GLOBAL JOURNAL OF BIO-SCIENCE AND BIOTECHNOLOGY

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EFFICACY OF ECO-FRIENDLY PESTICIDES ON THE MANAGEMENT OF DIAMONDBACK MOTH, *PLUTELLA XYLOSTELLA* (L.) ON CABBAGE, *BRASSICA OLERACEA, VAR. CAPITATA* (L.)

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ABSTRACT
An experiment was conducted in *Rabi* season during 2014-2015 study the relative efficacy of different eco-friendly pesticides comprising of three neem product (Neem oil 4%, NSKE 5% and Neem leaf extract 10%), one Bt products (*Bacillus thuringiensis* var. *Kurstaki* 2%), one Entomopathogenic fungus two concentrations, *Beauveria bassiana* (biorin 3%, 5%) and a chemical pesticide check standard (Cypermethrin 25 EC 0.05%) against diamondback moth (*Plutella xylostella* Linn.). All pesticides were superior in controlling the diamondback moth population in comparison to untreated control. Amongst the different treatments, T_7 Cypermethrin check recorded the highest larval population reduction (71.10%) and proved to be the most effective treatment, followed by T_2 *B. thuringiensis* 2% and T_5 *B. bassiana* 5% with larval populations reduction of (57.34%) and (55.80%) respectively, as against (0.00%) in untreated control. T_3 Neem leaf extract 10% was found to be the most inferior pesticide by recording the highest population of (46.98). Highest mean yield of cabbage was recorded in T_7 Cypermethrin 0.05% (273.32 q/ha) followed by T_2 *B. thuringiensis* 2% and T_4 Neem oil 4% (242.15 q/ha) and (228.87 q/ha) respectively, as against (96.84 q/ha) in untreated control. The cost benefit ratio of (1:6.17) was recorded in T_7 Cypermethrin 0.05% and proved to be effective among the treatments. However, recorded second highest cost benefit ratio of T_2 *B. thuringiensis* (1:5.59) followed by T_4 Neem oil 5% (1:4.98),T_5 *B. bassiana* 5% (1:4.38), T_6 NSKE 5% (1:4.01) T_1 *B. bassiana* 3% (1:3.78), T_3 Neem leaf extract 10% (1:3.51).

KEYWORDS - Cabbage, diamondback moth, *Plutella xylostella* (L.), botanicals, bio-pesticides.

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) is one of the most important cruciferous vegetable grown all over the country. India is the second largest producer of cabbage in the world after China producing 909.2 million tonnes in an area of 400.1 Hectares (4.3% of total vegetable area) with a productivity of 22.6 Mt/ha. Highest production of cabbage in India is found in West Bengal. Highest Cabbage producing states of India, West Bengal, Orissa and Bihar, 2197.4, 1150.9 and 735.0 tonnes respectively, (Anonymous, 2014). Cabbage has high nutritive value and it is used in the preparation of various kinds of dishes. It is used in stews, eaten raw in salads or boiled and eaten (Norman, 1992). Contents per 100 g are: 93 g water, 1.6 g protein, 6.0 g carbohydrates, 55 mg calcium, 0.8 mg iron, 0.3 mg carotene, 0.06 mg thiamine, 0.06 mg riboflavin, 0.3 mg niacin, 46 mg vitamin C and 92 kJ energy (De Lannoy, 2001). Among the pest complex of cabbage, diamondback moth, *Plutella xylostella* (L.) is the most destructive and dreaded pest. Though an important vegetable crop, cabbage is known to be infested by several insect pests *viz*., tobacco caterpillar, *Spodoptera litura* Fabricius; diamondback moth, *Plutella xylostella* Linnaeus; cabbage leaf webber, *Crocodolomia binotalis* Zeller; aphids, *Brevicornye brassicae* Linnaeus and *Lipaphis erysimi* Kalt; painted bug, *Bagrada cruciferum* Kirk.; and flea beetle, *Phyllotreta cruciferae* Goeze (Rao and Lal, 2005). Out of these, diamondback moth, *Plutella xylostella* (L.) is the most destructive pest (Mahla *et al*., 2005; Kumar *et al*., 2007). Fletcher (1914) recorded this pest for the first time in India on cruciferous vegetables and perusal of literature revealed that the pest is distributed all over India. In India, diamondback moth has national importance on cabbage as it causes 50-80% annual loss in the marketable yield (Devjani and Singh, 1999 and Ayalew, 2006). Kumar *et al*., (1983) and Krishnamoorthy (2004) also reported that there is 52% loss in yield due to the attack of diamondback moth. The most devastating pest that causes severe damage in cabbage production is the diamondback moth (DBM) (Kwarteng and Towler, 1994). However, this insect pest is resistant to many conventional pesticides and so spraying DBM-infested cabbage often has little effect on the pest; thus farmers may be tempted to carry out extensive spraying and eventually give up cabbage protection (Youdeowei, 2002). Furthermore, there is a growing concern about the pollution of the environment and its resultant effects on the health of humans and animals arising from the continued use of these pesticides. Though the agro-climatic condition of Allahabad is highly favourable for the successful cultivation of cabbage, this has not yet translated into higher yield mainly due to the attack of insect pests particularly diamondback moth. Though the pest has increasingly become a menace causing great economic losses, little work has been carried out and the information available at present is very meagre

and of little relevance. Hence, the present experiment was conducted to study the efficacy of eco-friendly pesticides on the management on cabbage, *Brassica oleracea, var.capitata* (L.) of diamondback moth, *Plutella xylostella* (L.) with the objective of arriving at the crucial conclusion on the most suitable techniques so as to decrease pest infestation for higher yield and productivity with least damage to the environment.

MATERIALS & METHODS

The field experiments were conducted during *Rabi* season 2014-2015 to relative efficacy of different eco-friendly pesticides comprising of three neem product (Neem oil 4%, NSKE 5% and Neem leaf extract 10%), one Bt products (*Bacillus thuringiensis* var. *Kurstaki* 2%), one Entomopathogenic fungus two concentrations, *Beauveria bassiana* (biorin 3%, 5%) and a check standard chemical pesticide (Cypermethrin 25 EC 0.05%) against diamondback moth, *Plutella xylostella* (Linn.) at Central Research Farm, Department of Entomology "Sam Higginbottom Institute of Agriculture, Technology & Science" Allahabad. Thirty day old seedlings of cabbage variety 'Golden Acre' was transplanted at 60 × 45 cm. spacing. The experiment was laid out in 'Randomized block design' and the plot size was 2m ×2 m with recommended standard agronomical practices except plant protection. In all the modules, two sprays were done for the management of diamondback moth, first spray was applied as soon as the pest level crossed the ETL *i.e.*, 4-5 larvae per plant after transplanting of cabbage seedlings. Subsequent sprays were given at 10 days interval as per the module. All the respective spray fluids were sprayed thoroughly to cover each plant in every treatment. The observations were recorded from five randomly selected plants of each treatment. Diamondback moth population was recorded one day before spray (pre-treatment) and one, seven, and ten days (Post-treatment) after spray. Diamondback moth population was counted from five leaves of the plants. Larvae were taken into consideration for counting the population of diamondback moth; the post treatment population count presented in the table 1 is the mean of 2 sprays in each module. The percent reduction in the population of this pest was worked out by using following formula:

$$P = \frac{Ta - Tb}{Ta} \times 100$$

Where,

P = Percent reduction in the population of pest.

Ta = Number of pest individuals before application (Pre-treatment count).

Tb = Number of surviving pest individuals on particular day after application.

Gross return was calculated by multiplying total yield with the market price of the produce. Cost of cultivation and cost of treatment imposition was deducted from the gross returns, to find out net returns and cost benefit ratio by following formula (Prasad *et al.*, 2007).

$$B:C = \frac{\text{Gross return}}{\text{Total Cost of treatment}}$$

The data thus obtained were statistically analysed after applying in the parentheses arc sin transformed values. Cost benefit ratio was also worked out for economical evaluation.

RESULTS & DISCUSSION

Effect of the insecticidal treatments on larval population of diamondback moth

First spray: - The larval population in all the treatments was uniform as indicated by the non significant differences a day before imposition of the treatment (Table 1). The mean diamondback moth population data recorded after the post treatment counts (3, 7 and 10 DAS) revealed that the most effective treatment with recorded in T_2 *B. thuringiensis* var. *Kurstaki* 2% (54.34%), as compared to check standard treated and untreated control (T_7 69.72% and T_0 0.00% respectively), followed by T_5 *B. bassiana* 5% (53.61%), T_4 Neem oil 5% (53.24%),T_6 NSKE 5% (51.57%), T_1 *B. bassiana* 3% (47.36%) and T_3 Neem leaf extract 10% (45.40%) was least effective among all the treatments after first spray. Treatments T_2 *B. thuringiensis* var. *Kurstaki* 2%, T_5 *B. bassiana* 5%, T_4 Neem oil 5%, and T_6 NSKE 5% were non-significant and statistically at par with each other and also treatment T_6 NSKE 5%, and T_1 *B. bassiana* 3%, were non-significant and statistically at par with each other.T_1 *B. bassiana* 3%, and T_3 Neem leaf extract 10% were non-significant and statistically at par with each other after first spray.

Second spray:- Among all the treatments used the maximum population reduction of diamond back moth population was recorded in T_2 *B. thuringiensis* var. *Kurstaki*.2% (60.35%) as compared to check standard treated and untreated control (T_7 72.49% and T_0 0.00% respectively), followed by T5-*B. bassiana* 5% (58.01%), T_4 Neem oil 5% (57.06%),T_6 NSKE 5% (54.20%),T_1 *B.bassiana* 3%, (52.49%) and T3-Neem leaf extract 10% (48.57%) was least effective among all the treatments after second spray. Treatment T_2 *B. thuringiensis* var. *Kurstaki* 2%, T_5 *B. bassiana* 5% and T_4 Neem oil 5%, were non-significant and statistically at par with each other. Treatment T_4 Neem oil 5%,T_6 NSKE 5% and T_1 *B. bassiana* 3%, were non-significant and statistically at par with each other.T_1 *B. bassiana* 3%, and T_3 Neem leaf extract 10% were non-significant and statistically at par with each other. It was revealed that all the pesticides treatments resulted in significant reduction of the diamondback moth population over control (Table 1).

TABLE 1: Efficacy of eco-friendly pesticides on the management of diamondback moth, *Plutella xylostella* (L.) on cabbage during *Rabi* season 2014-15

Treatment	Treatments Name	Percentage reduction in larval population of diamondback moth after 1st and 2nd spray										Pooled data overall mean% reduction after two sprays
		First Spray					Second Spray					
		1DBS*	3DAS**	7DAS	10DAS	Mean	1DBS	3DAS	7DAS	10DAS	Mean	
T_1	*B. bassiana 3%*	3.8	36.84 (37.37)***	46.36 (43.48)	57.89 (49.53)	47.36 (43.48)	2.8	47.85 (43.76)	52.50 (46.53)	57.14 (49.10)	52.49 (46.42)	49.91
T_2	*Bacillus thuringiensis* var. *Kurstaki* 2%	3.6	40.83 (39.71)	59.16 (50.27)	63.05 (52.56)	54.34 (47.48)	2.8	57.14 (49.10)	59.64 (50.55)	64.28 (53.29)	60.35 (50.97)	57.34
T_3	Neem leaf extrate10%	3.7	35.13 (36.34)	47.83 (43.75)	53.24 (46.85)	45.40 (42.36)	2.2	42.72 (40.81)	45.45 (42.38)	54.54 (47.60)	48.57 (44.18)	46.98
T_4	Neem oil 5%	3.8	38.68 (38.45)	57.89 (49.53)	63.15 (52.62)	53.24 (46.85)	2.4	51.23 (45.70)	55.83 (48.34)	64.16 (53.22)	57.06 (49.05)	55.15
T_5	*B. bassiana 5%*	3.5	39.14 (38.72)	58.00 (49.60)	63.71 (52.95)	53.61 (47.07)	2.6	53.22 (46.84)	59.23 (50.31)	61.53 (51.66)	58.01 (49.60)	55.80
T_6	NSKE 5%	3.8	40.52 (39.53)	54.47 (47.56)	59.73 (50.61)	51.57 (45.89)	1.5	48.78 (44.30)	54.06 (47.32)	59.76 (50.62)	54.20 (47.40)	52.88
T_7	Cypermethrin 25 EC 0.05% (Check standard)	3.6	61.11 (51.41)	72.22 (58.19)	75.83 (60.55)	69.72 (56.61)	1.2	66.66 (57.73)	72.50 (58.37)	78.33 (62.25)	72.49 (58.36)	71.10
T_0	Control	4.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Overall Mean		3.72	36.53	49.61	54.47	…….	2.05	45.87	49.90	54.92	…….	…….
F-Test		NS	S	S	S	.....	NS	S	S	S	.....	.....
S.Ed (±)		1.23	0.97	1.04	1.11	…….	1.04	0.96	0.75	0.67	…….	…….
C.D. (P= 0.05)		2.76	2.16	2.21	2.47	……..	2.19	2.10	1.90	1.78	……...	…….

*DBS=Days before spray **DAS=Day after spray, ***Figures in parentheses are arc sin transformed values

ISSN 2278 – 9103

TABLE 2. Economics of Cultivation

Treatment	Treatments Name	Yield (q/ha)	Cost of Production Rs/q	Total cost of production in (Rs)	Total Yield cost in (Rs)	Treatment cost in (Rs)	Total cost in (Rs)	Net returns in (Rs)	C:B ratio
T_1	*B. bassiana 3%*	174.53	715	124788.95	25260	800	26060	98728.95	1:3.78
T_2	*Bacillus thuringiensis* var. *Kurstaki* 2%	242.15	715	173137.25	25260	1000	26260	146877.25	1:5.59
T_3	Neem leaf extrate10%	165.24	715	118146.60	25260	800	26060	92086.60	1:3.53
T_4	Neem oil 5%	228.87	715	163642.05	25260	2100	27360	136282.05	1:4.98
T_5	*B. bassiana 5%*	196.41	715	140433.15	25260	800	26060	114373.15	1:4.38
T_6	NSKE 5%	182.25	715	130308.75	25260	800	26060	104248.75	1:4.01
T_7	Cypermethrin 25 EC 0.05% (Check standard)	273.32	715	195423.80	25260	1960	27220	168203.80	1:6.17
T_0	Control	96.84	715	70103.52	25260	-	25260	44843.52	1:1.77

Pooled data first and second spray:- The pooled mean data two spray presented in Table 1 revealed that T_2 *B. thuringiensis* var. *Kurstaki* 2% proved to be the most effective pesticide in suppression of diamondback moth population with highest mean population reduction percentage of (57.34%) as compared to treated and untreated control (T_7 71.05% and T0-0.00% respectively). It was followed by T_5 *B. bassiana* 5% with their corresponding mean population of (50.80%). But showed a significant difference from check treated. The lowest population reduction percentage T_4 Neem oil 5% (55.15%), T_6 NSKE 5% (52.88%), T_1 *B. bassiana* 3% (49.91%) and T_3 Neem leaf extract10% (46.98%) was least effective among all the treatments. Among the insecticides evaluated, the one Bt products namely dipel showed superior effect in reducing the larval population of diamondback moth compare them cypermethrin. The effectiveness of all the neem-based insecticides was found to be significantly inferior to that of the Bt products and bio-pesticide chemical *B. Bassiana*. But among the neem products, the maximum protection was given by neem oil @ 20 ml/litre with minimum population of (55.15%) which was at par with the population of (52.88%) recorded in the plots treated with NSKE @ 60 ml/litre. The results obtained in this experiment confirms the superiority of *Bacillus thuringiensis* var. *kurstaki 2*% for the control of diamondback moth population as it has also been consistently found by a number of other researchers (Raju and singh 2001; legwaila *et al.,* 2014). The effectiveness of *A. indica* (NSKE) under field conditions was studied by (Fagoonee, 1986; Srinivasan and Krishnamoorthy, 1993; Klemn and Schmutterer, 1993 and Sannaveerappanavar *et al.,* 1997) which is in agreement with the present findings. Moreover, neem products against DBM were also observed by Facknath (1993) who described the strong antifeedant action of neemark in suppressing insect damage. The findings of other researchers like (Malathi *et al.,* 1999; Saucke *et al.,* 2000; Shankar and Raju 2002; Vastrad *et al.,* 2003 and Liang *et al*., 2003) are also in agreement with our present findings. There was further revealation from the results that biorin, a product of entomopathogenic fungus, *Beauveria bassiana* also provided significant effect in suppressing the larval population as compared with the untreated control but inferior to the cypermethrin (check), one Bt products and one neem products *i.e*., Neem leaf extract but performed better than Neem oil and NSKE. Some of the past researchers (Ibrahim and Low, 1993; Masuda, 1998; Shelton *et al.,* 1998; Yoon *et al*., 1999; Jun *et al*., 1999 and Alverez and Chirinos, 2001) have also reported the effectiveness of *B. bassiana* against DBM and our results confirm their findings. From the present study, it can be inferred that apart from neem, Bt and bio-pesticides are also possessing good insecticidal properties apart from being environmentally safe and eco-friendly in nature.

Effect of eco-friendly pesticide treatments on the yield of cabbage

During *rabi* season 2004-15, (Table 2)the highest yield T_2 *B. thuringiensis* var. *Kurstaki* 2% (242.15 q/ha) as compared to treated and untreated control (T_7 273.34q/ha and T_0 96.84 q/ha respectively), followed by T_4 Neem oil 5% (238.87 q/ha), T_5 *B. bassiana* 5% (196.41 q/ha). All the treatments showed significant difference from each other (Table 3). The lowest yield of (165.24 q/ha) was recorded in the T_3 Neem leaf extract 10% treated plots, when cost benefit ratio was worked out, interesting result was achieved. Among the treatment studied, the best and most economical treatment was T_2 *B. thuringiensis* var. *Kurstaki* 2% (1:5.59) as compared to treated and untreated control (T_7 1:6.17 and T_0 1:1,17 respectively), followed by T_4 Neem oil 5% (1:4.98),T_5 *B. bassiana* 5% (1:4.38), T_6 NSKE 5% (1:4.01) T_1 *B. bassiana* 3% (1:3.78), T_3 Neem leaf extract 10% (1:3.51). Shankar and Raju (2002) have also compared the efficacy of different insecticides comprising Bt products, botanicals, conventional, pyrethroid, insect growth regulator against DBM and observed that significantly highest yield was obtained from the Bt treatments. Several earlier researchers have also recorded effective control of diamondback moth with substantial yield increase in cabbage with the use of Bt and neem products, (Seal, 1995; Asokan *et al*., 1996; Tambe *et al*., 1997; Kulkarni *et al*., 1999; Monnerat *et al*., 2000; Javaid *et al*., 2000; Loganathan *et al*., 2000; Biradar and Dhanorkar, 2001). Ibrahim and Low (1993) have also found that *B. bassiana* treated plots showed significant reduction of larval population as well as in increasing the yield when compared with alternating sprays of cypermethrin 0.1 % and phenthoate 0.1 %.

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