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D Sudha Rani
Scientist (Entomology), Agricultural Research Station, Garikapadu, Krishna, Andhra Pradesh, India

Ch. Naga Satya Sri
Teaching Associates, Agricultural Polytechnic, Garikapadu, Krishna, Andhra Pradesh, India

K Anand Kumar
Teaching Associates, Agricultural Polytechnic, Garikapadu, Krishna, Andhra Pradesh, India

MN Venkatesh
Teaching Associates, Agricultural Polytechnic, Garikapadu, Krishna, Andhra Pradesh, India

Correspondence
D Sudha Rani
Scientist (Entomology), Agricultural Research Station, Garikapadu, Krishna, Andhra Pradesh, India

Economic evaluation and efficacy of various insecticides against maize stem borers

D Sudha Rani, Ch. Naga Satya Sri, K Anand Kumar and MN Venkatesh

Abstract
In maize cultivation, the major biotic stress affecting yield was infestation by stem borers, which results in annual yield loss ranging from 25-78 per cent. The various insecticides including botanicals, biorationals, whorl application and foliar spray of conventional insecticides are evaluated for their bio efficacy against reduction of leaf injury and dead hearts damage by maize stem borers for two seasons during 2017-18. Among the various insecticides evaluated, the least per cent leaf injury and per cent dead heart was recorded with whorl application of carbofuran 3G @ 10 Kg ha^{-1} at 14 days after germination and recorded 68.36, 73.30 and 65.47, 72.48 per cent reduction of leaf injury over control at 7 and 14 DAT during *Kharif* and *Rabi* seasons respectively. With respect to reduction of per cent dead hearts over control also carbofuran 3G only recorded significantly highest control over other treatments with an average of 64-78 per cent reduction. The insecticides chlorantraniliprole 0.4% GR @ 10 Kg ha^{-1} and chlorantraniliprole 18.5%SC @ 150 ml ha^{-1} also found on par with carbofuran 3G in reduction of leaf injury and dead hearts damage by maize stem borers. Further, the botanical *Azadirachtin* (10000 ppm) @ 150ml ha^{-1} also exerted an average of 50 per cent reduction of dead hearts over control. The order of efficacy of treatments in reduction of stem borer damage infesting maize represents T_7: Carbofuran 3G > T_6: Chlorantraniliprole 0.4% GR > T_5: Chlorantraniliprole 18.5%SC > T_4: Novaluron 10% EC > T_1: *Azadirachtin* (10000ppm) > T_2: *B.bassiana* > T_3*: B. thuringiensis.* The highest kernel yield was also recorded in Carbofuran 3G (5895 & 5750) with 44.10 and 45.57 per cent yield advantage over control during *Kharif and Rabi*, 2017-18 respectively. The highest cost: benefit ratio was evinced in insecticidal treatment with carbofuran 3G (1:1.35 & 1:1.21) followed by Chlorantraniliprole 0.4% GR (1:1.14 & 1:1.11). Hence, insecticidal schedule embracing the application of Carbofuran 3G -*Azadirachtin* (10000ppm)- Chlorantraniliprole 0.4% GR/ Chlorantraniliprole 18.5%SC will combat with the pest infestation and may offer superior control.

Keywords: maize, stem borers, leaf injury, dead hearts, C: B ratio

Introduction
Maize (*Zea mays* L.), the queen of cereals is the most versatile cash crop with wider adaptability under varied agro climatic regimes besides, highest yield potential. In India, the average area under maize cultivation is 9.43 million hectare with an average production and productivity of 22.23 million tonnes and 2.5 tonnes per hectare respectively (Anno, 2014) [2]. The major biotic constraint to maize production is attack by stem borers. Among the pest complex of maize, the stem borers, *Chilo partellus* (Swinhoe), *Sesamia inferens* (Walker) and *Atherigona soccata* (Rondani) are of major importance during different seasons in India (Kumar *et al*., 2005) [6]. Yield losses in different agro climatic regions of India due to *C. partellus* and *S. inferens* ranged from 26.7 to 80.4 and 25.7 to 78.9 per cent, respectively (Chatterji *et al*., 1969) [3]. The stem borers initially damage by feeding on the leaf tissues, followed by tunneling and feeding within the stem and sometimes the maize cobs. For effective management of stem borers infesting maize, effective chemicals and their timing of application (early whorl stage) is significant as this pest is an internal feeder and control at later stage offers narrow scope for chemical control (Ravinder and Jawala, 2015) [11]. Focus on effective and environmentally safe insecticides with novel mode of action is to be prioritized as they play a vital role in insecticide resistance management strategies. Botanicals like neem oil, neem leaf extract, NSKE and *Jatropha* leaf extract has exhibited higher efficacy in deterring the oviposition of *C. partellus* adults (Saranya and Samiayyan, 2017) [15]. Similarly, Trangenic *Bt* hybrid maize (Ramkumar, *et al*., 2005; Mohammed *et al*., 2015) [10, 8], *Bt* products (James, 2003 and Siddalingaapa, 2010) [5, 17] and fungus based biopesticide *Beauveria bassiana* Maniania, 1993; [7] Devi *et al*., 2001 [4] and Sabbour *et al*., 2011 [12] also expressed moderate levels of efficacy in suppressing the stem borer larvae infesting maize. Among various management strategies, chemical control has its own effectiveness due to its rapid

knock down effect (Tende *et al*. 2010) [19]. But, over reliance on synthetic pesticides leads to ecological adversities besides human hazards. Thus, there is need of using more efficient insecticides against the pest and safe alternatives to insecticidal control for safeguarding the natural enemies. Whorl application with granules, dust formulations with biopesticides and foliar sprays of novel insecticides proven to be effective in management of maize stem borers. Hence, present investigation was undertaken to ascertain and reassess the field efficacy of botanicals, biorationals and insecticides against stem borers infesting maize both in terms of reduction of per cent leaf injury and per cent dead hearts so as to formulate the schedules of insecticide application as a best chemical component in IPM besides insecticide resistance management strategy.

Material and Methods

Field experiments were conducted at Agricultural Research Station, Garikapadu for two seasons during *Kharif*, 2017 and *Rabi*, 2017-18 to determine the efficacy of certain botanicals, bio rationals and insecticides in terms of suppressing the per cent leaf injury and dead hearts damage by maize stem borers. The experiment was laid out in randomized block design (RBD) with eight treatments including control that were replicated thrice. The various treatments encompasses T_1: *Azadirachtin* (10000 ppm), T_2: *Beauveria bassiana*, T_3: *Bacillus thuringiensis*, T_4: Novaluron 10% EC, T_5: Chlorantraniliprole 18.5%SC, T_6: Chlorantraniliprole 0.4% GR, T_7: Carbofuran 3G and T_8: Untreated control and were imposed in all three replications. Total 24 plots of 5.5 m × 5.5 m size were sown with local maize hybrid Kaveri 50 and spacing of 70 cm X 20 cm between plants and rows was maintained respectively. All the recommended agronomic practices *i.e*., fertilizer application, thinning, inter cultivation and weeding operations were practiced for all the treatments inclusive of untreated control. The treatments were imposed 14 days after germination of the crop. The observations pertaining to stem borer incidence was recorded before, 7 and 14 days after imposition of the treatments. The data of stem borer damage was recorded both in terms of per cent leaf injury and per cent dead hearts for which randomly 20 plants were examined in each treatment. The kernel yield in each treatment, yield advantage over control and cost benefit ratio also calculated for economic evaluation of the treatments imposed besides their efficacy. The recorded data was transformed and subjected to statistical analysis under SPSS package.

Results and Discussions

Incidence of maize stem borer

During *Kharif*, 2017 the maize stem borer, *Chilo partellus* and pink stem borer, *Sesamia inferens* was observed to infest the maize crop. However, during *Rabi*, 2017-18 only incidence of *S.inferens* was observed. On average the no. of larvae/plant pertaining to *C. partellus* and *S. inferens* during *Kharif*, 2017 ranged from 1.2 to 5.5 and 2.8 to 6.3 respectively. The incidence of *Sesamia* larvae during *Rabi*, 2017-18 recorded to be 3.5-7.8/plant.

Influence of various treatments on maize stem borers in terms of per cent leaf injury

The incidence of maize stem borers in terms of per cent leaf injury was recorded in various treatments 14 days after germination during *Kharif* and *Rabi*, 2017-18. The per cent leaf injury ranged from 2.35 to 29.71 and 2.07 to 25.05 during *Kharif* and *Rab*i, 2017-18 respectively (Table 1). During *Kharif* and *Rabi*, 2017-18 the infestation of maize stem borers one day before imposition of treatments did not differ in treatment plots. At 7 and 14 days after treatment, all the treatments were found significantly superior over control. Among all, T_7: Carbofuran 3G recorded lowest per cent leaf injury *i.e*., 3.78 & 3.70 at 7 DAT and 2.35 and 2.07 at 10 DAT during *Kharif* and *Rabi*, 2017-18 respectively. Carbofuran 3G was found on par with Chlorantraniliprole 0.4% GR (3.78) and Chlorantraniliprole 18.5%SC (4.69) in harbouring less leaf injury by stem borers at 7 DAT and did not differ among themselves at 14 DAT during *Kharif*, 2017. Whereas in *Rabi*, 2017-18 at 7 DAT Carbofuran 3G (2.72) found on par with Chlorantraniliprole 0.4% GR (3.70) and at 10 DAT Carbofuran 3G (2.07) found on par with Chlorantraniliprole 0.4% GR (3.25) and Chlorantraniliprole 18.5%SC (5.06) in terms of per cent leaf injury. The highest per cent leaf injury was recorded in untreated plots with 29.00 & 29.71 during *Kharif*, 2017 and with 18.55 and 21.28 during *Rabi*, 2017-18 at 7 and 14 DAT respectively. Azadirachtin treated plots exhibited comparatively less reduction of leaf injury over control with only 15.29 and 12.09 at 7 and 10 DAT during *Kharif* and during *Rabi*, 2017-18 exhibited 49.93 and 62.86 per cent reduction of leaf injury over control at 7 and 10 DAT. The biorationals like *B. bassiana* and *B. thuringiensis* recorded less than 30 per cent reduction over control in terms of leaf injury in both the seasons.

The order of efficacy of treatments in reduction of per cent leaf injury by stem borers infesting maize during *Kharif*, 2017 represents T_7: Carbofuran 3G (68.36 & 73.30) > T_6: Chlorantraniliprole 0.4% GR (65.58 & 67.26) > T_5: Chlorantraniliprole 18.5%SC (61.63 & 63.58) > T_4: Novaluron 10% EC (48.44 & 52.23) > T_1: *Azadirachtin* (29.37 & 38.35) > T_2: *B.bassiana* (21.44 & 16.97) > T_3: *B. thuringiensis* (11.11 & 7.63) at 7 and 10 DAT. The efficacy order during *Rabi*, 2017-18 represents $T_7 > T_6 > T_5 > T_4 > T_1 > T_2 > T_3$ (Fig 1).

The results are in accordance with the findings of Ramkumar and Tanweer, 2017 who inferred that chlorantraniliprole 20 SC @ 0.3 ml l^{-1} and carbofuran 3G @ 7 kg ha^{-1} has recorded highest per cent reduction of plant infestation (85.40 & 82.36) and dead hearts (84.0 & 75.74) over control. Similarly Sidar *et al*., 2017 evaluated bio efficacy of various insecticides against maize stem borers and recorded minimum leaf injury rating with carbofuran (3.00) which was at par with flubendamide (3.23) followed by thiamethoxam (3.43), emamectin benzoate (3.57), rynaxypyr (4.03) and cartap hydrochloride (4.17) treated plots.

Influence of various treatments on maize stem borers in terms of per cent dead hearts

During *Kharif*, 2017 the observations of per cent dead hearts as influenced by maize stem borer damage revealed that, all the treatments were found significantly superior over control and highest (64.17 & 78.24) being recorded in T_7: Carbofuran 3G with 2.00 and 1.07 per cent dead hearts at 7 and 14 DAT respectively (Table 2). T_7 was found on par with T_6, T_5 and T_4 with respect to reduction in per cent dead hearts (2.73 & 1.73; 3.13 & 2.43, 3.76 & 3.24) and also exhibiting highest per cent reduction over control (58.03 & 72.23, 55.03 & 67.05, 50.69 & 61.93) at 7 and 14 DAT. The treatment T_1, T_2 and T_3 consisting of *Azadirachtin* (3.84 & 61.95), *B.bassiana* (33.80 & 41.86) and *Bt* (33.55 & 43.85) treated plots has exhibited comparatively less efficacy to conventional insecticides with respect to reduction in per cent dead hearts over control at 7

and 10 DAT respectively (Fig 2).

Similar trend was observed during *Rabi*, 2017-18 where in the whorl application of Carbofuran 3G has recorded significantly less per cent dead hearts (1.97 & 1.98) as against untreated control (18.49 & 18.59) with 68.29 and 68.21 per cent reduction over control at 7 and 14 DAT respectively. Granular application of Chlorantraniliprole 0.4% GR and foliar spray of Chlorantraniliprole 18.5%SC were found on par in suppression of per cent dead hearts harbouring only 2.83 & 2.57 per cent at 7 DAT and 3.53 and 2.42 per cent at 10 DAT respectively. The *Azadirachtin* treated plots also performed well with an average of above 50 per cent reduction of dead hearts over control. The order of efficacy with respect to per cent reduction of dead hearts over control followed the same trend as in *Kharif*, 2017 representing T_7 (68.29 & 68.21) > T_6 (61.95 & 63.80) ≥ T_5 (57.46 & 64.89) > T_1 (51.1 & 53.07) > T_4 (32.37 & 42.08) > T2 (15.91 & 15.99) ≥ T_3 (13.41 & 18.65) at 7 and 14 DAT respectively.

Sidar *et al*., 2017 reports were in concurrence with the present results who affirmed that the minimum per cent of dead heart damage was recorded in carbofuran (36.67%) which was at par with flubendamide (43.33%) followed by rynaxypyr (45.50%), thiamethoxam (46.67%), emamectin benzoate (50.0%), and cartap hydrochloride (56.67%) treated plots. Findings of Abdur, 2017 also support the present results in which the maximum mortality of *C. partellus* was observed in carbofuran (89.3±11.13 adults per five plants) and fipronil (80.9±7.98 adults per five plants) treated plots and minimum loss with respect to dead hearts was also recorded in carbofuran (0.1±0.12 number of dead hearts) and fipronil (0.20±0.00 number of dead hearts) treatments. Reports of Saleem *et al*., 2014 [14] confirmed that granular application of insecticides like carbofuran 3G exhibited better control of maize stem borer as compared to the emulsifiable concentrates (EC) as a foliar application. Said and Amjab, 2000 revealed that Furadan 3G proved significantly more effective in the reduction of percent dead hearts (5.52), pest infestation (12.23) and increase of average number of cobs/plant (0.92) and grain yield kg/ plot (3.23).

Influence of various treatments on maize kernel yield and C: B ratio

The crop yield in the form of kernel output in each treated plot was recorded and converted to hectare basis (Kg ha^{-1}) presented in Table. 3 revealed that the highest grain yield (Kg ha^{-1}) was recorded in whorl application of Carbofuran 3G (5895 & 5750) with 44.10 & 45.57 per cent yield advantage over control during *Kharif and Rabi*, 2017-18 respectively. Carbofuran 3G is found at par with Granular application of Chlorantraniliprole 0.4% GR (5415 & 5335) and foliar spray of Chlorantraniliprole 18.5%SC (5350 & 5250) with respect to kernel yield (Kg ha^{-1}) during *Kharif* and *Rabi*, 2017-18 respectively. The C: B ratio also holds superior in Carbofuran 3G (1:1.35 & 1:1.21) treated plots with a net return (Rs ha^{-1}) of Rs. 47480.00 & Rs. 44000.00 as against untreated control (0.98 & 0.85) where no plant protection measures were adapted with net returns of Rs. 29700 & Rs. 27400.00 during *Kharif* and *Rabi*, 2017-18 respectively.

The results are in close agrrement with the findings of Ramkumar and Tanweer, 2017 who reported that chlorantraniliprole 20 SC @ 0.3 ml l^{-1} and carbofuran 3G @ 7 Kg ha^{-1} has recorded kernel yield of 36.2 and 28.2 q ha^{-1} with a C: B ratio of 1: 9.44 and 1:8.51 respectively. Similar studies by Simoom *et al*., 2015 stated that highest yield (2.23 and 2.95 ton/ha) was obtained from carbofuran (1.5 kg a.i ha^{-1}) treated plots followed by *A. indica* (30 Kg ha^{-1}) (2.20 and 2.90 t ha^{-1}) treated plots in early plantings of 2009 and 2010, respectively.

Table 1: Effect of various insecticides on reduction of per cent leaf injury by stem borers infesting maize

Treatments	Dose/ha	*Kharif*, 2017					*Rabi*, 2017-18				
		Before*	7DAT*	%ROC	14 DAT*	%ROC	Before*	7DAT*	%ROC	14 DAT*	%ROC
T_1: Azadirachtin (10,000ppm)	150ml	14.55 (22.42)	15.29 (23.02)	29.37	12.09 (20.35)	38.38	18.55 (25.51)	5.65 (13.75)	49.93	3.74 (11.16)	62.86
T_2: *Beauveria bassiana*	1kg	17.80 (24.95)	18.67 (25.60)	21.44	21.21 (27.42)	16.97	16.75 (24.16)	13.70 (21.72)	20.94	12.87 (21.02)	30.00
T_3: *Bacillus thuringenis*	1 kg	14.50 (22.38)	23.45 (28.96)	11.11	25.77 (30.51)	7.63	16.58 (24.03)	19.56 (26.25)	4.46	21.30 (27.49)	8.48
T_4: Novaluron 10% EC	500ml	16.50 (23.97)	8.35 (16.80)	48.44	7.39 (15.78)	52.23	17.38 (24.64)	10.55 (18.96)	31.00	9.82 (18.26)	39.19
T_5: Chlorantraniliprole 18.5%SC	150ml	18.50 (25.47)	4.69 (12.50)	61.63	4.34 (12.03)	63.58	18.56 (25.52)	5.61 (13.71)	50.12	5.06 (13.00)	56.70
T_6: Chlorantraniliprole 0.4%GR	10 Kg	11.55 (19.87)	3.78 (11.22)	65.58	3.52 (10.81)	67.26	16.54 (24.00)	3.70 (11.09)	59.63	3.25 (10.39)	65.40
T_7: Carbofuran 3G	10 Kg	18.00 (25.10)	3.20 (10.31)	68.36	2.35 (8.82)	73.30	17.68 (24.86)	2.72 (9.49)	65.47	2.07 (8.27)	72.48
T_8:Untreated control		15.45 (23.15)	29.00 (32.58)	-	29.71 (33.03)		18.55 (25.51)	21.28 (27.47)		25.05 (30.03)	
SEm±		NS	1.68		0.51		NS	4.63		5.59	
CD (P=0.05)			5.07		1.55			14.02		16.92	
CV%			27.25		4.38			152.09		183.60	

*Figures in parenthesis are arc sine transformed values

Table 2: Effect of various insecticides on reduction of per cent dead hearts by stem borers infesting maize

Treatments	Dose/ ha	*Kharif*, 2017					*Rabi*, 2017-18				
		Before*	7DAT*	%ROC	14 DAT*	%ROC	Before*	7DAT*	%ROC	14 DAT*	%ROC
T_1: Azadirachtin (10,000ppm)	150ml	7.50 (15.89)	13.80 (21.80)	3.84	3.24 (10.36)	61.95	11.58 (19.89)	4.65 (12.45)	51.11	4.29 (11.95)	53.07
T_2: *Beauveria bassiana*	1kg	6.50 (14.77)	6.71 (15.01)	33.80	7.45 (15.84)	41.86	9.55 (18.00)	13.33 (21.42)	15.91	13.31 (21.40)	15.99
T_3: *Bacillus thuringenis*	1 kg	7.50 (15.89)	6.76 (15.07)	33.55	6.96 (15.30)	43.83	10.58 (18.98)	14.10 (22.06)	13.41	12.52 (20.72)	18.65
T_4: Novaluron 10% EC	500ml	6.50 (14.77)	3.76 (11.18)	50.69	3.24 (10.37)	61.93	9.00 (17.46)	8.77 (17.23)	32.37	6.48 (14.75)	42.08
T_5: Chlorantraniliprole 18.5%SC	150ml	8.00 (16.43)	3.13 (10.20)	55.03	2.43 (8.97)	67.05	12.58 (20.77)	3.53 (10.83)	57.46	2.42 (8.94)	64.89
T_6: Chlorantraniliprole 0.4%GR	10 Kg	7.50 (15.89)	2.73 (9.52)	58.03	1.73 (7.57)	72.23	15.80 (23.42)	2.83 (9.69)	61.95	2.57 (9.22)	63.80
T_7: Carbofuran 3G	10 Kg	6.50 (14.77)	2.00 (8.12)	64.17	1.07 (5.93)	78.24	11.55 (19.87)	1.97 (8.08)	68.29	1.98 (8.10)	68.21
T_8:Untreated control		7.00 (15.34)	14.86 (22.67)		20.95 (27.24)		11.58 (19.89)	18.49 (25.47)		18.49 (25.47)	
SEm±		NS	2.10		66.77		NS	4.42		4.62	
CD (P=0.05)			6.36		4.66			13.38		13.97	
CV%			8.71		14.10			145.14		179.09	

*Figures in parenthesis are arc sine transformed values

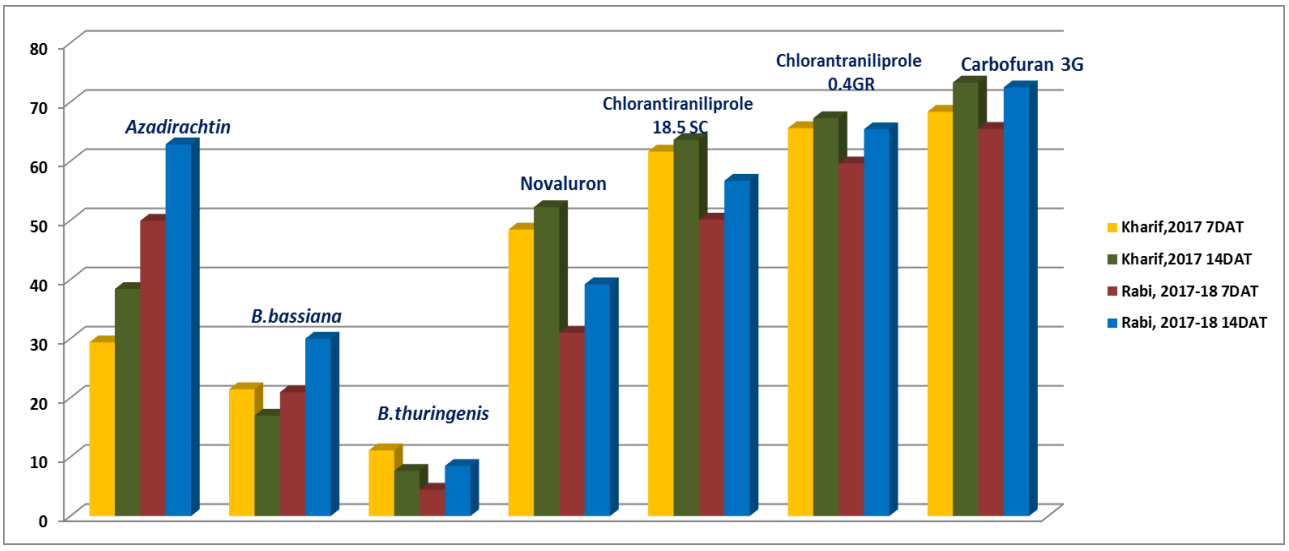

Fig 1: Influence of various insecticides on per cent reduction of leaf injury against maize stem borers

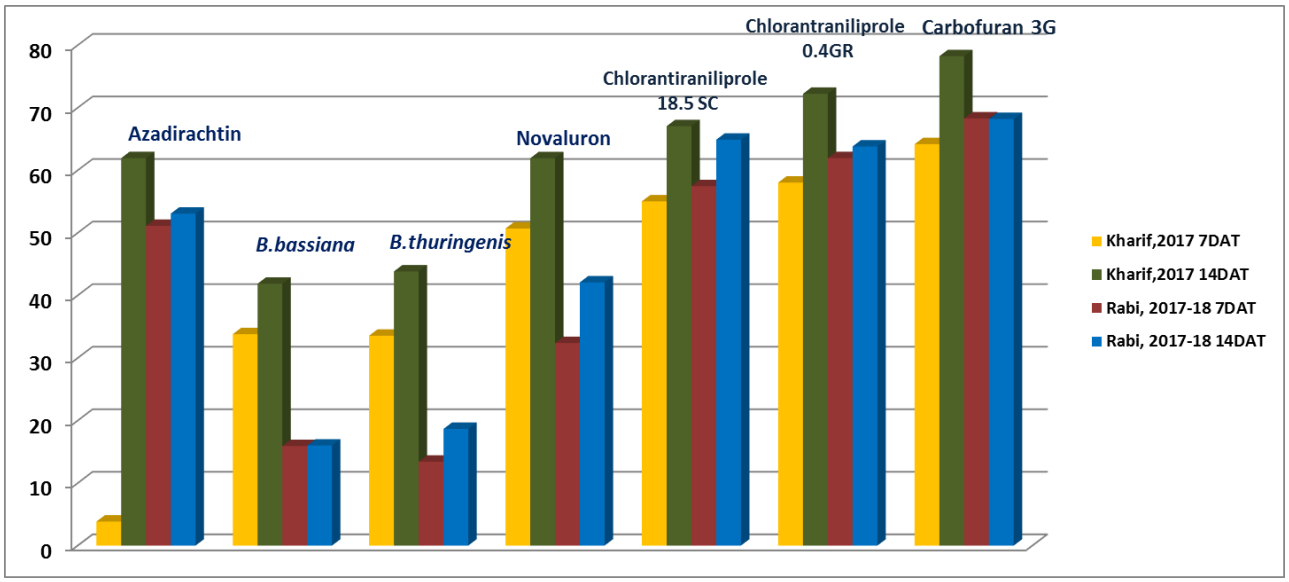

Fig 2: Influence of various insecticides on per cent reduction of dead hearts against maize stem borers

Table 3: Economic evaluation of various insecticides on maize kernel yield

Treatments	Kernel Yield (kg ha^{-1})		Yield advantage over control (%)		Cost of cultivation (Rs ha^{-1})		Gross returns (Rs ha^{-1})		Net returns (Rs ha^{-1})		C: B Ratio	
	Kharif, 2017	*Rabi* 2017-18	*Kharif*, 2017	*Rabi* 2017-18	*Kharif*, 2017	*Rabi* 2017-18	*Kharif*, 2017	*Rabi* 2017-18	*Kharif*, 2017	*Rabi* 2017-18	*Kharif*, 2017	*Rabi* 2017-18
T_1: Azadirachtin (10,000ppm)	5129	5050	25.40	27.85	34050	35055	71806	70700	37756	35645	1:1.10	1:1.01
T_2: *Beauveria bassiana*	4995	4820	22.12	22.02	35800	35850	69930	67480	34130	31630	1:0.95	1:0.88
T_3: *Bacillus thuringenis*	4856	4725	18.72	19.62	34500	35450	67984	66150	33484	30700	1:0.97	1:0.86
T_4: Novaluron 10% EC	5050	4950	23.47	25.32	33850	33900	70700	69300	36850	35400	1:1.08	1:1.05
T_5: Chlorantraniliprole 18.5%SC	5350	5250	30.80	32.91	35560	35650	74900	73500	39340	37850	1:1.10	1:1.06
T_6: Chlorantraniliprole 0.4%GR	5415	5335	32.40	35.06	35350	35450	75810	74690	40460	39240	1:1.14	1:1.11
T_7: Carbofuran 3G	5895	5750	44.10	45.57	35050	36500	82530	80500	47480	44000	1:1.35	1:1.21
T_8:Untreated control	4090	3950	-	-	29860	29900	57260	55300	27400	25400	1:0.91	1:0.85
CD(0.05)	828.5	758.8	-	-	NS	NS	386.94	355.68	2565.8	2156.5	-	-
CV%	11.9	18.1	-	-			9.8	11.6	9.1	12.8	-	-

Conclusion

From the present investigation it can be concluded that, whorl application of carbofuran 3G and chlorantraniliprole 0.4% GR and foliar spray of chlorantraniliprole 18.5%SC and *Azadirachtin* (10000 ppm) were found effective in control of maize stem borers both in terms of per cent leaf injury and dead hearts. Keeping in view, the repeated application of insecticides with similar mode of action leading to resistance and resurgence effects alternate application of different insecticides with novel mode of action are to be selected for managing the pest damage. In this context, sequential application of carbofuran 3G- *Azadirachtin* (10000 ppm) - chlorantraniliprole 0.4% GR/ chlorantraniliprole 18.5%SC may reduce the chance of resistance development and confirms superiority in managing the maize stem borers.

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