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Ecologically sustainable management of shoot fly and stem borer in pearl millet

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Abstract
A field experiment was conducted for the management of shoot fly and stem borer in pearl millet during *kharif* at Junagadh Agriculture University, Junagadh. The results showed that seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *Beauveria bassiana* WP @ 0.007% or seed treatment of clothianidin WDG @7.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% recorded lower infestation of shoot fly and stem borer in pearl millet crop. The highest grain yield (2452 kg/ha) was obtained from the seed treatment with clothianidin WDG @ 7.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% and lowest yield of 1663 kg/ha was obtained from the control plot. The highest benefit cost ratio was obtained from the seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% (1: 16.19) and seed treatment of clothianidin WDG @ 7.5 g /kg seed followed by spray of *B. bassiana* WP @ 0.007% (1: 15.35).

Keywords: Shoot fly, stem borer, *Beauveria bassiana*, clothianidin, pearl millet

Introduction
Pearl millet, [Pennisetum glaucum (L.) R. Br.] is the staple food of majority of the poor and small land holders, as well as feed and fodder for live stock in the rain fed region of the country. Pearl millet excels all other cereals due to these features - C_4 plant with high photosynthesis efficiency and high dry matter production capacity. It requires less input, matures in short duration and is usually grown under the most adverse agro-climatic condition where other crops like sorghum and maize fail to produce economic yield. In India, pearl millet was grown on 7.4 million ha with an average production of 9.13 million tones and productivity of 1237 kg/ha during 2017-18 (Anony., 2019a) [1]. The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana which account for more than 90% of pearl millet acreage in the country.

Pearl millet is rich source energy, carbohydrate, fat, ash, dietary fibers, iron and zinc. It is a rich source of vitamins like thiamine, riboflavin and niacin and minerals like potassium, phosphorus, magnesium, iron, zinc, copper and manganese. Due to low yield potential as well as fluctuating grain prices, plant protection measures were hardly taken. However, potentially of very high yielding hybrid varieties attract heavy incidence of pearl millet diseases and pests. Twenty six insects and two non-insect pests were found feeding on pearl millet (Balikai, 2010) [3]. Among them, shoot fly, *Atherigona approximata* and stem borer, *Chilo partellus* are comparatively more

serious pests attacking on pearl millet crop. Shoot fly is a major grain yield limiting factor that causes damage when the sowing is delayed and late sown crop is most affected. Other than shoot fly, stem borer occurring in all the bajra areas of the country, but it is found to be more dominant in Gujarat & Delhi regions. Incidence of stem borer was noticed 15 days of germination of the crop and gradually increased to its peak at 77 days after germination of the crop (Raghvani *et al.*, 2008) [9]. Losses in yield of *Bajra* crop due to shoot fly estimated to the tune of 23.3 to 36.5% in grain and 37.55% in fodder, while estimated losses in Bajra yield due to stem borer is 20 to 60% (Prem Kishor, 1996) [8]. Chemical control is most widely used and it became primary source in farmers field for managing insect pests in pearl millet it leads to resistance for insect pests and harmful to ecosystem. It has drawn the attention of entomologists to develop eco-friendly and sustainable management practices. Among eco-friendly approaches, seed treatment and use of bioagents are one of the most important components, which are being employed to control of pests in pearl millet ecosystem. Hence, the research work for the management of this pest was under taken.

Materials and methods

The experiment was conducted in Randomized Block Design with ten treatments including control with four replications at Junagadh Agricultural University, Junagadh during *Kharif* 2018. The pearl millet variety GHB-558 was sown at 50 × 15 cm spacing for this purpose. The gross plot size was 5.0 × 2.5 m and net plot size was 4.0 × 1.5 m. Seed treatment and furrow applications of insecticides were given at the time of sowing. While, foliar application was given at ear head stage of the crop. At vegetative stage, observation was recorded on 20 plants of net plot plant by counting the dead heart. Thus shoot fly dead heart percentage were worked out. For stem borer, plants sowing parallel holes due to stem borer larvae in the leaves were considered as damaged plants. At ear head stage, numbers of earheads sowing shoot fly and stem borer (empty/white ear head) damage were recorded separately and thus percentage was worked out from 20 earhead of each net plot. Grain and fodder yield was recorded from net plot area at harvest and data thus, obtained was analyzed statistically (Panse and Sukhatme, 1989) [4].

Treatment details

1. ST with clothianidin 50 WDG @ 7.5 g /kg seed + *B. bassiana* @ 0.007% at ear head stage
2. ST with clothianidin 50 WDG @ 7.5 g /kg seed + *Ha*NPV @ 450LE/ha at ear head satge
3. ST with clothianidin 50 WDG @ 7.5 g /kg seed + panchagavya @ 3% at ear head stage
4. ST with fipronil 40% + imidacloprid 40% WG @ 2.5 g/kg seed + *B. bassiana* @ 0.007% at earhead stage
5. ST with fipronil 40% + imidacloprid 40% WG @ 2.5 g/kg seed + *Ha*NPV @ 450LE/ha at earhead satge
6. ST with fipronil 40% + imidacloprid 40% WG @ 2.5 g/kg seed + panchagavya @ 3% at earhead stage
7. FA with carbofuran 3G @33 kg/ha + *B. bassiana* @ 0.007% at ear head stage
8. FA with carbofuran 3G @33 kg/ha + *Ha*NPV @ 450LE/ha at ear head stage
9. FA with carbofuran 3G @33 kg/ha + panchagavya @ 3% at ear head stage
10. Control

Results and Discussion

Shoot fly

All the insecticidal treatments were found to be significantly superior over the untreated check in reducing the plant infestation due to shoot fly during *kharif*-2018, however, considerable difference was noticed between the different treatments (Table1). The minimum plant infestation due to shoot fly (5.24%) was recorded in furrow application of carbofuran @33 kg/ha followed by spray of *B. bassiana* WP @ 0.007% (T_7) at vegetative stage. However, it was at par with the treatment T_4 comprising of seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% (6.6%) and treatment T_1 seed treatment with clothianidin WDG @7.5 g /kg seed followed by spray of *B. bassiana* WP @ 0.007% (6.88%). The medium plant infestations were recorded in the treatment of furrow application of carbofuran @ 33 kg/ha followed by spray of *Ha*NPV @ 450 LE/ha (T_8) and seed treatment of the fipronil + WG @ 2.5 g/kg seed followed by spray of *Ha*NPV @ 450 LE/ha (T_5) with 9.94 and 11.28% infestation, respectively and these treatments were found statistically at par with each other.

The maximum plant infestation (14.28%) was recorded in seed treatment of clothianidin WDG @7.5 g /kg seed followed by spray of panchagavya 3% (T_3) and it was at par with the seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of panchagavya 3% (T_6) and furrow application of carbofuran @ 33 kg/ha followed by spray of panchagavya 3% (T_9) resulted 12.41, 14.10 and 13.21% infestation, respectively and these were comparable with each other. The plant infestation in untreated control was 26.42%. Similar trend of shoot fly infestation was observed at earhead stage of the pearl millet crop.

Stem borer

The minimum plant infestation due to stem borer (8.55%) was recorded in the seed treatment with clothianidin WDG @ 7.5 g /kg seed followed by spray of *B. bassiana* WP @ 0.007% (T_1) at vegetative stage, which was at par with the treatment T7 comprising of furrow application of carbofuran @ 33 kg/ha followed by spray of *B. bassiana* WP @ 0.007% (9.16%) and treatment T_4 seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% (10.13%). The medium plant infestations were recorded in seed treatment with clothianidin WDG @ 7.5 g/kg seed followed by spray of *Ha*NPV @ 450 LE/ha (T_2) and furrow application of carbofuran @ 33 kg/ha followed by spray of *Ha*NPV @ 450 LE/ha (T_8) with 11.99 and 12.87% infestation, respectively and these treatments were found at par with each other.

The maximum plant infestation due to stem borer (19.12%) was recorded in the seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of panchagavya 3% (T_6) which was at par with the treatment T_9 of furrow application of carbofuran @33 kg/ha followed by spray of panchagavya 3% (18.59%), seed treatment of clothianidin WDG @7.5 g /kg seed followed by spray of panchagavya 3% (T_3) and seed treatment of the fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *Ha*NPV @ 450 LE/ha (T_5), which resulted 16.30 and 15.59% infestation, respectively and these treatments were observed at par with each other. The plant infestation in untreated control was 36.75%. Similar trend of stem borer infestation was observed at earhead stage of the pearl millet crop.

Our results are in accordance with the findings of Pavani *et al*. (2012) [7], who evaluated the Detected efficacy of different insecticides and bioagents against *S. inferens* in maize and reported that carbofuran was found effective in reducing dead heart formation recording only 33.75% at 14 days after germination. However, among the bio-pesticides, the lower dead hearts were recorded in *B. bassiana* 1×10^7 (36.25%). Seed treatment of clothianidin WDG was found effective for the control of shoot fly in wheat crop (Patil *et al*., 2007) [6]. Seed treatment of clothianidin WDG @ 7.5 g/kg seed followed by spray of fipronil @ 0.01% at 35 days after germination of crop, recorded lowest shoot fly incidence, highest grain & fodder yield (Anony., 2019b) [2]. Parmar *et al*. (2019) [5] also reported that the treatment of *B. bassiana* WP @ 5 g/l recorded the least incidence of shoot fly (7.2%) and stem borer (5.36%) at earhead stage of pearl millet crop.

Yield and Economics

Significantly the highest grain yield (2452 kg/ha) was recorded (Table 2) in the seed treatment with clothianidin WDG @ 7.5 g /kg seed followed by spray of *B. bassiana* WP @ 0.007% (T_1). However, it was found statistically at par

with the treatments T_7 comprises furrow application of carbofuran @ 33 kg/ha followed by spray of *B. bassiana* WP @ 0.007% (2371 kg/ha) and treatment T_4 seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% (2322 kg/ha). On the basis incremental cost benefit ratio, the seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% (T_4) gave the highest cost benefit ratio of (1: 16.19). The next in order being seed treatment of clothianidin WDG @ 7.5 g /kg seed followed by spray of *B. bassiana* WP @ 0.007% (1:15.35) and treatment T_2 seed treatment with clothianidin WDG @7.5 g/kg seed followed by spray of *Ha*NPV @ 450 LE/ha (1: 10.25).

Conclusion

By considering the overall data, results showed that seed treatment of fipronil + imidacloprid WG @ 2.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% or seed treatment of clothianidin WDG @7.5 g/kg seed followed by spray of *B. bassiana* WP @ 0.007% found to be most effective in reducing the infestation of shoot fly and stem borer at vegetative and earhead stage of the crop. The eco-friendly approaches are useful in formulating bio-intensive IPM relying on the use of seed treatments and bio-control agents with less reliance on chemical pesticides.

Table 1: Effect of seed treatment and foliar application of bio-pesticides against infestation of shoot fly and stem borer in pearl millet

Treats	% shoot fly incidence		% stem borer incidence	
	Vegetative stage	Ear head stage	Vegetative stage	Ear head stage
T_1	15.21 (6.88)	7.98 (1.93)	17.01 (8.55)	14.02 (5.87)
T_2	20.63 (12.41)	13.06 (5.10)	20.26 (11.99)	17.01 (8.56)
T_3	22.20 (14.28)	15.10 (6.79)	23.81 (16.30)	20.66 (12.45)
T_4	14.89 (6.60)	7.49 (1.69)	18.56 (10.13)	16.19 (7.78)
T_5	19.63 (11.28)	11.99 (4.31)	23.26 (15.59)	20.07 (11.76)
T_6	22.06 (14.10)	14.90 (6.62)	25.93 (19.12)	23.80 (16.21)
T_7	13.23 (5.24)	5.68 (0.98)	17.61 (9.16)	15.15 (6.83)
T_8	18.38 (9.94)	11.09 (3.69)	21.02 (12.87)	18.20 (9.76)
T_9	21.31 (13.21)	14.03 (5.87)	25.54 (18.59)	22.44 (14.57)
T_{10}	30.93 (26.42)	23.03 (15.31)	37.31 (36.75)	33.43 (30.35)
S. Em. ±	0.88	0.73	0.93	0.93
C. D. 5%	2.55	2.13	2.88	2.72
C. V.%	8.90	11.81	8.66	9.34

Figures in parentheses are retransformed values; those outside are arcsine transformed values

Table 2: Economics of different treatments applied for the control of major pests of pearl millet

Treat	Total cost of insecticides (Rs/ha)	Yield of bajra grains (kg/ha)	Net gain in yield over control (kg/ha)	Gross realization (Rs/ha)	Net Realization over control (Rs/ha)	ICBR
T_1	1285	2452	789	61300	19725	1:15.35
T_2	1126	2131	468	53275	11700	1:10.39
T_3	3829	1737	74	43425	1850	1:0.48
T_4	1017	2322	659	58050	16475	1:16.19
T_5	858	1992	329	49800	8225	1:9.58
T_6	3561	1704	41	42600	1025	1:0.28
T_7	3876	2371	708	59275	17700	1:4.56
T_8	3717	2047	384	51175	9600	1:2.58
T_9	6420	1777	114	44425	2850	1:0.44
T_{10}	0.000	1663	-	41575	-	-

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