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Bio-efficacy of Insecticides against Stem Borer, *Chilo partellus* Swinhoe and Shoot Fly, *Atherigona approximata* Malloch in Dual Purpose Pearl millet-A Combination Techniques

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ABSTRACT: A field trial was conducted during 2014-15 and 2015-16 at Experimental Farm, Rajasthan Agricultural Research Institute (SKNAU), Durgapura, Rajasthan to manage stem borer and shoot fly in dual purpose pearl millet crop by using different newer insecticides in combinations as seed treatment and foliar spray. The results indicated that imidacloprid 600 FS @ 8.75 ml kg^{-1} as seed treatment with combination of imidacloprid 17.8 SL @ 300 ml ha^{-1} as foliar spray at 35 days after germination (DAG) (T_1) was observed most effective than other treatments against stem borer and shoot fly in dual purpose pearl millet at vegetative and earhead stage. This treatment were recorded highest grain yield (22.37 q ha^{-1}) and fodder yield (45.89 q ha^{-1}), respectively. Among the tested molecules, T_1 was gave highest net returns is Rs. 14495 ha^{-1} followed by T_7 is Rs. 12373 ha^{-1} (Imidacloprid 600 FS @ 8.75 ml kg^{-1} as seed treatment with foliar spray of fenvalerate 0.4% @ 20 kg ha^{-1} at 35 DAG). The maximum B:C ratio was recorded with T_7 (1:8.67) followed by T_1 (1:8.58) and lowest was recorded with thiamethoxam 35 FS (10 ml kg^{-1}) as seed treatment with foliar spray of spinosad 45 SC (200 ml ha^{-1}).

Keywords: Infestation, management, pearl millet, stem borer, shoot fly, yield.

INTRODUCTION

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is a one of the important millet crops and a staple diet for vast majority of poor people specially living in rural areas of the semi-arid regions of Asia and Africa. It is multiuse crop, which is mainly grown for food for humans, feed for poultry, green and dry fodder for livestock etc. The pearl millets grains are rich source minerals and vitamins to make a balance food for the economically poor communities which is living in rural areas. Also in recent years popularity of millets increase in urban areas due to presence of all essential nutrients as required quantity and utilize for making of various processed foods. Pearl millet is a nutritionally better than other cereals and it is a good source of protein (13-14%), fat (5-6%), carbohydrate (74%), minerals (1-2%) particularly iron (2.8%) and also good source of carotene, vitamin B_2 and vitamin B_4.

In India, Rajasthan is the leading states in pearl millet area and production followed by Uttar Pradesh, Maharashtra, Haryana and Gujarat and these states are contributing around 90% area and production of the country. Whereas, in Rajasthan pearl millet crop grown in 4.15 million ha areas and its production is 3.76 million ton with productivity of 906 kg ha^{-1} (Anonymous, 2019). The yield potential of pearl millet is low due to higher incidence of insect pests in high yielding varieties. In this crop more than dozen of insect-pests were reported to damage crop produced as well as financial loss (Balikai, 2010). Shoot fly, *Atherigona approximata* Malloch; stem borer, *Chilo partellus* Swinhoe; White grub, *Holotrichia consanguinea* Blanchard; Root bug, *Aethus latticolis* Orientalis; Red hairy caterpiler, *Amsacta moorei* Butler; Grey weevil, *Myllocerus* spp. F.; Leaf roller, *Marasmia* spp.; Thrips, *Anaphothips sudanensis* Trybom; Shoot bug, *Eysarcoris inconspicuous*; Blister beetle, *Cylindrothorax tenuicolis* (Pallas); Chaffer beetle, *Rhinyptia laeviceps* (Arrow) and Earhead bug, *Nysius ericae* (Sch.) (Anonymous, 1990).

Among them, stem borer and shoot fly are quite more serious pests attacking on pearl millet crop in the semi-arid regions of Rajasthan. Shoot fly is a key pest to restrictive pearl millet grain yield that causes more damage when crop sowing is delayed. The female of shoot fly are lays eggs alone on the underneath surface of leaves. After hatching of eggs, larvae attack on growing/tip points and cut the central leaf, resulting of expression dead heart in crop and

normally infestation occurs in seedling stage to one month old crop. Also tillering capacity of the crop may be affected under higher shoot fly incidence conditions (Anonymous, 1988).

Stem borer incidence occurring in all the pearl millet growing areas of the country and incidence was started in crop at seedling stage (15 days old crop) to progressively increased up to its peak at 77 days old crop (Raghvani *et al.*, 2008). Also stem borer larva affected plant show dead hearts similar to shoot fly. The individually estimated yield losses in pearl millet crop by shoot fly is 23.3-36.5% in grain and 37.55% in fodder and over all yield losses by stem borer is 20-60% (Prem Kishor, 1996).

The productivity of pearl millet crop mainly hamper by above these two insects. Now-a-days chemical molecules have played a key role in increasing pearl millet production through effective management of these insects. But judicious use of these chemical molecules is very important otherwise indiscriminate use has led to numerous environmental problems, development of resistance, chemical residues in food, fodder and their adverse effect on end users. The appropriate work on management of these insects through chemical insecticides is very meagre. In the present research paper, an attempt was made to sustainable management (through combination of newer molecules) of stem borer and shoot fly in dual purpose pearl millet crop.

MATERIALS AND METHODS

The study was carried out at experimental farm of Rajasthan Agricultural Research Institute, Durgapura, Rajasthan, during *Kharif* 2014-15 and 2015-16. Pearl millet variety, RHB-177 was sown in 10.5 m^2 plot size areas with 7 rows at spacing of 50 cm between rows and 15 cm distance between plants in 3.5 × 3.0 m plot size. The treatments combinations were studied with randomized block design and replicated thrice (Table 1).

Table 1: Details of insecticides tested against stem borer and shoot fly under semi-arid conditions.

Treatment	Treatment details
T_1	Seed treatment by imidacloprid 600 FS (8.75 ml kg^{-1} seed) + foliar spray of imidacloprid 17.8 SL (300 ml ha^{-1}) at 35 days after germination (DAG)
T_2	Seed treatment by imidacloprid 600 FS (8.75 ml kg^{-1}) seed + foliar spray of thiamethoxam 25 WG (200 g ha^{-1}) at 35 DAG
T_3	Seed treatment by imidacloprid 600 FS (8.75 ml kg^{-1}) seed + foliar spray of spinosad 45 SC (200 ml ha^{-1}) at 35 DAG
T_4	Seed treatment by thiamethoxam 35 FS (10 ml kg^{-1}) seed + foliar sprayof imidacloprid 17.8 SL (300 ml ha^{-1}) at 35 DAG
T_5	Seed treatment by thiamethoxam 35 FS (10 ml kg^{-1}) seed + foliar spray of thiamethoxam 25 WG (200 g ha^{-1}) at 35 DAG
T_6	Seed treatment by thiamethoxam 35 FS (10 ml kg^{-1}) seed + foliar spray of spinosad 45 SC (200 ml ha^{-1}) at 35 DAG
T_7	Seed treatment by imidacloprid 600 FS (8.75 ml kg^{-1}) seed + foliar application of fenvalerate 0.4% (20 kg ha^{-1}) at 35 DAG
T_8	Control (treatment not applied)

Other crop management practices were used during entire crop duration as per recommended to the study area. All the treatment combinations were applied in two ways one is seed treatment at the time sowing at least 2-hours before and another is foliar spray applied 35 days after germination (DAG) of crop. Observations of stem borer and shoot fly incidences were recorded at 7 days intervals from each plot treatment which were examined in per cent infestation at vegetative and earhead stages of the pearl millet crop. Also crop yields were recorded from each treatments and it's converted into monetary returns for obtained profitability by subtracting treatment wise total inputs cost from gross returns. The data on percent incidence, yields and economics were statistically analysed in RBD by using analysis of variance at 0.5% level of significance (Gomez and Gomez, 1984).

RESULT AND DISCUSSION

The two years results revealed that the incidence and per cent damage of stem borer and shoot fly on pearl millet crop is varied under different newer insecticides. Although, both pests were found as a major during entire crop growing period in pearl millet crop.

A. Stem borer (C. partellus)

Insecticide combinations significantly influenced stem borer plant infestation in pearl millet crop and were found significantly effective over control during both the years as well as in pooled results (Table 2).

Among the insecticides treatments, most effective and lowest infestation of stem borer was observed with T_7 (1.67%) followed by T_1 (1.90%) and T_3 (2.26%). These treatments were found statistically at par with each other and significantly superior to other treatments at vegetative stage of pearl millet. The succeeding effective insecticides treatments were observed infestation of 3.57% with T_6 and 4.05% with T_4 and least effective insecticide was found T_5 (5.95%). The maximum plant infestation was observed in T_8 (control) with 10.71%.

At earhead stage in pearl millet crop, significantly most effective insecticide against stem borer with least plant infestation were recorded under T_1 (2.98%) followed by T_7 (3.33%) and T_3 (3.57%) showed. These treatments were recorded on par with each other and significantly superior with rest of treatments. Subsequently, effective treatments were observed is 5.12% and 5.47% stem borer infestation under T_4 and T_6, respectively and these were analogous with each other. Although, among the insecticide maximum infestation was observed under T_5 (7.86%) followed by T_2 (7.38%). The least effective with highest plant infestation of stem borer were observed under T_1 (13.45%). Similar findings are reported by Tandi and Bajiya (2013); Anonymous (2015) on stem borer in pearl millet.

Table 2: Efficacy of different insecticides combinations against stem borer in pearl millet.

Treatment	Stem borer infestation (%)					
	2014		2015		Pooled	
	Vegetative stage	Earhead stage	Vegetative stage	Earhead stage	Vegetative stage	Earhead stage
T_1	1.43 (6.87)*	2.38 (8.87)	2.38 (8.87)	3.57 (10.89)	1.90 (7.87)	2.98 (9.88)
T_2	4.76 (12.60)	6.67 (14.96)	6.67 (14.96)	8.09 (16.53)	5.71 (13.78)	7.38 (15.74)
T_3	1.67 (7.42)	2.86 (9.73)	2.86 (9.73)	4.28 (11.94)	2.26 (8.57)	3.57 (10.84)
T_4	3.10 (10.14)	4.76 (12.60)	5.00 (12.92)	6.19 (14.41)	4.05 (11.53)	5.47 (13.50)
T_5	5.00 (12.92)	6.90 (15.23)	6.90 (15.23)	8.81 (17.26)	5.95 (14.07)	7.86 (16.25)
T_6	2.86 (9.73)	4.28 (11.94)	4.28 (11.94)	5.95 (14.12)	3.57 (10.84)	5.12 (13.03)
T_7	1.19 (6.26)	2.62 (9.32)	2.14 (8.41)	4.05 (11.60)	1.67 (7.34)	3.33 (10.46)
T_8	10.23 (18.66)	12.38 (20.60)	11.18 (19.54)	14.52 (22.40)	10.71 (19.10)	13.45 (21.50)
SEm±	0.61	0.68	0.59	0.67	0.42	0.48
CD at 5%	1.86	2.06	1.78	2.02	1.23	1.38

* Figures in the parentheses are angular transformed values and outside are original values

Bajiya and Shrikant (2010) observed that maximum protection against stem borer with application of imidacloprid 70 WS @ 7.5 g kg^{-1} seed as seed treatment in pearl millet crop. However, Parmar*et al.*,(2015) reported that application of profenophos 0.05% or fenobucarb 0.1% two sprays recorded least infestation of stem borer in pearl millet.

B. Shoot fly (A. approximata)

On the basis of individual year as well as pooled results revealed that application of all insecticides in combinations as seed treatment along with foliar spray were found most effective and observed that significantly lower shoot fly plant infestation as compared to control treatment (Table 3). At vegetative stage, significantly lowest shoot fly infestation were observed with T_1 treatment (4.28%) followed by T_7 (4.52%) and T_3 (4.76%), as compared to other treatments and which is statistically at par to each other in term of efficacy. However, T_4 (6.90%) and T_6 (7.26%) were found subsequent effective treatments as compared to T_2 (9.64%), T_5 (9.88%) and T_8 (15.11%) treatments, respectively. Among the treatments T_5 were found least effective for shoot fly infestation.

Table 3: Efficacy of different insecticides combinations against shoot fly in pearl millet.

Treatment	Shoot fly infestation (%)					
	2014		2015		Pooled	
	Vegetative stage	Earhead stage	Vegetative stage	Earhead stage	Vegetative stage	Earhead stage
T_1	3.81 (11.25)*	1.90 (7.93)	4.76 (12.60)	2.62 (9.32)	4.28 (11.93)	2.26 (8.62)
T_2	8.57 (17.02)	5.47 (13.53)	10.71 (19.10)	6.19 (14.40)	9.64 (18.06)	5.83 (13.97)
T_3	4.28 (11.94)	2.38 (8.87)	5.23 (13.22)	3.10 (10.14)	4.76 (12.58)	2.74 (9.50)
T_4	6.19 (14.41)	3.81 (11.25)	7.62 16.02)	4.76 (12.60)	6.90 (15.21)	4.28 (11.93)
T_5	8.81 (17.26)	5.95 (14.12)	10.95 (19.32)	6.43 (14.69)	9.88 (18.29)	6.19 (14.40)
T_6	6.43 (14.69)	3.57 (10.89)	8.09 (16.53)	4.52 (12.27)	7.26 (15.61)	4.05 (11.58)
T_7	4.05 (11.60)	2.14 (8.41)	5.00 (12.92)	2.86 (9.73)	4.52 (12.26)	2.50 (9.07)
T_8	14.28 (22.20)	10.95 (19.32)	15.95 (23.54)	13.57 (21.61)	15.11 (22.87)	12.26 (20.47)
SEm±	0.77	0.59	0.84	0.55	0.57	0.41
CD at 5%	2.32	1.80	2.56	1.68	1.65	1.18

* Figures in the parentheses are angular transformed values and out

Results of two year mean showed that the application of T_1 (2.26%) treatment were most effective and observed lowest shoot fly infestation followed by T_7 (2.50) and T_3 (2.74) treatments at earhead stage, and which is at par with each other. The subsequent T_6 (4.05%) and T_4 (4.28%) treatments were found effective and statistically on par over T_2 (5.83%), T_5 (6.19%) and T_8 (12.26%) in both the years as well as pooled, respectively. Among the insecticides treatments, T_5 observed least effective and which is at par with T_2 in shoot fly infestation. The treatment T_1 contains seed treatment with imidacloprid 600 FS and imidacloprid 17.8 SL both are systemic insecticide and give extreme results. These similar findings were also concluded (Anonymous, 2013 and 2014). Similarly, Tandi and Bajiya (2013) stated that the lowest shoot fly infestation at both stages in pearl millet crop were found with imidacloprid 600 FS @ 8.75 ml kg^{-1} seed as seed treatment with fenvalerate 0.4% @ 20 $kgha^{-1}$ as dusting at 35 DAG. Also similar findings were noted by Bajiya and Shrikant (2010) with imidacloprid as seed treatment and by Kishore and Rai (1999) with dusting of fenvalerate 0.4% dust @ 20 kg ha^{-1} was found effective against stem borer and shoot fly in pearl millet. Balkai and Bhagwat (2009) reported that with thiamethoxam 70 WS at 3 gkg^{-1} seed in rabi sorghum and Shahzad *et al.*, (2010) reported that with imidacloprid 70 WS @ 5 or 7 gkg^{-1} seed as seed

treatments in maize were found effective against shoot fly.

C. Grain and fodder yields

Pearl millet grain and fodder yields recorded significantly higher under different insecticides treatments as compared to control treatment during both years as well as pooled data (Table 4). Among the insecticides treatments, significantly higher grain and fodder yields were recorded with T_1 treatment (21.57 and 45.67 q ha^{-1}) as compared to other treatments and which were at par with T_7 (20.00 and 43.05 q ha^{-1}) and T_3 (19.98 and 42.98 q ha^{-1}), respectively. The subsequent grain and fodder yield produced by T_6 and T_4 which produced of 17.43 and 38.16 qha^{-1}, 17.11 and 37.91 qha^{-1} grain and fodder yields, respectively. Among the insecticides treatments, lowest grain and fodder yield were recorded under T_5 followed by T_2. However, least grain and fodder yield produced by T_1 (control) is 11.97 and 28.67 qha^{-1}. The highest grain and fodder yields might be due to the effective control of both stem borer and shoot fly and plants developing appropriate growth and yield parameters and ultimately leading to producing higher yields. Similarly, Tandi and Bajiya (2013) reported that grain and fodder yields was maximum by application of imidacloprid 600 FS @ 8.75 ml kg^{-1} seed as seed treatment with dusting of fenvalerate 0.4% @ 20 $kgha^{-1}$ at 35 days after germination of crop showed maximum effective treatment against shoot fly at vegetative and ear head stages of the crop pearl millet.

Table 4: Pearl millet grain and fodder yields in different tested insecticides.

Treatments	Yield (q ha^{-1})					
	2014		2015		Pooled	
	Grain	Fodder	Grain	Fodder	Grain	Fodder
T_1	21.57	45.67	23.17	46.10	22.37	45.89
T_2	15.03	32.93	15.96	34.09	15.50	33.51
T_3	19.98	42.98	21.67	44.63	20.83	43.81
T_4	17.11	37.91	18.46	39.31	17.79	38.61
T_5	14.39	33.11	15.72	34.41	15.06	33.76
T_6	17.43	38.16	18.79	39.72	18.11	38.94
T_7	20.00	43.05	21.69	44.65	20.85	43.857
T_8	11.97	28.13	13.16	29.21	12.57	28.67
SEm±	0.68	1.57	0.81	1.60	0.53	1.12
CD at 5%	2.07	4.78	2.46	4.86	1.53	3.25

D. Economics of different treatments

On the basis of two year pooled as well as individual years data showed that economics of the different treatments were significantly influenced by insecticides combinations and all the insecticides treatment observed higher net profit and B:C ratio over control treatment in Table 5. Pooled data showed that the significantly highest net profit of Rs. 14495 ha^{-1} was recorded with T_1 treatment followed by Rs. 12373 ha^{-1} with T_7 treatment over rest treatments and which were at par with each other. The T_3, T_4 and T_6 treatments were observed as subsequent economically profitable treatments which were gave of Rs. 3876, 6832 and 8639 ha^{-1}. Among the insecticides treatment combinations, lowest net profit were recorded under T_2 and T_5 treatments with getting of Rs. 2275 and 3876 ha^{1}, respectively and significantly lower to other insecticides treatments and higher to control. The highest B:C ratio was observed with T_7 (used as a standard check- seed treatment by imidacloprid 600 FS @ 8.75 ml kg seed with dusting of fenvalerate 0.4% @ 20 kg/ha at 35 DAG) (8.67) followed by 8.58 with T_1 (Seed treatment by imidacloprid 600 FS @ 8.75 ml kg^{-1} seed with foliar spray of imidacloprid 17.8 SL @ 300 ml ha^{-1} at 35 DAG) and 3.52 with T_4 (Seed treatment by thiamethoxam 35 FS @ 10 ml kg^{-1} seed with foliar spray of imidacloprid 17.8 SL @ 300 ml ha^{-1} at 35 DAG). The similar results observed by Raghvani *et al*., (2010) with application fenvalerate 10 EC 0.01% against stem borer and by Tandi and Bajiya (2013) reported with application of imidacloprid 600 FS @ 8.75 ml kg^{-1} seed as seed treatment with dusting of fenvalerate 0.4% @ 20 kg ha^{-1} at 35 DAG against shoot fly in pearl millet crop.

Table 5: Comparative economics of insecticides for management of stem borer and shoot fly pearl millet.

Treatment	Pooled yield (q ha^{-1})		Increase over control (q ha^{-1})		Increase income due to treatment (Rs. ha^{-1})	Expenditures (Rs. ha^{-1})	Net Profit (Rs. ha^{-1})	B:C ratio
	Grain	Fodder	Grain	Fodder				
T_1	22.37	45.89	9.80	17.22	16184	1689	14495	8.58
T_2	15.50	33.51	2.93	4.84	4777	1727	3050	1.77
T_3	20.83	43.81	8.26	15.14	13766	5127	8639	1.69
T_4	17.79	38.61	5.22	9.94	8774	1942	6832	3.52
T_5	15.06	33.76	2.49	5.09	4255	1980	2275	1.15
T_6	18.11	38.94	5.54	10.27	9256	5380	3876	0.72
T_7	20.85	43.85	8.28	15.18	13800	1427	12373	8.67
T_8	12.57	28.67	—	—	—	—	—	—

CONCLUSION

It is concluded that based on two year study, application of insecticides in combinations found most effective against stem borer and shoot fly in pearl millet. Seed treatment with imidacloprid 600 FS@ 8.75 ml kg^{-1} seed + foliar spray of imidacloprid 17.8 SL@ 300 ml ha^{-1} at 35 days after germination was observed lowest infestation of both the insects, highest grain yield and economic returns followed by seed treatment with imidacloprid 600 FS@ 8.75 ml kg^{-1} seed + foliar application of fenvalerate 0.4% @ 20 kg ha^{-1} at 35 days after germination in pearl millet crop.

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Conflict of Interest. Nil.

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