https://doi.org/ 10.33307/entomon.v48i2.900
ENTOMON 48(2): 309-314 (2023)
Short Communication No. ent. 48215

Evaluation of cauliflower genotypes and eco-friendly molecules for management of Diamond back moth, *Plutella xylostella* (Linnaeus) (Lepidoptera, Yponemeutidae) and their safety to natural enemies

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ABSTRACT: Four late season cauliflower genotypes namely Pusa Snowball 1 (PSB 1), Pusa Snowball K1 (PSB K1), Pusa Snowball K25 (PSB K25) and Plantsman Snowball (PMS) were evaluated for their resistance to Diamond Back Moth (DBM), *Plutella xylostella* (Linnaeus), during 2018-19. Among the genotypes screened PSB1 and PMS were comparatively less susceptible. Biochemical analyses of leaves from 85 days old healthy plants showed that PMS had higher phenol content (89.9 mg $100g^{-1}$) which on par with PSB-1 with 81.43 mg $100g^{-1}$ of leaf. This was followed by PSB K25 and PSB K1 with 69.5 and 54.23 mg $100g^{-1}$ respectively. The varieties with higher phenol content offered more resistance to DBM. Protein content of the plant showed no correlation with DBM infestation. Foliar application of spinosad (45 % SC @ 56.25 g ai ha^{-1} +NSKE 2.5 %) recorded a higher reduction (94.40 %) of DBM population over control, with comparatively higher number of syrphids and coccinellids indicating its safety to natural enemies.

KEY WORDS: Resistance, phenol, spinosad, NSKE, syrphids, coccinellids

Cauliflower, *Brassica oleracea* var *botrytis* (n=9), belonging to Brassicaceae family is a winter vegetable of global importance due to its nutritive and economic value. Lo Scalzo *et al.* (2013) evidenced that cauliflower produced organically contained high amount of carotenoids, polyphenols and ascorbic acid and showed increased antioxidant activity. India is the second largest producer of cauliflower and one of the largest exporters of cauliflower as well. Punjab is one of the major cauliflower producing Indian states (Department of Horticulture, Govt. of Punjab, 2021). Cauliflower cultivation is challenged by nearly 40 species of insect pests. Diamondback moth (*Plutella xylostella* L.), cabbage white butterfly (*Pieris brassicae* L.), cabbage head borer (*Hellula undalis* F.), cabbage webworm (*Crocidolomia binotalis* Zeller), tobacco caterpillar (*Spodoptera litura* F.), mustard saw fly (*Athalia lugens proxima* Klug.), pea leaf miner (*Chromatomyia horticola* Goureau), green peach aphids (*Myzus persicae* Sulzer), mustard aphid (*Lipaphis erysimi* Kaltenbach) and painted bug (*Bagrada hilaris* Burmeister) are major insect pests for cauliflower in India (Ahuja *et al.*, 2015; Bhushan and Pathma, 2019). Diamond back moth (DBM), *Plutella*

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Table 1. Effect of genotypes and plant age on DBM infestation in cauliflower

Genotypes	Number of DBM per plant*					
	74	81	88	95	102	109
PSB 1	0.00 (0.70)[a]	0.00 (0.70)[a]	0.27 (0.87)[a]	1.30 (1.34)[a]	0.30 (0.9)[b]	0.30 (0.9)[ab]
PSB K1	0.03 (0.72)[a]	0.03 (0.72)[a]	0.17 (0.81)[a]	1.73 (1.49)[a]	0.67 (1.08)[c]	0.73 (1.10)[b]
PSB K25	0.07 (0.75)[a]	0.03 (0.72)[a]	0.27 (0.87)[a]	1.73 (1.49)[a]	0.50 (1.00)[bc]	0.77 (1.12)[b]
PMS	0.00 (0.70)[a]	0.00 (0.70)[a]	0.30 (0.9)[a]	1.07 (1.25)[a]	0.00 (0.70)[a]	0.17 (0.81)[a]

DAS – Days After Transplanting, * Mean of six replicates
Figures in parentheses are $\sqrt{x+0.5}$ transformed values
In column, means followed by a common letter are not significantly different by DMRT (P=0.05)

xylostella (L.) (Lepidoptera, Yponemeutidae) is one of the most destructive pests damaging brassica crop worldwide. Management of this noxious pest is of global concern owing to its short life cycle, high migratory potential, evolutionary traits and gut microbiota which had enabled them to develop resistance to almost all known classes of synthetic insecticides as well as to *Bacillus thuringiensis* (Furlong *et al.*, 2013; Dotasara *et al.*, 2017; Gautam *et al.*, 2018; Li *et al.*, 2018; Qin *et al.*, 2018; Xia *et al.*, 2018; Liao *et al.*, 2019; Wang *et al.*, 2020).

Under Indian scenario DBM cause a significant damage (31-100%) and heavy economic loss (Talekar and Shelton, 1993; Lingappa *et al.*, 2006; Uthamasamy *et al.,* 2011; Imran, 2018). Numerous pesticides have been used to control DBM as well as other pest complex on cauliflower and its threatening to understand that majority of the cauliflower samples tested elsewhere globally showed increased levels of pesticide residues than the permissible limits (IARI, 2009; Panhwar and Sheikh, 2013; Pujeri *et al.*, 2015; Prodhan *et al.*, 2016). A study was formulated to assess a few popular Indian cauliflower genotypes suitable for late season cultivation in Kapurthala, Punjab, India for its degree of resistance as well as evaluate eco-friendly molecules and their combinations with neem seed kernel extract against *P. xylostella* with minimum impact on non-target organisms.

The experiments were carried out in research farm of Lovely Professional University (LPU), Phagwara, Punjab, India (31° 15' 47" N; 75° 41' 20" E). For both the trials cauliflower plants were grown with a spacing of 60×45 cm in Randomized block design (RBD) in plots of size 17.28 m^2 (3.6 × 4.8m). All the cultivation practices except crop protection were followed as per the recommendation**.** Seedlings were raised in the hi-tech poly-house facility in LPU and were transplanted on main field on 40 days after sowing (DAS). Four popular Indian late season cauliflower genotypes *viz*., Pusa Snowball 1 (PSB1), Pusa Snowball K1 (PSB K1), Pusa Snowball (PSB K25) and Plantsman snowball (PMS) were used in the study with six replications. Observations were made at weekly intervals on the incidence of DBM on different cauliflower genotypes. Morphological features such as seedling colour, leaf size, leaf colour, leaf shape, surface wax, curd color, curd compactness etc., of different cauliflower genotypes were studied. Total phenol (Zieslin and Ben-Zaken, 1993) and total proteins (Lowry *et al.,* 1951) of the genotypes were estimated using standard protocol in order to assess the influence of the plant biochemistry on incidence of DBM.

To study the bio-efficacy of synthetic and natural insecticides and their combination in half their recommended doses on management of DBM, a total of eight treatments with three replications were maintained. The treatments (Table 3) were imposed 85 DAS. Cauliflower variety PSB K1 which showed resistance to black rot but showed

Table 2. Morphological characters of different cauliflower genotypes

Parts	PSB 1	PSB K 1	PSB K 25	PMS
		Leaf		
Attitude	Erect	Semi-erect	Erect	Erect
Length	Medium	Large (>50 cm)	Medium	Large (>50 cm)
Width	Medium (15-25cm)	Medium (15-25cm)	Medium (15-25cm)	Broad > 25cm
Shape	Narrow elliptic	Broad elliptic	Broad elliptic	Broad elliptic
Crimping near main vein	Medium	Strong	Strong	Medium
Colour	Light	Light	Light	Dark
Profile (dorsal)	Flat type leaf	Convex	Concave	Concave
Puckering	Absent	Medium	Strong	Medium
		Maturity Group		
Curd maturity	Late	Late	Late	Late
Curd initiation	Late (>100)	Late (>100)	Late (>100)	Late (>100)
Curd colour	Creamy white	White	White	Creamy white
		Surface wax		
Waxiness	Light leaf wax	Light leaf wax	Strong leaf wax	Stronger leaf wax
		Seedling colour		
Anthocyanin colouration of hypocotyl	Present	Present	Present	Absent
Colour	Light violet	Light violet	Light violet	Light green

increased susceptibility to DBM was used. Observations were made on 0, 1, 3, 5, 7, 9 and 14 days after treatment (DAT) and the mean pest population and percent reduction over control were estimated. Data on natural enemies present in the ecosystem were also recorded to understand the impact of pesticides used on them.

The data were subjected to analysis of variance (ANOVA). The means were separated by Duncan's New Multiple Range Test (DMRT) (Gomez and Gomez, 1984). For all statistical analysis SPSS version 22.0 was used.

DBM incidence was observed by the last week of February and reached peak by the fourth week of March (1.46 DBM per plant). Observations on DBM incidence on the four different cauliflower cultivars showed that all the varieties showed similar infestation levels until 95 days after transplanting. At 102 DAT, PMS showed less infestation followed by PSB 1 and PSB K25 which were on par with each other while PSB K1 showed higher infestation levels. When the crop was ready to harvest at 109 DAT PMS and PSB 1 showed lower levels of infestation and were statistically similar while PSB K1 and PSB K25 showed increased levels of infestation by DBM (Table 1). Observations on morphological traits of genotypes showed no significant difference however, PMS, which showed least suscelibility to DBM infestation, had dark green leaves with stronger surface wax as compared to the other genotypes (Table 2).

The total phenol as well as the total protein content significantly varied among the genotypes. PMS showed higher phenol content (89.9 mg per 100 g of leaves) followed by PSB1, PSB K25 and PSB K1 with 81.43, 69.50 and 54.23 mg per 100 g of leaves respectively. PSB K1 recorded higher total proteins (154.26 mg/g) followed by PSB1 (136.69 mg g^{-1}), PMS (111.73 mg g^{-1}) and PSB K25 recorded the lowest total protein content of 32 mg/g of leaf sample.

In the bioefficacy of the treatments against DBM, all the treatments except control were found equally effective on 1, 3, 5, 7, 9, and 14 DAT against DBM.

Table 3. Efficacy of insecticides and NSKE and their combination against DBM on cauliflower

Treatment	No. of DBM / per plant								% Reduction
	PTC	1DAT	3DAT	5DAT	7DAT	9DAT	14DAT	Mean	
T1 - Spinosad 45 % SC 112.5 g ai/ha	1.80 (1.51)[ab]	0.93 (1.19)[a]	0.33 (0.91)[a]	0.20 (0.83)[a]	0.07 (0.75)[ab]	0.20 (0.83)[a]	0.13 (0.79)[a]	0.31	86.63
T2 - Chlorantraniliprole 18.5% SC 40 g ai/ha	2.33 (1.68)[ab]	0.40 (0.94)[a]	0.33 (0.91)[a]	0.20 (0.83)[a]	0.20 (0.83)[abc]	0.20 (0.83)[a]	0.07 (0.75)[a]	0.23	90.08
T3 - Acetamiprid 20% SP 20 g ai/ha	2.73 (1.80)[ab]	0.27 (0.87)[a]	0.40 (0.94)[a]	0.13 (0.79)[a]	0.00 (0.70)[a]	0.27 (0.87)[a]	0.00 (0.70)[a]	0.18	92.24
T4 - NSKE 5 %	1.27 (1.33)[ab]	0.40 (0.94)[a]	0.07 (0.75)[a]	0.20 (0.83)[a]	0.33 (0.91)[c]	0.20 (0.83)[a]	0.40 (0.94)[a]	0.27	88.36
T5 - Spinosad 45 % SC 56.25 g ai/ha +NSKE 2.5%	1.80 (1.51)[ab]	0.13 (0.79)[a]	0.47 (0.98)[a]	0.07 (0.75)[a]	0.07 (0.75)[ab]	0.00 (0.70)[a]	0.07 (0.75)[a]	0.13	94.40
T6 – Chlorantraniliprole 18.5% SC 20 g ai/ha +NSKE 2.5 %	0.53 (1.01)[a]	0.47 (0.98)[a]	0.53 (1.01)[a]	0.13 (0.79)[a]	0.13 (0.79)[abc]	0.20 (0.83)[a]	0.40 (0.94)[a]	0.31	86.63
T7 - Acetamiprid 20% SP 10 g ai/ha +NSKE 2.5 %	1.80 (1.51)[ab]	0.33 (0.91)[a]	0.40 (0.94)[a]	0.07 (0.75)[a]	0.27 (0.87)[bc]	0.27 (0.87)[a]	0.20 (0.83)[a]	0.26	88.80
T8 - Control (water)	3.60 (2.02)[b]	3.20 (1.92)[b]	4.00 (2.12)[b]	2.60 (1.76)[b]	1.60 (1.44)[d]	1.40 (1.37)[b]	1.13 (1.28)[b]	2.32	

* Mean of three replicates (DBM were counted on 5 randomly selected plants per replication and was expressed as no. of DBM per plant) PTC – Pre treatment count; DAT – Days after Treatment; Figures in parentheses are $\sqrt{x+0.5}$ transformed values

However, spinosad (45 % SC @ 56.25 g ai ha^{-1}) +NSKE (2.5 %) was showed maximum reduction (94.40 % over control), followed by acetamiprid (20% SP @ 20 g ai ha^{-1}) which offered 92.24 per cent, chlorantraniliprole (18.5% SC @ 40 g ai ha^{-1}) offering 90.08 per cent. Acetamiprid (20% SP @ 10 g ai ha^{-1}) + NSKE (@ 2.5 %), NSKE (@ 5 %), spinosad (45 % SC @ 112.5 g ai ha^{-1}) and chlorantraniliprole (18.5% SC @ 20 g ai ha^{-1}) +NSKE (@ 2.5 %) offering 88.80, 88.36, 86.63 and 86.63 per cent reduction over control (Table 3). Assessment of effect of pesticides under study on the natural enemies (coccinellids and syrphids) showed that there was no significant difference in coccinellid and syrphid population among the treatments imposed throughout the experimental period. Higher number of beetles were recorded on plots treated with spinosad (45 % SC @ 112.5 g ai ha^{-1}) (mean 0.07 beetles plant^{-1}) and chlorantraniliprole (18.5% SC @ 40 g ai ha^{-1}) (0.13 beetles plant^{-1}) on 3 DAT. Plots treated with spinosad (45 % SC @ 112.5 g ai ha^{-1}), Spinosad (45 % SC @ 56.25 g ai ha^{-1}) +NSKE (2.5 %), chlorantraniliprole (18.5% SC @ 20 g ai ha^{-1}) +NSKE (2.5 %) and acetamiprid (20% SP @ 10 g ai ha^{-1}) + NSKE (2.5%) recorded a mean population of 0.20, 0.07, 0.07, 0.07 beetles per plant respectively on 7 DAT. Observations on syrphid population showed that no significant difference among the treatments throughout the study period except on 7 DAT where plots treated with NSKE (5 %) and Spinosad (45 % SC @ 56.25 g ai ha^{-1}) + NSKE (2.5 %) recorded higher syrphids (0.07 and 0.13 per plant respectively).

Genotypes PSB K1 and PSB K25 showed increased levels DBM infestation while PSB1 and PMS showed comparatively lesser levels of DBM infestation. Analysis of total phenolics and total protein of the healthy leaves of 85 days old crop showed that all varieties possessed a different biochemistry which might be the potential reason behind the varying degrees of insect pest incidence at the early stages of crop growth. In the current study PMS recorded higher phenol content followed by PSB 1 which contributed to comparatively low DBM incidence on these two genotypes. PMS had dark coloured leaf with strong surface wax which could possibly influence pest incidence making it less prone to oviposition and subsequent feeding damage by DBM. Leaf size, colour and surface wax thickness influence the pest incidence in different crops (Radcliffe and Chapman, 1966; Myers, 1985; Eigenbrode *et al.,* 1991; Talsma *et al.,* 2008). Additionally current investigation shows that host plants physiological age decides its biochemical and morphological traits thereby influencing its preference by insect pests for feeding and oviposition. The results were in line with previous investigations (Renwick and Lopes, 1999; Jankowska, 2006; Cartea *et al.,* 2009; Metspalu *et al.,* 2009, Lo Scalzo *et al.,* 2013)

Spinosad +NSKE treated plots recorded the higher number of syrphids as well as coccinellids indicating its safety to natural enemies. The results were in line with findings of Aswathi *et al.* (2013). From the investigation it is evident that use of PMS variety along with use of Spinosad (45 % SC @ 56.25 g ai ha^{-1}) +NSKE (2.5 %) will act as an effective module for management of DBM.

ACKNOWLEDGEMENTS

The authors wish to thank Lovely Professional University for providing necessary facilities for carrying out field trials and laboratory experiments. The authors also thank Dr. Guneshori Maisnam, Department of Agricultural extension, Lovely Professional University for helping in statistical analysis.

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(Received Jauary, 2023; revised ms accepted April 08, 2023; published June 30, 2023)