soil and known to be an exhaustive crop. The importance of nitrogen, phosphorus, potassium and sulfur on the growth and yield of vegetable crops is well established (Islam et al., 2017). The lower production and productivity of cabbage in Nepal mostly include insect pest damage (Kafle et al., 2012) and improper nutrient supply. Diamondback moth (DBM), *Plutella xylostella* L, (Lepidoptera: Plutellidae), is crucifer specialist and destructive insect-pest around the world. Remedial technique for *P. xylostella* hasshowed that the trend of pesticide use is increasing in Nepal by 10-20% per year (Sharma et al., 2013) and vegetable farming use about 90% of total pesticides (Atreya & Sitaula, 2010).

In Nepal, pesticide misuse has been reported from farmers, distributors and importers (Sharma et al., 2013) whereas *P. xylostella* has become resistant against 877 different insecticides (Mota-Sanchez & Wise, 2020). Minimizing the use of harmful chemical pesticides to control *P. xylostella* and reduce their intensity in the field is crucial.Eco-friendly research in the aspects of managing such pests in the field has been well-marked. This study is therefore, deliberated on eco-friendly management of *P. xylostella* in the field situation by adopting different components of integrated pest management (IPM).

MATERIALS AND METHODS

The research was conducted from November 2018 to March 2019 in Bharatpur Metropolitan City, Ward No. 18, Chitwan district, Nepal. The site is located at latitude of 27^0 63'North; longitude 84^0 28' and altitude of 168 above mean sea level.The experiment was performed in randomized complete block design (RCBD) consistingfive management treatments with four replications. The five treatments were: Manic

(*Metarhizium anisopliae*) @ 2ml/l, Racer (*Beauveriabassiana*) @ 2ml/l, Kingstar (Emamectin benzoate 5% SC) @ 0.4gm/l, Neemix (Neem oil 60% w/w, *Azadirachtin* 300 ppm) @ 2 ml/l and control. Each plot size was 3 m x2.25 m (6.75 m^2) consisting of 20 plants with spacing of 60 cm row to row and 45 cm plant to plant. Cabbage seedlings were transplanted in the field. Insecticidal treatments were applied as foliar spray in respective plots. The first spray of the treatments was done 50 days after transplanting of cabbage when insect population started to appear and second and third sprays were repeated at 13 days interval.

Agro-meteorological features

The meteorological features like maximum and minimum temperature, rainfall and relative humidity were taken from National Maize Research Program (NMRP), Rampur, Chitwan. The weekly mean maximum and minimum temperature, rainfall and relative humidity during the crop growing duration is presented in the graph below (Figure 1).

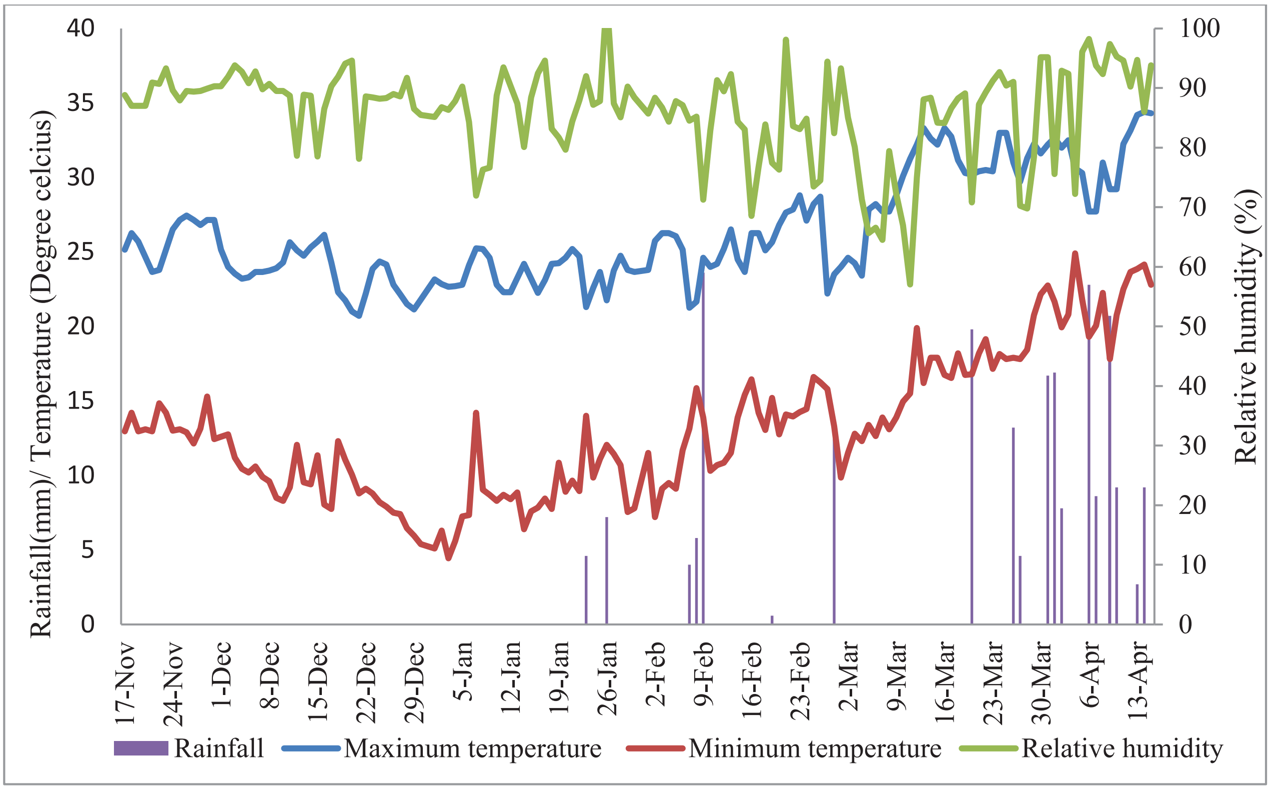

Figure 1. The weekly average rainfall, maximum and minimum temperature and relative humidity over the experimental period in Rampur, Chitwan 2018/19

Planting material, planting and harvesting

Well grown 35 days old seedlings of cabbage variety "Green Coronet" was used for the experiment. Seedlings were transplanted in the main field in 28th December, 2018 (35 days old seedlings). Basal dose of fertilizer was applied @ 120:80:60 kg NPK/ha in which half dose of N and full dose of P and K were applied and remaining dose (i.e. 50kg/ha) was applied after 45 days after transplanting (DAT) as top dressing in the field. Two hand/hoe weeding were done at 15 DAT and 35 DAT and earthing-up was done at 45 DAT. Field was irrigated as per required to maintain optimum moisture condition throughout the cropping period.

Data collection

Six plants per plot were selected randomly in each plot as sample unit for study. Whole plant of sample unit was taken for counting of the diamondback moth population. Data were recorded a day before and 4th, 8th and 12th days after the application of treatments. Biological weight was taken after uprooting the cabbage and clearing the mud (soil) in its root region. Then gross (head) weight was measured after removing the root portion of the plant. The total numbers of insect damaged wrapper leaves on the heads were removed and counted and net weights of undamaged cabbage heads were measured.

Statistical analysis

Field collected abnormal data were transformed by using √(x+0.5) to normalize the data(Gomez & Gomez, 1984). The transformed data was subjected to statistical analysis. The data was entered in Microsoft-Excel spreadsheet. Data was statistically analyzed by using Analysis of Variance (ANOVA) using R-Studio (Version 3.6.1) software package. Mean separation of the treatments was done by using Duncan's Multiple Range Test (DMRT at 5% level of significance.

The average of data regarding insect population was taken for statistical analysis. The percentage of DBM population reduction over control was calculated by using Abbott's formula (1925) as given below:

$$\text{PROC (\%)} = \left[1 - \frac{\text{N in T after treatment}}{\text{N in Co after treatment}}\right] \times 100$$

Where,
PROC = Population reduction over control
N = Insect population
T = Population in treated plots
Co = Population in control plots

Comparison of yield from different treatment and percentage increase in yield over control was calculated with the formula as given below.
Increase in yield over control (%) = (T – C/C) ×100
Where,
T = Yield from treatment plot
C = Yield from control plot

Economic analysis

Benefit cost (BC) ratio was calculated to verify the treatments whether the treatments were financially feasible or not. To find the benefit cost ratio, the prevailing price of insecticide, market rate, labor charges, rent of land and sprayer were taken into consideration. The cost of various levels of agricultural management was worked out and gross income was calculated on the basis of prevailing market price, i.e. farm gate price of cabbage. Benefit cost ratio was calculated by dividing the gross income with cost of cultivation in hectare basis.

RESULTS AND DISCUSSION

Effects of treatments on *P. xylostella* population

Emamectin benzoate 5% SG was observed the most effective soft chemical which restricted maximum *P.xylostella* larval population build up where up to 95% pest control was observed compared to control plot throughout the study period (Table1, 2 &3). Similar result was observed by Akbar et al. (2014) and reported that Emamectin benzoate was proved to be the best one with significantly higher level i.e. 90.80 % larval mortality of *P. xylostella*. Likewise, in different studies,Emamectin benzoate 5% SG was one of the effective treatment with 68.20% in the field (Harika et al., 2019) in field and 76.25% in lab condition (Sambathkumar,2020), for reduction of larval population of *P. xylostella.*

Botanical pesticide Neemix had a significant result in the control of *P.xylostella* larvae. It was found effective in reduction of *P.xylostella* population up to 86% as compared to control plot (Table 1, 2 &3). This finding is consistent withNgosong et al. (2020), who revealed that neem seed extract effectively controlled*P. xylostella* and was one of the eco-friendly, cost effective and safe bio-pesticide that enhanced livelihood of resource poor farmers in Ghana. Sow et al. (2013), Pandey and Raju (2003) reported similar result when neem products was used to control of *P. xylostella* on crucifers.

Bio-pesticides such as *M.anisopliae* and *B. bassiana* were observed effective after first spray withefficacy of 76% and 65% reduction over control respectively (Table 1). Similar finding was concluded by Loc and Chi (2007) who suggested that various isolates of *M. anisopliae* and *B. bassiana* are potential bio-agents for *P. xylostella* control in cruciferous crops. In this study,efficacy of microbial pesticides was lower after the second and third spray (Table 2&3) as compared to control. The decrease in their efficacy was observed in later sprays when the average daily mean temperature slightly increased with the onset of spring season. Similar trend of bio-pesticides was also stated by Vandenberg et al. (1998) who reported the efficacy of *B. bassiana* affected by a range of temperature differences.

Table 1. Mean number of *P. xylostella* per plant after first spray on cabbage in Chitwan, 2019

Treatments	Pre spray population	4 DAS	PROC	8 DAS	PROC	12 DAS	PROC
M. anisopliae@2ml/l	4.66 (2.25)	1.00^{bc}±0.20 (1.14)	76.91	1.00^{b}±0.21 (1.13)	73.89	3.83±0.21 (2.02)	32.33
B. bassiana @ 2ml/l	5.66 (2.47)	1.83^{b}±0.10 (1.51)	57.74	1.33^{b}±0.20 (1.27)	65.27	2.66±0.18 (1.73)	53.00
Emamectin benzoate @0.4gm/l	4.66 (2.26)	0.33^{c} ±0.11 (0.87)	92.38	0.16^{b}±0.09 (0.79)	95.82	1.33±0.21 (1.26)	76.50
Neemix @2ml/l	5.50 (2.43)	1.66^{b}±0.11 (1.51)	61.66	0.50^{b}±0.15 (0.93)	86.95	2.66±0.26 (1.68)	53.00
Control	4.50 (2.23)	4.33^{a}±0.31 (2.08)		3.83^{a}±0.28 (1.98)		5.66±0.46 (2.25)	
Sem (±)		0.023		0.035		0.110	
LSD at 0.05	0.260	0.460		0.570		1.007	
CV (%)	9.01	26.30		37.59		45.34	
F-test	Ns	**		*		Ns	

Note: DAS: Days After Spraying of Treatment; PROC: Population Reduction Over Control; CV: Coefficient of Variation; **: Significance at 1% ($p<0.001$); *: Significance at 5% ($p<0.005$); Ns: Non-Significant; LSD: Least Significant Difference; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); Sem(±) indicate standard error and figure in parenthesis indicate $\sqrt{(x+0.5)}$ transformation

Table 2. Mean number of *P. xylostella*per plant, after the second spray on cabbage in Chitwan, 2019

Treatments	Pre spray population	4 DAS	PROC	8 DAS	PROC	12 DAS	PROC
M. anisopliae@2ml/l	3.83±0.21 (2.02)	7.16^{a}±0.20 (2.73)	0.00	4.50±0.19 (2.19)	6.83	11.50±0.30 (3.39)	11.33
B. bassiana @ 2ml/l	2.66±0.18 (1.73)	8.50^{a}±0.16 (2.97)	18.72	6.50±0.32 (2.54)	-34.58	9.33±0.49 (2.93)	9.68
Emamectin benzoate @0.4gm/l	1.33±0.21 (1.26)	2.00^{b}±0.19 (1.52)	72.07	2.16±0.21 (1.56)	55.28	4.66±0.22 (2.22)	54.89
Neemix @2ml/l	2.66±0.26 (1.68)	6.33^{a}±0.37 (2.48)	11.59	3.00±0.25 (1.78)	37.89	9.83±3.06 (3.06)	4.84
Control	5.66±0.46 (2.25)	7.16^{a}±0.40 (2.62)		4.83±0.29 (2.21)		10.33±0.30 (3.22)	
Sem(±)	0.110	0.068		0.066		0.152	
LSD at 0.05	1.007	0.795		0.780		1.185	
CV (%)	45.34	26.03		30.57		32.21	
F-test	Ns	*		Ns		Ns	

Note: DAS:Days After Spraying of Treatment; PROC: Population Reduction Over Control; CV: Coefficient of Variation; *: Significance at 5% ($p<0.005$); Ns: Non-Significant; LSD: Least Significant Difference; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); Sem(±) indicate standard error and figure in parenthesis indicate $\sqrt{(x+0.5)}$ transformation

Table 3.Mean number of *P. xylostella* per plant, after the third spray on cabbage in Chitwan,2019

Treatments	Pre spray population	4 DAS	PROC	8 DAS	PROC	12 DAS	PROC
M. anisopliae@2ml/l	11.50±0.30 (3.39)	9.83^{a}±0.27 (3.15)	15.69	13.00^{a}±0.21 (3.64)	21.21	21.50a±0.28 (4.65)	0.00
B. bassiana @ 2ml/l	9.33±0.49 (2.93)	11.83^{a}±0.22 (3.47)	1.46	14.33^{a}±0.13 (3.84)	13.15	20.50ab±0.19 (4.56)	4.65
Emamectin benzoate @0.4gm/l	4.66±0.22 (2.22)	2.66^{b}±0.23 (1.70)	77.19	9.16^{b}±0.27 (3.05)	44.48	15.83±0.36 (3.95)	26.37
Neemix @2ml/l	9.83±3.06 (3.06)	7.66^{a}±0.26 (2.79)	34.31	14.33^{a}±0.23 (3.81)	13.15	19.66±0.27 (4.45)	8.56
Control	10.33±0.30 (3.22)	11.66^{a}±0.18 (3.46)		16.50^{a}±0.11 (4.11)		21.50a±0.22 (4.66)	
Sem(±)	0.152	0.063		0.029		0.046	
LSD at 0.05	1.185	0.765		0.519		0.651	
CV (%)	32.21	21.18		11.36		11.80	
F-test	Ns	*		*		Ns	

Note: DAS: Days After Spraying of Treatment; PROC: Population Reduction Over Control; CV: Coefficient of Variation; *: Significance at 5% (p<0.005); Ns: Non-Significant; LSD: Least Significant Difference; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); Sem(±) indicate standard error and figure in parenthesis indicate $\sqrt{(x+0.5)}$ transformation.

Effects of treatments on yield of cabbage

The maximum biological yield was obtained from Emamectin benzoate treated plots (104.89 mt/ha) which were significantly different (p<0.05) from other treatments; followed by Neemix treated plots (88.05 mt/ha) and *M. anisopliae* treated plots (86.69 mt/ha). The least biological yield was recorded from control plots (69.58 mt/ha) followed by *B. bassiana* treated plots (77.87 mt/ha) (Table 4).

Table 4. Effects of treatments on yield of cabbage in experimental field in Chitwan, 2019

Bioassay materials	Biological yield (mt/ha)	Net yield (mt/ha)	No. of damaged wrapper leaves/plant
M. anisopliae@2ml/l	86.69^{b}±3.78	61.87^{ab}±3.43	4.77^{b}±0.14
B. bassiana @ 2m/l	77.87^{bc}±3.34	53.87^{bc}±3.20	4.041^{c}±0.11
Emamectin benzoate @0.4gm/l	104.89^{a}±7.34	71.77^{a}±6.38	2.437^{e} ±0.19
Neemix @2ml/l	88.05^{b}±6.97	60.84^{ab}±4.81	3.27^{d}±0.20
Control	69.58^{c}±6.72	44.17^{c}±6.17	6.375^{a}±0.15
Sem(±)	25.520	19.911	0.026
LSD at 0.05	15.323	13.535	0.490
CV (%)	14.48	18.68	9.48
F-test	*	*	**

Note: CV: Coefficient of Variation; **: Significance at 1% (p<0.001); *: Significance at 5% (p<0.005); LSD: Least Significant Difference; Values with the same letters in a column are not significantly different at 5% by DMRT (Duncan's Multiple Range Test); Sem(±) indicate standard error

The highest net yield was obtained with Emamectin benzoate 5 SGtreatment (71.77 mt/ha) which was significantly different (p<0.05) from other treatments but statistically at par with *M. anisopliae* (61.87 mt/ha) and Neemix (60.84 mt/ha) treated plots. The least net yield was obtained from control plots (44.17 mt/ha) plots which was significantly different (p<0.05) from other treatments (Table 4). Emamectin benzoate was the most effective treatment which had the lowest number of damaged leaves (2.437/plant), followed by Neemix (3.27/plant) and *B. bassiana* (4.041/plant) treated plots. Regarding the efficacy of Emamectin benzoate, our result is in conformity with Kumar and Devappa (2006), who reported higher yield of cabbage heads with different concentrations with Emamectin benzoate treatments.

Benefit:Cost ratio of cabbage production

The Benefit-Cost ratio was calculated the highest in Emamectin benzoate (3.47) followed by *M. anisopliae* (2.96) and Neemix (2.92) treated plot and the lowest from untreated control plots (2.20) (Table 5). Patil et al. (2017) also investigated the economics of cabbage production with different insecticide treatments in India and revealed that higher benefit-cost ratio was observed with Emamectin benzoate treated plots followed by neem kernel-extract treated plots.

Table 5. Benefit-Cost ratio from different treatments on cabbage in Chitwan, 2019

Treatments	Net yield (mt/ha)	Yield gain over control (%)	Total return (Rs/ha)* (A)	Cost of cultivation (Rs/ha) (B)	Net profit (Rs/ha) (A-B)	Benefit: cost ratio (A/B)
M. anisopliae@2ml/l	61.87	40.07	494960	166950	328010	2.96:1
B. bassiana @ 2m/l	53.87	21.96	430960	166650	264310	2.59:1
Emamectin benzoate @0.4gm/l	71.77	62.48	574160	165600	408560	3.47:1
Neemix @2ml/l	60.84	37.74	486720	166560	320160	2.92:1
Control	44.17		353360	160500	192860	2.20:1

*The selling price in rupees of cabbage head at farm gate price NRs. 8 per kg in Chitwan, March 25, 2019

CONCLUSION

The diamondback moth, *P. xylostella* is one of the major pests of cabbage that results severe decline in production. The Emamectin benzoate 5 SG is reported asthe most effective treatment for *P. xylostella* population management in the cabbage field; it isa relatively safe semi-synthetic insecticide. Neemix was observed moderately effective whereas both bio-pesticides (*M.anisopliae* and *B. bassiana*) exhibited lower efficacy for the *P. xylostella* management in field condition. The highest yield of the cabbage was obtained from the Emamectin benzoate 5SG followed by Neemix treated plots. Therefore, Emamectin benzoate 5SG and Neemix are recommended for the management of *P. xylostella* in field conditions.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the Directorate of Research and Extension (DOREX) of Agriculture and Forestry University (AFU), Rampur for the financial support and Department of Entomology, AFU, Rampur for the technical support during this study.

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