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Efficacy and economics of seed treatment and foliar spray with insecticides against *Bagrada hilaris* (Burmeister) in Indian mustard (*Brassica juncea* L.)

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Abstract

Bioefficacy studies of various insecticides against painted bug on Indian mustard [*Brassica juncea* (L.) Czern & Coss.] during 2013-14 and 2014-15 at CCS Haryana Agricultural University, Hisar, revealed that seed treatment with imidacloprid 600 FS @ 5 ml/kg seed (mean per cent reduction over control 84.4%) was most effective in managing painted bug population at initial stage of crop and it was found on par with thiamethoxam 35 FS @ 5 ml/kg seed (mean per cent reduction over control 82.80%). Among the insecticides applied as foliar spray, imidacloprid 17.8 SL (78.3%) and thimethoxam 25 G (76.2%) found to be most effective, while dimethoate 30 EC (62.35%), profenophos 50 EC (63.76%), malathion 50 EC (63.3%), chlorpyriphos 20 EC (60.3%) and quinalphos 20 EC (60.2%) were found moderately effective. The treatment with nimbecidine was found least effective but superior over control (47.9%) against the painted bug. Based on the economic returns imidacloprid 17.8 SL, imidacloprid 600 FS and thimethoxam 25 G were adjudged as best treatments for the effective management of painted bug.

Keywords: *Bagrada hilaris, bio-efficacy, Indian mustard, seed treatment*

Introduction

Brassicas also referred to as rapeseed-mustard, are an important group of oilseed crops in the world, comprise eight cultivated crops of tribe Brassiceae within the family Cruciferae (Brassicaceae). At national level it is grown over an area of 6.45 million ha with production and productivity of 7.28 million tons and 1128 kg/ha, respectively (Anonymous, 2015). Haryana is the second most important state in the country with production of 0.88 million tons over an area of 0.54 million ha with average yield of 1639 kg/ha during 2013-2014 (Anonymous, 2015). In India, the factors responsible for low and unstable yield of rapeseed-mustard are poor plant population, inadequate fertilization and vulnerability to insect-pests and diseases. Amongst these, the incidence of insect-pests is of immense importance (Singh and Malik, 1993). About 50 insect species have been found infesting rapeseed-mustard in India among which, the painted bug *Bagrada hilaris* (Burmeister) (Hemiptera: Penatatomidae), formerly known as *Bagrada cruciferarum* Kirkaldy and *Bagrada picta* (F.) is the most important pest of crucifer crops in India ((Sharma and Singh, 2010; Singh, 2008). It is a serious pest of rapeseed mustard at seedling (October-November) as well as at harvest stage (March-April) (Vora *et al*., 1985, Singh and Malik, 1993 and Singh, 1996). The pest incidence at seedling stage resulted into complete failure of the mustard crop necessitating re-sowing (Bakhetia, 1986 and Singh *et al*., 1993). The losses at seedling stage varied from 26.8 to 70.8 per cent whereas at the pod formation and maturity stages 30.1 per cent losses in yield and 3.4 per cent in oil content has been reported (Singh *et al*., 1980).

The potential for the pest to cause significant crop losses coupled with the lack of biological control alternatives for *B. hilaris* (Reed *et al*., 2013) has left little alternative but to use insecticides. Furthermore, because *B. hilaris* can rapidly damage seedling plants (Huang *et al*., 2014), effective insecticide treatments applied in the field must act quickly.The effect of broad spectrum insecticides on the eco-system in particular on the natural enemies associated with *B. hilaris* crop pest was well documented by several workers (Singh *et al*., 2011 and Chandel *et al*., 2011). The much safer new and efficacious chemical formulations available in the market need to be evaluated against the *B. hilaris* are the need of the hour. This pest can be controlled by use of different insecticides which are quite effective but their excessive and injudicious use may lead to imbalance in agro-ecosystem and various health hazards. Therefore, present studies were conducted to find out the efficacious and less hazardous insecticide for the management of painted bug.

Materials and Methods

The present studies were conducted at Research area of Oilseed Section, Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana) India, on the variety, RH 30 during '*Rabi*' season of 2013-14 and 2014-15 in randomized block design with three replications. Two seed treatments namely, imidacloprid 600 FS @ 5 ml/kg, thiamethoxam 35 FS @ 5ml/ kg and ten foliar spray *viz*., imidacloprid 17.8 SL @ 100 ml/ha, thiamethoxam 25 G @ 100 g/ha, dimethoate 30 EC @ 625 ml/ha, profenophos 50 EC @ 1000 ml/ha, chlorpyriphos 20 EC @ 1000 ml/ha, fenvalerate 20 EC @ 375 ml/ha, quinalphos 20 EC @ 1000 ml/ha, nimbecidine 1500 ppm @ 2000 ml/ha, buprofezin 25 SC @ 1000 ml/ha and malathion 50 EC @ 500 ml/ha along with control were evaluated for bio-efficacy. The crop was sown in October with plot size of 4.2m x 3m and distance between row to row and plant to plant was 30cm and 10cm, respectively. All the recommended agronomic practices were followed to raise the good crop. Foliar application of different insecticides was done at economic threshold of painted bug (one nymph or adult/m row length or 10 per cent plant infested). In the initial stage of crop, the observations were taken on the basis of total population of adults and nymphs on per meter row length in each plot. The observations were recorded one day before spray and after 1, 3, 7 and 10 days after spray. Five observations per plot were observed at initial stage. In the later stage of crop, the observation recorded on the basis of total population of adults and nymphs on 10 randomly selected tagged plants in each plot.

The seed yield was recorded from net plot area and converted in to kg per hectare. The cost benefit ratio was calculated for each treatment. Data so obtained were statistically analyzed.

Results and Discussion

Efficacy of insecticides against *B. hilaris* at seedling stage

In 2013-14 crop season, all the insecticides tested against the painted bug recorded lower population as compared to control. One day after spray, imidacloprid 17.8 SL was found most effective in reducing the test insect (0.67 bugs/meter row length) and it was on par with thiamethoxam 25 G and dimethoate 30 EC with 0.70 and 0.73 bugs/ meter row length, respectively. All other insecticides showed moderate efficacy with population of 0.77 to 0.97 bugs per meter row length, as compared to control (1.67 bugs/meter row length). Among seed treated plots, minimum pest was recorded in imidacloprid 600 FS (0.32 bugs/meter row length). At three days after spray similar pattern was observed with the lowest number of test insect recorded in the plants sprayed with imidacloprid 17.8 SL (0.50 bugs/meter row length) and thiamethoxam (0.55 bugs/meter row length). Foliar spray with nimbecidine 1500 ppm had little effect on painted bug registering a population of 0.87 bugs/meter row length. Similarly, in seed treated plots, minimum populations were recorded on plots treated with imidacloprid 600 FS (0.33 bugs/meter row length) (Table 1). At seven days after spray, highest population of 2.00 per meter row length was recorded in control followed by plants treated with nimbecidine 1500 ppm, buprofezin 25 SC and fenvalerate 20 EC retained their efficacy by recording 0.90, 0.67 and 0.57 bugs/meter row length, respectively. Similarly, in seed treated plots, minimum populations were recorded on plots treated with imidacloprid 600 FS (0.33 bugs/meter row length). At ten days after spray significantly higher population was observed in case of control compared to plants sprayed with insecticides. Treatment with imidacloprid 17.8 SL and thiamethoxam 25 G were effective in controlling painted bug recording 0.13 and 0.16 bugs/meter row

Table 1. Efficacy of insecticides against *B. hilaris* at seedling stage on rapeseed-mustard (Cv. RH 30)

	Treatment	2013-14 Mean number of painted bug population(nymph and adult)/ meter row length					2013-14 Per cent reduction	2014-15 Mean number of painted bug population(nymph and adult)/ plant					2014-15 Per cent reduction	Pooled Mean number of painted bug population(nymph and adult)/ plant					Pooled Per cent reduction
	Seed treatment	15^{th} DAS	16^{th} DAS	18^{th} DAS	22^{th} DAS	25^{th} DAS	-	15^{th} DAS	16^{th} DAS	18^{th} DAS	22^{th} DAS	25^{th} DAS	-	15^{th} DAS	16^{th} DAS	18^{th} DAS	22^{th} DAS	25^{th} DAS	-
T1	Imidacloprid 600 FS	0.32 (1.45)	0.32 (1.49)	0.33 (1.15)	0.33 (1.60)	0.39 (1.18)	82.02	0.24 (1.12)*	0.24 (1.12)	0.24 (1.12)	0.25 (1.12)	0.27 (1.13)	88.17	0.28 (1.13)	0.28 (1.132)	0.29 (1.34)	0.29 (1.14)	0.33 (1.15)	84.44
T2	Thiamethoxam 35 FS	0.36 (1.16)	0.36 (1.15)	0.36 (1.17)	0.37 (1.19)	0.42 (1.20)	80.18	0.27 (1.13)	0.27 (1.13)	0.26 (1.12)	0.28 (1.13)	0.30 (1.14)	86.87	0.32 (1.15)	0.31 (1.15)	0.31 (1.15)	0.33 (1.16)	0.36 (1.17)	82.80
	Foliar spray	Before Spray	1^{st} DAT	3^{rd} DAT	7^{th} DAT	10^{th} DAT	-	Before Spray	1^{st} DAT	3^{rd} DAT	7^{th} DAT	10^{th} DAT	-	Before Spray	1^{st} DAT	3^{rd} DAT	7^{th} DAT	10^{th} DAT	
T3	Imidacloprid 17.8 SL	1.37 (1.54)	0.67 (1.29)	0.50 (1.22)	0.30 (1.14)	0.13 (1.06)	79.05	1.48 (1.57)	0.57 (1.25)	0.39 (1.18)	0.27 (1.12	0.15 (1.07)	83.88	1.42 (1.56)	0.62 (1.27)	0.44 (1.20)	0.28 (1.13)	0.14 (1.07)	80.58
T4	Thiamethoxam 25 G	1.37 (1.54)	0.70 (1.30)	0.55 (1.25)	0.33 (1.15)	0.16 (1.08)	77.13	1.43 (1.56)	0.60 (1.26)	0.39 (1.18)	0.32 (1.15)	0.22 (1.10)	82.00	1.40 (1.55)	0.65 (1.28)	0.47 (1.21)	0.33 (1.15)	0.19 (1.09)	78.57
T5	Dimethoate 30 EC	1.40 (1.55)	0.73 (1.32)	0.63 (1.28)	0.40 (1.18)	0.30 (1.14)	72.98	1.44 (1.56)	0.72 (1.31)	0.61 (1.27)	0.40 (1.18)	0.31 (1.15)	75.98	1.42 (1.56)	0.73 (1.31)	0.62 (1.27)	0.40 (1.18)	0.31 (1.14)	73.16
T6	Profenophos 50 EC	1.37 (1.54)	0.77 (1.33)	0.70 (1.30)	0.45 (1.20)	0.35 (1.16)	70.32	1.36 (1.54)	0.75 (1.32)	0.79 (1.34)	0.43 (1.19)	0.37 (1.17)	72.41	1.36 (1.53)	0.76 (1.32)	0.75 (1.32)	0.44 (1.20)	0.36 (1.17)	69.84
T7	Chlorpyriphos 20 EC	1.37 (1.54)	0.86 (1.37)	0.77 (1.33)	0.53 (1.24)	0.40 (1.18)	66.43	1.42 (1.56)	0.86 (1.36)	0.84 (1.36)	0.53 (1.24)	0.42 (1.19)	68.67	1.39 (1.55)	0.86 (1.36)	0.81 (1.34)	0.53 (1.24)	0.41 (1.19)	65.82
T8	Fenvalerate 20 EC	1.30 (1.52)	0.93 (1.39)	0.83 (1.35)	0.57 (1.25)	0.37 (1.17)	64.69	1.38 (1.54)	0.92 (1.38)	0.83 (1.35)	0.57 (1.25)	0.35 (1.16)	68.63	1.34 (1.53)	0.93 (1.38)	0.83 (1.35)	0.57 (1.25)	0.36 (1.17)	64.93
T9	Quinalphos 20 EC	1.33 (1.53)	0.80 (1.34)	0.67 (1.29)	0.47 (1.21)	0.46 (1.21)	68.62	1.49 (1.58)	0.83 (1.35)	0.80 (1.34)	0.50 (1.22)	0.46 (1.21)	69.58	1.41 (1.55)	0.81 (1.34)	0.73 (1.32)	0.48 (1.21)	0.46 (1.21)	67.42
T10	Nimbecidine 1500 ppm	1.43 (1.56)	0.97 (1.40)	0.87 (1.37)	0.90 (1.38)	0.95 (1.40)	51.68	1.42 (1.55)	1.00 (1.33)	0.91 (1.38)	0.96 (1.40)	1.07 (1.44)	53.58	1.43 (1.56)	0.98 (1.40)	0.89 (1.38)	0.93 (1.39)	1.01 (1.42)	50.07
T11	Buprofezin 25 SC	1.40 (1.55)	0.93 (1.39)	0.78 (1.28)	0.67 (1.39)	0.23 (1.11)	65.74	1.42 (1.56)	0.94 (1.39)	0.80 (1.34)	0.70 (1.30)	0.20 (1.10)	68.83	1.41 (1.55)	0.94 (1.39)	0.79 (1.31)	0.68 (1.27)	0.22 (1.10)	65.56
T12	Malathion 50 EC	1.43 (1.56)	0.77 (1.33)	0.63 (1.28)	0.43 1.21	0.33 (1.15)	71.63	1.44 (1.56)	0.77 (1.33)	0.75 (1.32)	0.65 (1.28)	0.36 (1.16)	70.20	1.44 (1.56)	0.77 (1.33)	0.69 (1.30)	0.54 (1.24)	0.35 (1.16)	69.27
T13	Control	1.47 (1.57)	1.67 (1.63)	1.80 (1.67)	2.00 (1.73)	2.17 (1.76)	-	1.49 (1.58)	1.85 (1.69)	2.08 (1.75)	2.23 (1.78)	2.30 (1.82)	-	1.48 (1.57)	1.76 (1.66)	1.94 (1.72)	2.12 (1.76)	2.24 (1.79)	-
	SE (m)±	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	-	(0.02)	(0.03)	(0.02)	(0.02)	(0.02)	-	(0.02)	(0.02)	(0.01)	(0.02)	(0.01)	-
	CD at 5%	(N.S)*	(0.07)	(0.06)	(0.07)	(0.06)	-	(0.05)	(0.08)	(0.06)	(0.07)	(0.07)	-	(0.06)	(0.05)	(0.03)	(0.05)	(0.04)	-

Figures in parentheses are square root transformed values

*Based on foliar spray

DAT- Days after treatment, **DAS**- Days after sowing length, respectively. The remaining insecticides had moderate effect on painted bug population with more than 50 per cent population reduction over control. In case of seed treatment, imidacloprid 600 FS recorded minimum pest incidence (0.39 bugs/meter row length). Among all tested insecticides the maximum per cent reduction in painted bug population over control was recorded in treatment with imidacloprid 600 FS (82.02%), followed by thimethoxam 35 FS (80.18%), imidacloprid 17.8 SL (79.05%) and thimethoxam 25 G (77.13%) while lowest in the treatment with nimbecidine 1500 ppm (51.68%), (Table 1).

In 2014-15, almost similar trend was observed w.r.t. painted bug population to that observed in 2013-14. All the treatments resulted in significant decline in painted bug population after 1, 3, 7 and 10 days of spray (Table 1). Among all tested insecticides the maximum per cent reduction in painted bug population over control was recorded in treatment with imidacloprid 600 FS (88.17%), followed by thimethoxam 35 FS (86.87%), imidacloprid 17.8 SL (83.88%) and thimethoxam 25 G (82.00%) while lowest in the treatment with nimbecidine 1500 ppm (53.58%) (Table 1).

From the pooled data of two years again, it is evident that imidacloprid 17.8 SL and thiamethoxam 25 G were the most effective insecticides against painted bug at one day after spray, which recorded a population of 0.62 and 0.65 bugs per meter row length, respectively. Foliar spray, dimethoate 30 EC, profenophos 50 EC, malathion 50 EC, chloropyriphos 20 EC and quinalphos 25 EC were the next promising chemicals against painted bug. Almost similar trend was observed after 3, 7 and 10 days of treatment. Among seed treated plots, minimum pest was recorded in imidacloprid 600 FS (0.28 bugs/meter row length) while thiamethoxam 35 FS recorded 0.31 painted bug/meter row length. Among all tested insecticides the maximum per cent reduction in painted bug population over control was recorded in treatment with imidacloprid 600 FS (84.44%), followed by thimethoxam 35 FS (82.80%), imidacloprid 17.8 SL (80.58%) and thimethoxam 25 G (78.57%) while lowest in the treatment with nimbecidine 1500 ppm (50.07%), (Table 1).

Efficacy of insecticides against *B. hilaris* at maturity stage

The data revealed that the application of insecticides resulted in the reduction of painted bug population with declined in their efficacy over time (Table 2). At one day after spray all the insecticides tested showed moderate effect on the painted bug with lowest population of (0.43 bugs /meter row length) recorded in the case of plants sprayed with imidacloprid 17.8 SL followed by thiamethoxam 25 G with 0.49 bugs/meter row length. The remaining insecticides resulted in slight reduction in the painted bug with a population of 0.73 to 0.95 painted bugs/ meter row length against 1.38 bugs per meter row length recorded in the case of control. At three days after spray the plants sprayed with imidacloprid 17.8 SL and thiamethoxam 35 FS recorded the lowest adult population of 0.29 and 0.32 painted bug/meter row length against 1.43 per meter row length in control, respectively. Treatment with dimethoate 30 EC was the next effective which was on a par with profenophos 50 EC, quinalphos 25 EC, malathion 50 EC and chloropyriphos 20 EC. Foliar spray with nimbecidine 1500 ppm was poor in checking painted bug population and recorded the highest population of 0.83 insects per meter row length. At seven days after spray again maximum per cent reduction in painted bug population over control was recorded in treatment with imidacloprid 17.8 SL (74.78%) followed by thimethoxam 25 G (77.13%) and dimethoate 30 EC (59.94%) while lowest in the treatment with nimbecidine 1500 ppm (45.10%), (Table 2).

During 2014-15, again maximum per cent reduction in painted bug population over control was recorded in treatment with imidacloprid 17.8 SL (77.10%), followed by thimethoxam 25 G (75.25%) and dimethoate 30 EC (64.29%) while lowest in the treatment with nimbecidine 1500 ppm (46.08%).

From the pooled data of two years it is evident that imidacloprid 17.8 SL and thiamethoxam 25 G were the most effective insecticides against painted bug. At ten days after spray, plants sprayed with insecticides significantly recorded lower number of test insect as compared to control. The Spraying with imidacloprid 17.8 was the most effective treatment

Table 2. Efficacy of insecticides against *B. hilaris* at maturity stage on rapeseed-mustard (Cv. RH 30

	Treatment	2013-14						2014-15						Pooled					
		Mean number of painted bug population(nymph and adult)/ meter row length					% reduction	Mean number of painted bug population(nymph and adult)/ plant					Per cent reduction	Mean number of painted bug population(nymph and adult)/ plant					Per cent reduction
	Seed treatment	15th DAS	16th DAS	18th DAS	22nd DAS	25th DAS	-	15th DAS	16th DAS	18th DAS	22nd DAS	25th DAS	-	15th DAS	16th DAS	18th DAS	22nd DAS	25th DAS	-
T1	Imidacloprid	1.35	1.32	1.46	2.07	2.70	-	1.33	1.53	1.93	2.53	3.10		1.34	1.43	1.69	2.30	2.90	
	600 FS	(1.53)	(1.52)	(1.57)	(1.75)	(1.92)		(1.53)	(1.59)	(1.71)	(1.88)	(2.02)	-	(1.53)	(1.56)	(1.64)	(1.82)	(1.98)	-
T2	Thiamethoxam	1.31	1.33	1.40	2.00	2.73	-	1.31	1.48	2.00	2.80	3.25		1.31	1.41	1.70	2.40	2.99	
	35 FS	(1.52)	(1.53)	(1.55)	(1.73)	(1.93)		(1.52)	(1.58)	(1.73)	(1.95)	(2.06)	-	(1.52)	(1.55)	(1.64)	(1.84)	(2.00)	-
	Foliar spray	Before Spray	1st DAT	3rd DAT	7th DAT	10th DAT		Before Spray	1st DAT	3rd DAT	7th DAT	10th DAT		Before Spray	1st DAT	3rd DAT	7th DAT	10th DAT	
T3	Imidacloprid	1.33	0.43	0.29	0.43	0.77		1.48	0.50	0.26	0.53	0.88		1.41	0.47	0.28	0.48	0.83	
	17.8 SL	(1.53)	(1.20)	(1.13)	(1.20)	(1.33)	74.78	(1.58)	(1.22)	(1.12)	(1.24)	(1.37)	77.10	(1.55)	(1.21)	(1.13)	(1.22)	(1.35)	76.07
T4	Thiamethoxam	1.33	0.49	0.32	0.48	0.83		1.50	0.55	0.29	0.58	0.93		1.42	0.52	0.31	0.53	0.88	
	25 G	(1.53)	(1.22)	(1.15)	(1.22)	(1.35)	71.98	(1.58)	(1.24)	(1.13)	(1.26)	(1.39)	75.25	(1.55)	(1.23)	(1.14)	(1.24)	(1.37)	73.79
T5	Dimethoate 30	1.37	0.73	0.57	0.78	0.97		1.58	0.77	0.62	0.87	1.15		1.48	0.75	0.59	0.83	1.06	
	EC	(1.54)	(1.32)	(1.25)	(1.34)	(1.40)	59.94	(1.61)	(1.33)	(1.27)	(1.37)	(1.47)	64.29	(1.57)	(1.32)	(1.26)	(1.35)	(1.43)	62.35
T6	Profenophos 50	1.33	0.77	0.62	0.93	1.17		1.44	0.80	0.70	0.97	1.30		1.39	0.78	0.66	0.95	1.23	
	EC	(1.53)	(1.33)	(1.27)	(1.39)	(1.47)	54.25	(1.56)	(1.34)	(1.30)	(1.40)	(1.51)	60.43	(1.54)	(1.34)	(1.29)	(1.40)	(1.49)	57.68
T7	Chlorpyriphos	1.30	0.81	0.69	0.97	1.23		1.31	0.84	0.73	1.00	1.50		1.31	0.83	0.71	0.77	1.37	
	20 EC	(1.52)	(1.35)	(1.30)	(1.40)	(1.49)	51.40	(1.52)	(1.36)	(1.31)	(1.41)	(1.58)	57.28	(1.52)	(1.35)	(1.31)	(1.32)	(1.54)	54.67
T8	Fenvalerate 20	1.30	0.88	0.73	0.98	1.33		1.43	0.86	0.77	1.10	1.70		1.37	0.87	0.75	1.04	1.52	
	EC	(1.52)	(1.37)	(1.32)	(1.41)	(1.53)	48.34	(1.56)	(1.36)	(1.33)	(1.45)	(1.64)	53.54	(1.54)	(1.37)	(1.32)	(1.43)	(1.59)	51.23
T9	Quinalphos 20	1.33	0.74	0.63	0.90	1.30		1.31	0.78	0.71	1.20	1.80		1.32	0.76	0.67	1.05	1.55	
	EC	(1.53)	(1.32)	(1.28)	(1.38)	(1.52)	53.06	(1.52)	(1.33)	(1.31)	(1.48)	(1.67)	52.84	(1.52)	(1.33)	(1.29)	(1.43)	(1.64)	52.94
T10	Nimbecidine	1.30	0.95	0.83	1.00	1.40		1.29	0.92	0.82	1.40	2.00		1.30	0.93	0.82	1.20	1.70	
	1500 ppm	(1.52)	(1.40)	(1.35)	(1.41)	(1.55)	45.10	(1.51)	(1.38)	(1.35)	(1.55)	(1.73)	46.08	(1.52)	(1.39)	(1.35)	(1.48)	(1.51)	45.64
T11	Buprofezin 25	1.33	0.90	0.69	0.82	1.00		1.35	0.93	0.69	1.00	1.53		1.34	0.92	0.69	0.77	1.27	
	SC	(1.53)	(1.38)	(1.30)	(1.35)	(1.41)	55.30	(1.53)	(1.39)	(1.30)	(1.41)	(1.59)	56.34	(1.53)	(1.39)	(1.30)	(1.32)	(1.52)	55.88
T12	Malathion 50	1.23	0.73	0.67	0.87	1.07		1.37	0.74	0.66	1.02	1.56		1.30	0.74	0.66	0.72	1.32	
	EC	(1.49)	(1.31)	(1.29)	(1.37)	(1.44)	56.22	(1.54)	(1.32)	(1.29)	(1.42)	(1.60)	58.12	(1.52)	(1.32)	(1.29)	(1.30)	(1.95)	57.28
T13	Control	1.32	1.38	1.43	2.20	2.60	-	1.42	1.80	2.10	2.60	3.03	-	1.37	1.59	1.77	2.40	2.82	-
		(1.52)	(1.54)	(1.56)	(1.79)	(1.90)		(1.56)	(1.67)	(1.76)	(1.90)	(2.01)		(1.54)	(1.61)	(1.66)	(1.84)	(1.97)	
	SE (m)±	(0.03)	(0.04)	(0.04)	(0.04)	(0.03)	-	(0.04)	(0.04)	(0.02)	(0.03)	(0.02)	-	(0.03)	(0.02)	(0.02)	(0.07)	(0.02)	-
	CD at 5%	(N.S.)	(0.10)	(0.10)	(0.12)	(0.09)	-	(N.S.)	(0.10)	(0.07)	(0.08)	(0.06)	-	(N.S.)	(0.07)	(0.06)	(0.21)	(0.05)	-

Figures in parentheses are square root transformed values; DAT- Days after treatment, DAS- Days after sowing with minimum population (0.83 bugs/meter row length) which was on a par with thiamethoxam 25 G (0.88 bugs/meter row length). Remaining insecticides were failed to manage pest painted bug below ETL.

The results of the present investigation are in agreement with observations recorded by Singh *et al*. (2011) as they reported seed treatment with imidacloprid 70 WS @ 5g and 7g/kg seed and thiamethoxam 70 WS @ 5 and 7g/kg seed provided significant reduction in painted bug population and higher yield. Ahuja *et al*. (2008) also reported the supremacy of seed treatment with imidacloprid @ 5 g/kg seed in controlling the *B. hilaris* followed by irrigation. The population of *B. hilaris* was found to be increasing after 25th day of sowing in seed due to decline in the efficacy of seed treatment against *B. hilaris* as earlier observed by Singh *et al*. (2011).

The study conducted by Singh *et al*. (2011) also revealed that among the insecticidal treatments, comparatively higher painted bug control and yield was obtained in plots treated with imidacloprid 17.8 SL@ 40 g a.i./ha, spinosad 45 SC @ 75 g a.i./ha, indoxacarb 14.5 SC @ 75 g a.i./ha and acetamiprid 20 SP @ 40 g a.i./ha. Ahuja and Joshi (1995) showed that among seven tested insecticide against *B. hilaris* the sprays of malathion, 0.05 per cent, dimethoate, 0.03 per cent and monocrotophos, 0.036 per cent were found effective for control of this pest.

During the study on the management of painted bug, *B. hilaris* Nagar *et al*. (2011) observed, malathion 50 EC @ 500 ml/500 litre of water most effective among the tested eight insecticides. Other studies with neonicotinoids showed that *Halyomorpha halys* was not as susceptible to acetamiprid compared with dinotefuran (Nielson *et al*. 2008, Lesky *et al*., 2012).

Dhingra and Seema (1998) found that toxicity of lamdacyhalothrin, chlorpyriphos, cypermethrin, lindane, fenvalerate and fluvalenate were higher than endosulfan while toxicity of demeton methyl, pyrethrin and malathion were less than endosulfan. Ghoshal *et al*. (2006) observed that use of phosphomidon, chlorpyriphos, dimethoate, methyl parathion and cypermethrin was effective. Studies conducted by Chauhan and Yadav (2007), on chemical control revealed that, Fenvalerate 0.4 D @ 8 kg per acre effectively checked painted bug, *B. hilaris* infesting turnip. In the greenhouse trials, the pyrethroid bifenthrin had superior knockdown and residual performance as 100% mortality was demonstrated within 24 h when *B. hilaris* adults were exposed to plants 1 h post-treatment (Palumbo *et al*., 2015).

Insecticides that exert an inhibitory effect on developing insects, the thiadizinon-type insecticide buprofezin 50 EC @ 1000 ml a.i./ha (mean per cent reduction over control 60.72%) was relatively effective against *B. hilaris*. The benzoylurea-type insecticide novaluron was relatively effective against *B. hilaris* immatures, whereas spirotetramat had little mortality impact on nymphs in the leaf-spray bioassay, or against adults on treated plants in the greenhouse (Palumbo *et al*., 2015). Kamminga *et al*. (2012) showed that novaluron was effective against brown marmorated stink bug nymphs in bean dip bioassays.

Cost benefit ratio

Among the different insecticides evaluated against the painted bug, *B. hilaris* on rapeseed-mustard, foliar spray imidacloprid 17.8 SL found to be highly cost effective with highest cost benefit ratio (1:9.84) followed by seed treatment with imidacloprid 600 FS (1:8.36). Thiamethoxam 25 G (1:6.49), dimethoate 30 EC (1:5.97), seed treatment with thiamethoxam 35 FS (1:5.54), fenvalerate 20 EC (1:5.51), chlorpyriphos 20 EC (1:5.31), malathion 50 EC (1:5.26), quinalphos 20 EC (1:4.66), buprofezin 25 SC (1:3.93) and profenophos 50 EC (1:3.43) were next best treatments with higher monetary returns per rupee invested on plant protection measures. Whereas, treatment with nimbecidine 1500 ppm (1:1.70) was the least economically feasible with lower economic returns per unit of input cost. In spite of higher seed yields in treatment with thiamethoxam 35 FS, buprofezin 25 SC and profenophos 50 EC the lower cost benefit ratio was due to higher cost of involved and the reverse is true in case of treatments with imidacloprid 600 FS, dimethoate 30 EC and fenvalerate 20 EC. Whereas, high cost inputs of treatment nimbecidine 1500 ppm

Table 3. Pooled cost benefit ratio in management of painted bug, *B. hilaris*

Treatments	Quantity of insecticide (two application)	Cost of treatment (Rs)	Labour charges (Rs)	Total expenditure (Labour+ Insecticide)	Yield (kg/ha)	Increased yield over control (kg/ha)	Value of increased yield (Rs)	Net profit over control (Rs)	Cost benefit ratio (ICBR)
T1- Imidacloprid 600 FS	25 ml	250	150	400	1965.0	111.5	3345	2945	1:8.36
T2- Thiamethoxam 35 FS	25 ml	475	150	625	1969.0	115.5	3465	2840	1:5.54
T3- Imidacloprid 17.8 SL	200 ml	410	500	910	2152.0	298.5	8955	8045	1:9.84
T4- Thiamethoxam 25 G	200 ml	600	500	1100	2091.5	238.0	7140	6040	1:6.49
T5- Dimethoate 30 EC	1250 ml	420	500	920	2036.5	183.0	5490	4570	1:5.97
T6- Profenophos 50 EC	2000 ml	1000	500	1500	2025.0	171.5	5145	3645	1:3.43
T7- Chlorpyriphos 20 EC	2000 ml	440	500	940	2020.0	166.5	4995	4055	1:5.31
T8- Fenvalerate 20 EC	750 ml	330	500	830	2006.0	152.5	4575	3745	1:5.51
T9- Quinalphos 20 EC	2000 ml	450	500	950	2001.0	147.5	4425	3475	1:4.66
T10- Nimbecidine 1500 ppm	4000 ml	1480	500	1980	1966.0	112.5	3375	1395	1:1.70
T11-Buprofezin 25 SC	2000ml	1000	500	1500	2050.0	196.5	5895	4395	1:3.93
T12- Malathion 50 EC	1000 ml	450	500	950	2020.0	166.5	4995	4045	1:5.26
T13- Control	-	-	-	-	1853.5	-	-	-	-

Labour charge- Rs. 250/day; Market price for Rapeseed-mustard- 3000 (Rs/qt); Cost of insecticides:
Imidacloprid 600 FS- Rs 50/10 ml ; Thiamethoxam 35 FS- Rs 95/10 ml ; Imidacloprid 17.8 SL- Rs 2100/L; Thiamethoxam 25 G- Rs 3000/kg; Dimethoate 30 EC- Rs 350/L ; Profenophos 50 EC- Rs 500/L ; Chlorpyriphos 20 EC- Rs 220/L ; Fenvalerate 20 EC- Rs 440/L ; Quinalphos 20 EC- Rs 225/L ; Nimbecidine 0.03%- Rs 370/L ; Buprofezin 25 SC- Rs 500/L; Malathion 50 EC – Rs 450/L

failed to achieve desired economic benefits owing to lower seed yield due to high pest pressure at the susceptible stage of the crop. The current findings are in lines with studies of Singh *et al*. (2011) which revealed that the favourable incremental cost-benefit ratio was obtained under imidacloprid 70 WS @ 5g/kg seed (1:33) followed by imidacloprid 70 WS @ 7g/kg seed (1:31), thiamethoxam 70WS @ 5g/kg seed (1:8), thiamethoxam 70WS @ 7g/kg seed (1:3), irrigation at 25-30 days after sowing (1:2) and endosulfan 4% dust @ 10 kg/ha (1:23).

Ahuja *et al*. (2008) found that the sowing of mustard seeds treated with imidacloprid at 5-7 g/kg in second fortnight of October in dry soil followed by irrigation gives higher productivity (2769-2859 kg/ha), higher economic returns (Rs. 41,102-42, 666/ha) and less damage (4.9-5.8%) due to *B. hilaris* which confirms the present finding. During the study on the management of painted bug, *B. hilaris* Nagar *et al*. (2011) observed the highest incremental cost benefit ratio of 1:11.7 was obtained in malathion 50 EC @ 500 ml/500 litre of water followed by endosulfan 4% dust @ 10 kg/ha (1:11.1) and endosulfan 35 EC @ 500 ml/500 litre of water (1:11). Singh *et al*. (2011) showed most favourable incremental cost benefit ratio was obtained by the treatments imidacloprid 17.8 SL@ 40 g a.i./ha (1:32) followed by acetamiprid 20 SP @ 40g a.i./ha (1:28), dimethoate 30 EC @ 300 g a.i./ha (1:27), endosulfan 35 EC @ 350 g a.i./ha (1:24), oxy-demeton methyl 25 EC @ 250 g a.i./ha (1:19), indoxacarb 14.5 SC @ 75 g a.i./ha (1:17.0), spinosad 45 SC @ 75 g a.i./ ha (1:17) and fipronil 5 SC @ 75 g a.i./ha (1:9). It can be concluded that seed treatment with neonictionoids was most effective treatment against *B. hilaris* at seedling stage. Further, at the crop maturity stage foliar spray with imidacloprid can protect the crop from infestation of painted bug.

Based on the economic returns imidacloprid 17.8 SL, imidacloprid 600 FS and thimethoxam 25 G were adjudged as best treatments for the effective management of painted bug, *B. hilaris* in rapeseed-mustard.

Finally, it can be conclude that in the management of painted bug the efficacy of insecticide was observed to be more on initial spray at seedling stage as compare to spray done at the maturity stage. The seed treatment with neonicotionoids was most effective treatment against *B. hilaris* at seedling stage. Further, at the crop maturity stage foliar spray with imidacloprid can protect the crop from infestation of painted bug.

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