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ENTOMOLOGY

Bio-Effectiveness of a Pro-Insecticide, Diafenthiuron 50% WP Against Diamond Back Moth, *Plutella xylostella* (Lin.) in Cabbage in Gangetic Alluvial Plains of West Bengal

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Abstract

Diamond back moth (DBM), *Plutella xylostella* (Lin.) has crippled the production of cabbage all over the world having the capacity to dwindle down yield and cause even up to 100% crop loss. Since chemical control has been the most effective means of management over decades, an attempt was made to evaluate diafenthiuron 50% WP on the basis of its bio-effectiveness, non-target toxicity and phytotoxicity in the present experiment. The results exhibited that diafenthiuron 50 % WP at the rate of 600 ml/ha provided most effective reduction of DBM population (88.68%-90.82% reduction of pest over control) with substantial increase in yield (184.75 q/ha) subsequently the highest cost benefit ratio of 1:5.89. All the doses of test molecule were found to be soft against prevailing coccinellids and hymenopteran parasitoids. Further it was observed that the test chemical did not produce any phytotoxic symptoms.

Highlights

- Diafenthiuron 50 % WP @ 600ml/ha provided effective reduction of DBM in cabbage and was soft to prevailing natural enemies without any phytotoxicity.

Keywords: DBM, diafenthiuron, bio-effectiveness, natural enemies and phytotoxicity

Cabbage, *Brassica oleracea*, an herbaceous plant of Family Brassicacea, is a widely cultivated vegetable throughout the world as a long standing dietary supplement. It is sturdy, inexpensive, and abundant and its long lasting storage capacity makes it available throughout the year. It is a low calorie vegetable full of vitamins, anthocyanins, sulphur and potassium just to mention a few of the immense nutritional supplements that aid in numerous health benefits such as weight loss, prevention of nerve damage, reduction of blood pressure, detoxification etc. which increases its popularity among people all over the world.

In India, cabbage is cultivated over 0.245 M with an average production of 5.6 M mt and a productivity of 22.9 mt/ha out of which West Bengal contributes to about 1.9 M mt of cabbage from over 65 k ha. However, the optimum cabbage production is severely limited due to the attack of insect pests, the most important of which is the diamond back moth (DBM), *Plutella xylostella* (Mahla *et al*., 2005; Kumar *et al*., 2007) whose annual management costs were estimated to be more than US$ 1.0 billion globally (Grzywaez *et al.*, 2010).The loss yield caused by this pest varies from 31-100% (Lingappa *et al.*, 2006). Pesticides have been the primary means to control *P. xylostella* for more than 40 years. Irrational use of chemical insecticides at higher doses results in depredation of natural enemies (Haseeb *et al.*, 2004) and also developed resistance in DBM (Liu *et al.,* 2003). The moth is reported to have developed resistance to many of the organophosphates, carbamates and pyrethroids and is well on its way to develop multiple resistance in India (Chauhan *et al.,* 2014). To combat these precarious conditions scientists are searching high and low for effective management strategies based on the principles of agroecosystem analysis (AESA) so that the pest can be managed with an ecofriendly approach. For such an approach the chemicals to be used in bringing down the pest population need to have a novel mode of action as well as be less harmful to the ecosystem.

Diafenthiuron [1-tert-butyl-3-(2,6-di-isopropyl-4-phenoxyphenyl)thiourea] is one of the most active thiourea compound that acts as a pro-insecticide and converts to carbodiamide under light or inside the plant. It inhibits mitochondrial respiration in the target insectresulting in quick knockdown through immediate paralysis of the pest. It has translaminar action, which allows control of hidden pests in the plant canopy and on the underside of the leaves and provides excellent control of OP and pyrethroid resistant pests (Stanley *et al.,* 2010). Being selective to beneficial insects (Streibert *et al.*, 1988), it fits well in IPM programs (Stanley *et al.,* 2016). Not only is it effective in pest suppression but also it degrades into a urea derivative resulting in a phytotonic effect.

Keeping these views in backdrop present studies were undertaken to test the field efficacy of diafenthiuron against DBM and the predatory natural enemies and phytotoxicity of the applied chemical in cabbage under inceptisol of India.

Materials and Methods

The present experiment was arranged in Randomized Block Design with seven treatments viz. T1-diafenthiuron 50 %WP @ 300 g/ha, T2-diafenthiuron 50 %WP @ 600 g/ ha, T3-diafenthiuron 50% WP @ 1200 g/ ha, T4-diafenthiuron 50 %WP @ 2400 g/ ha, T5-Indoxacarb 14.5% SC @ 200 ml/ ha, T6-Chlorpyrifos 20% EC @ 2000ml/ha and an T7-untreated check all of which were replicated four times. The seedlings of variety Pusa Snowball were transplanted in plot size of 3m × 3m with a spacing 50cm × 40cm during last week of November in the year 2013 and 1st week of December 2014. All recommended agronomic practices were followed to raise the crop under irrigated condition. The target pest was DBM and the defenders coccinellids and hymenopteran parasitoids most importantly *Cotesia plutellae*. Two rounds of sprays were imposed on coinciding with the ETL (3 larvae/plant) with a high volume of knapsack sprayer.

The data on population of pest was counted as number of DBM larvae from 5 randomly selected plants from each plot. Pre-treatment count was taken 1 day before spraying which was followed by observations on pest incidence at 1st, 3rd, 5th and 7th days after spraying (DAS). The larval mortality in each plot was calculated and was subjected to arc sine transformation to normalize the data for statistical analysis. The population count of important predators like *Coccinella septempunctata* and *Coccinella transversalis;* and parasitized DBM larvae by *Cotesia plutellae* were recorded from same plants on respective dates of observation. Important larval parasitoids, *Cotesia plutellae* were taken at 1 day before treatment and 7 days after treatment from five metre row length and subsequently transformed into $\sqrt{x+0.5}$ for statistical interpretations.

Phytotoxicity observation were recorded (as per CIB and RC guideline) at 3, 7 & 14 days after spraying on leaf injury on tips and leaf surface, wilting, necrosis, vein clearing, epinasty, hyponasty, etc. using 0-10 phytotoxicity rating scale as follows at standard, 2X and 4X dosages.

The mean values after suitable transformation were subjected to ANOVA as per Gomez and Gomez (1984) for interpretation of the results. The data thus collected were subjected to analysis of variance after necessary transformation where ever required.

Results and Discussion

Bioefficacy of diafenthiuron 50% WP

Table 1 depicts the pooled data on bio-effectiveness of different treatment schedules of diafenthiuron 50% WP against DBM over two seasons of 2013-2014 and 2014-2015. All the treatments showed significant reduction in larval population in both the seasons. All the treatment schedules of diafenthiuron 50% WP proved to be superior to the standard check treatments indoxacarb 14.5% SC and chlorpyrifos 20% EC. The overall percentage reduction in larval population after two consecutive rounds of sprays over that of untreated control were 80.23%, 97.34% and 99.02% during 2013-2014 and 80.30%,

Table 1: Bioefficacy of Diafenthiuron 50% WP against diamondback moth, *Plutella xylostella* (L.) on cabbage at Kalyani, 2013-14 and 2014-2015 (Pooled)

Treatment	2013-2014											2014-2015										
	Pre treat-ment count	% larval reduction over control days after the sprays								Overall % reduction over control		Pre treat-ment count	% larval reduction over control days after the sprays								Overall % reduction over control
		I^st Spray				II^nd Spray							I^st Spray				II^nd Spray				
		1	3	5	7	1	3	5	7				1	3	5	7	1	3	5	7	
Diafenthiuron 50 %WP @ 300 g/ ha	39.79	73.08 (58.74)	78.72 (62.52)	82.70 (65.42)	79.02 (62.73)	74.07 (59.38)	77.58 (61.73)	79.24 (62.89)	80.23 (63.60)	78.38		29.19	76.92 (61.28)	81.22 (64.31)	83.27 (65.85)	81.42 (64.46)	73.35 (58.91)	78.98 (62.71)	82.83 (65.52)	84.40 (66.73)	80.30
Diafenthiuron 50 %WP @ 600 g/ ha	41.20	79.96 (63.40)	83.71 (66.19)	85.72 (67.79)	84.46 (66.78)	85.99 (68.01)	94.89 (76.93)	97.44 (80.79)	97.34 (80.61)	88.68		29.88	81.16 (64.27)	87.52 (69.31)	89.02 (70.64)	87.31 (69.13)	87.89 (69.63)	95.64 (77.94)	98.77 (83.63)	99.22 (84.93)	90.82
Diafenthiuron 50 %WP @ 1200 g/ ha	37.37	80.92 (64.09)	89.93 (71.49)	93.01 (74.66)	92.79 (74.42)	88.31 (70.00)	97.11 (80.21)	99.02 (84.31)	99.02 (84.31)	92.51		30.37	83.91 (66.35)	92.28 (73.86)	95.01 (77.09)	93.64 (75.39)	91.17 (72.71)	98.77 (83.63)	99.02 (84.31)	100.00 (90.00)	94.22
Indoxacarb 14.5 % SC @ 200 ml/ ha	40.40	66.23 (54.47)	69.32 (56.36)	72.43 (58.32)	68.17 (55.98)	72.19 (58.17)	76.02 (60.67)	76.22 (60.81)	73.19 (58.81)	71.72		31.45	70.02 (56.80)	74.23 (59.49)	79.22 (62.88)	79.84 (63.32)	74.23 (59.49)	83.51 (66.04)	84.19 (66.57)	85.52 (67.63)	78.85
Chlorpyrifos 20%EC @ 2000ml/ ha	39.90	39.42 (38.89)	45.46 (42.40)	48.64 (44.22)	37.98 (38.04)	34.96 (36.25)	40.76 (39.79)	45.95 (42.68)	52.13 (46.22)	43.16		29.09	33.05 (35.09)	46.39 (42.93)	51.39 (45.80)	50.22 (45.13)	44.99 (42.13)	47.77 (43.72)	52.31 (46.32)	49.09 (44.48)	46.90
Untreated Control	42.17	—	—	—	—	—	—	—	—	—		30.61	—	—	—	—	—	—	—	—	—
CD (P=O.05)	NS	2.45	3.05	2.56	4.18	3.45	3.56	4.01	**2.56**			NS	0.52	1.12	2.36	3.01	1.25	1.08	2.01	0.21	

Data in parentheses are angular transformed values

Table 2: Effect of Diafenthiuron 50% WP on natural enemies in cabbage at Kalyani, 2013-14 and 2014-2015 (pooled)

Treatment	Dosage		2013-2014				2014-2015			
	Formulation (g or ml/ ha)	Active ingredient (g/ha)	Pre treatment count of natural enemies/ 5 metres row length		Population of natural enemies/5 metre row length 7 days after treatment		Pre treatment count of natural enemies/ 5 metres row length		Population of natural enemies/5 metre row length 7 days after treatment	
			Predators (Coccinellids)	Percent parasitisation (Hymenopter-ans)	Predators (Coccinellids)	Percent parasitisation (Hymenopter-ans)	Predators (Coccinellids)	Percent parasitisation (Hymenopter-ans)	Predators (Coccinellids)	Percent parasitisation (Hymenopter-ans)
Diafenthiuron 50 %WP	300	150	0.52 (1.22)*	1.19 (20.17)**	0.99 (1.49)*	1.98 (26.42)**	0.02 (0.64)*	1.11 (19.46)**	1.77 (1.83)*	2.94 (32.84)**
Diafenthiuron 50 %WP	600	300	0.55 (1.24)	0.57 (13.81)	0.86 (1.43)	1.82 (25.25)	0.33 (1.07)	0.72 (15.57)	1.53 (1.74)	2.06 (26.99)
Diafenthiuron 50 %WP	1200	600	0.35 (1.09)	1.36 (21.64)	0.54 (1.23)	1.37 (21.72)	0.51 (1.21)	1.34 (21.47)	0.64 (1.30)	1.13 (19.64)
Indoxacarb 14.5 % SC	200	29	0.66 (1.31)	0.93 (17.76)	0.69 (1.33)	1.79 (25.03)	0.86 (1.43)	1.35 (21.56)	1.46 (1.71)	2.00 (26.57)
Chlorpyrifos 20%EC	2000	400	0.43 (1.16)	0.71 (15.45)	0.32 (1.06)	0.59 (14.06)	0.56 (1.25)	0.72 (15.57)	0.23 (0.98)	0.66 (14.89)
Untreated Control	—	—	0.80 (1.39)	0.94 (17.85)	1.63 (1.78)	2.27 (28.45)	0.79 (1.39)	0.56 (13.69)	1.85 (1.86)	3.10 (33.83)
CD (P=O.05)			NS	0.15	0.26	0.86	NS	0.12	0.32	0.16

** Data in parentheses are square root transformed values, ** Data in parentheses are angular transformed values*

Table 3: Yield of cabbage and economics of different treatment schedules of Diafenthiuron 50 %WP against DBM (*Plutella xylostella*) during 2013-14 and 2014-15 (Pooled)

Treatment	Dosage Season 1		CabbageYield (q/ha) Season 2		Mean Yield (q/ha)	Percent increase in yield over untreated control	Cost of treatments including labour charges(₹/ha)	Gross realization (₹/ha)	Net realization (₹/ha)	Net profit (₹/ha)	Cost Benefit Ratio
Diafenthiuron 50 %WP	300	150	173.88 (13.69)	166.65 (13.41)	170.27	10.91	24760	194030	170270	145510	1:5.87
Diafenthiuron 50 %WP	600	300	187.14 (14.18)	182.36 (14.00)	184.75	20.34	26830	211580	184750	157920	1:5.89
Diafenthiuron 50 %WP	1200	600	195.20 (14.47)	188.99 (14.25)	192.10	25.13	28640	220740	192100	163460	1:5.71
Indoxacarb 14.5 % SC	200	29	170.29 (13.55)	171.14 (13.58)	170.72	11.20	26015	196735	170720	144705	1:5.56
Chlorpyrifos 20%EC	2000	400	152.91 (12.87)	163.53 (13.29)	158.22	3.06	23260	181480	158220	134960	1:5.80
Untreated Control	—	—	149. 70 (12.74)	157.34 (13.04)	153.52	—	—	—	—	—	—
CD (P=O.05)			12.56	5.15	6.24						

Data in parentheses are square root transformed values

Market price of cabbage: 1000.00 per quintal (As of 16 March, 2015, Govt. of India. http:// http://agmarknet.nic.in/)

Labour charges (skilled): 222.00 day as per govt. of W.B. Labour Commission Cicular, 2014

Table 4: Phytotoxicity effects of Diafenthiuron 50% WP at doses (normal, double & four times) on cabbage at Kalyani, 2013-14 and 2014-2015 (pooled)

Treatment	Dosage		Phytotoxicity on scale points (0-10) after days of treatment				
	Formulation (kg /ha)	Active ingredient (kg/ha)	1	3	5	7	10
Diafenthiuron 50 %WP @ 300 g/ ha (Lower dose)	0.3	0.15	0.0	0.0	0.0	0.0	0.0
Diafenthiuron 50 %WP @ 600 g/ ha (Standard dose)	0.6	0.3	0.0	0.0	0.0	0.0	0.0
Diafenthiuron 50 %WP @ 1200 g/ ha (Double dose)	1.2	0.6	0.0	0.0	0.0	0.0	0.0
Diafenthiuron 50 %WP @ 2400 g/ ha (Four times dose)	2.4	1.2	0.0	0.0	0.0	0.0	0.0
Untreated Control	—	—	0.0	0.0	0.0	0.0	0.0

90.82% and 94.22% during 2014-2015 respectively for treatments diafenthiuron 50% WP @ 300g/ha, diafenthiuron 50% WP @ 600g/ha, and diafenthiuron 50% WP @ 1200g/ha. The results are in conformity with that of Jiang *et al.* 2015 who reported that all field populations of DBM were found to be susceptible to diafenthiuron. Zhang *et al.* 2016 also reported that DBM showed susceptibility to application of diafenthiuron.

Effect of test chemistry on natural enemies

Table 2 represents the efficacy of test molecule that was recorded on the common natural enemies. It was observed that the doses of diafenthiuron 50% WP administered were relatively safe to the prevailing non-target fauna the coccinellids and the hymenopteran parasitoids. Untreated check recorded population (mean population of 2 two rounds of spray) variation of coccinellids to the tune of 1.63-1.85 respectively over two seasons whereas the coccinellid population varied over 0.99-1.77, 0.86-1.53, 0.54-0.64 per 5 metres row length at seven days after spray of different treatment schedules of difenthiuron 50% WP (at the rate 300, 600 and 1200g/ha) over two seasons. Standard check indoxacarb followed the same trend as that of diafenthiuron (0.69-1.86/5metres row length) whereas chlorpyrifos harboured quite less number of coccinellids than diafenthiuron (0.23-0.32/5 metres row length) after two rounds of spray over two seasons. Percent parasitisation of larvae by hymenopteran parasitoids was also found to be almost unaltered due to diafenthiuron application in different doses.

Untreated check recorded the population of hymenopteran parasitoids 7 days after two round of spray (application of water) as 2.27-3.10 per 5 metres row length over two seasons. Different treatment schedules of difenthiuron 50% WP (300, 600 and 1200 g/ha) recorded percent parasitisation to the tune of 1.98-2.94, 1.82-2.06, 1.13-1.37 per 5 metres row length over two seasons. Standard check indoxacarb also recorded similar percent parasitisation of hymenopteran parasiotids as that of diafenthiuron over two seasons (1.79-2.00 per 5 metres row length). However, standard check chlorpyrifos recorded very low percent parasitisation than that of diafenthiuron (0.59-0.66 per 5 metres row length) over two seasons. The results are in conformity with that of Stanley *et al.* 2016.

Yield

Table 3 represents the yield economics of cabbage under different treatment schedules over two seasons. Plots treated with higher doses of diafenthiuron 50% WP gave significantly higher yield (184.75-192.10 q/ha) than that of untreated control (153.52 q/ha). The yield increment was promising in the treated plots with diafenthiuron 50% WP at higer doses (20.34-25.13 % increase over control) than that of standard checks indoxacab 14.5%SC and chlorpyrifos 20% EC (11.20% and 3.06%). Highest cost: benefit ratio (1: 5.89) was obtained from diafenthiuron 50% WP at the rate 600 g/ha closely followed by diafenthiuron 50% WP at the rate 300g/ha (1:5.87) and the least being standard check indoxacarb 14.5%SC (1:5.56).

Phytotoxicity

Table 4 depicts that no phytotoxic symptoms were observed after 10th day of sprays as may be recorded over two seasons.

Hence based on the two seasons results, it may be concluded that diafenthiuron 50% WP was effective inmanaging DBM in cabbage ecosystem and its application at 300 g a.i./ha can be suggested best among the treatments considering entomological, ecological and economic aspects of our socio-economic condition of farming community.

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