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Effect of application of different insecticides on incidence of shoot fly *Atherigona soccata* (Rondani) on *rabi* sorghum

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Abstract
An investigation was undertaken to study the bio-efficacy of different newer insecticides on incidence of shoot fly *Atherigona soccata* (Rondani) on *rabi* sorghum 2021-22 at research farm of department of Argil. Entomology College of agriculture Latur with nine treatments and four replications. The results revealed that all the insecticidal treatments were significantly effective against shoot fly over untreated control. Significantly least dead heart observed in Imidacloprid 48% FS seed treatment 5 ml/kg fib Abamectin Benzoate 5% SG 4 g/10 *l* to the extent of 9.09%, 11.01% 13.90%, and 17.99% per m row after first spray and 18.04%, 19.94%, 21.18% and 25.02% per m row after second spray at 1, 3, 7 and 14 days, respectively followed by Imidacloprid 48% FS seed treatment 5 ml/kg fib Chlorantraniliprole-18.5% SC 3 ml/10 *l* evidenced next best treatment in suppressing population of dead heart to the extent of 9.55%, 12.69%, 14.10% and 18.39% per m row after first spray and 18.78%, 19.07%, 20.26% and 24.78% per m row after second spray at 1, 3, 7, and 14 days, respectively and Thiamethoxam 30 FS seed treatment 10 ml/kg fib Chlorantraniliprole-18.5% SC 3 ml/10 *l* observed subsequently effective treatment in suppressing dead heart population to the extent of 9.66%, 12.13%, 14.37% and 18.89% per m row after first spray and 19.31% ,19.72, 20.22% and 24.24% per m row after second spray at 1, 3, 7, and 14 days, respectively. Result revealed that all the treatments were found significantly effective in reducing the incidence of shoot fly and thus increasing the yield as compared to control. The higher grain yield in treatment Imidacloprid 48%FS seed treatment 5 ml/kg fib Abamectin Benzoate 5% SG 4 g/10 *l* (32.19 q per ha) and the highest incremental cost benefit ratio (1:25.1) was attained by Imidacloprid 48%FS (seed treatment).

Keywords: Sorghum, *Atherigona soccata*, chlorantraniliprole, imidacloprid, thiamethoxam, dead heart

Introduction
Sorghum (*Sorghum bicolor* (Linnaeus) Muench) an ancient crop belonging to the family Pinaceae is a warm-season cereal of African origin, which was first cultivated in the region of Ethiopia or Chad over 5000 years ago and spread to India by 4000 years (Rosentrater and Evers, 2018) [20]. More than half of the world's sorghum is grown in the semi-arid regions, and it is fundamental food for over 500 million people who live in the semi-arid tropics (Mohammed *et al.,* 2015) [11]. Sorghum is the world's fifth most important cereal after maize, rice, wheat and barley (Balakrishna *et al*., 2019) [2].

There are four main classes of sorghum *viz*., grain sorghum, sweet sorghum, broom corns and grassy sorghum (Rosentrater and Evers, 2018) [20]. It is grown globally for human and animals for food, feed, fodder, fiber and fuel or bioenergy (Padmaja, 2016) [12]. Nutritionally sorghum (per 100 g) is rich in water (12.4 g), energy (329 kcal), protein (10.62 g), lipid (3.46 g), ash (1.43 g), carbohydrate (72.09 g), fibers (6.7 g), total sugar (2.59 g), Ca (13 mg), Fe (3.36 mg), Mg (165 mg), P (289 mg), K (363 mg), Na (2 mg), Zn (1.67 mg), Cu (0.284 mg), Mn (1.605 mg), Se (12.2 µg), folate (20 µg), vitamin B-6 (0.443 mg), vitamin E (0.5 mg), many phytochemicals, etc. (USDA, 2021). Sorghum is one of the most important staple food crops of the world adapted to a wide range of ecological conditions and low input cultivation with diverse uses in industries for ethanol, adhesives, starch and paper production (Karthikeyan, 2017) [7].

As a global food ingredient, sorghum is a versatile crop cultivated in more than 109 countries over 40.25 million ha producing 58.70 million tons of grains with an average productivity of 1458.5 kg per ha (FAOSTAT, 2021) [4]. In India, the area under sorghum crop is 5.5 million ha with the production of 4.7 million tons and the average yield of 866 kg per ha (FAOSTAT, 2021) [4].

Sorghum is mainly cultivated under rainfed conditions during *kharif* (rainy) as well as during *rabi* (winter) season mainly concentrated in the southern and central India. Sorghum is cultivated on an area of 1.75 and 2.34 million ha with 1.73 and 1.74 million tons of production and 989 and 744 kg per ha of productivity, during *kharif* and *rabi* season, respectively (INDIASTAT, 2021) [5]. In Maharashtra, it is cultivated over an area of 2320 thousand hectares with production of 2186 thousand tons and with average productivity of 942 kg/ha during *kharif* and *rabi* season, respectively. (Anonymous, 2021) [1].

In sorghum fields, more than 35 percent crops losses are reported due to insect pests estimated at $580 million in India (Reddy and Zehr, 2004) [19]. The early stage of the crop *i.e*., seedling stage was mainly attacked by shoot fly and flea beetle wherein the shoot fly was predominant (Patel and Purohit, 2015) [13]. The peak incidence of shoot fly in *kharif* season was in the month of August while in *rabi* season it was in the month of October – November (Pawar *et al.*, 2015) [15]. The shoot fly, *Atherigona soccata* (Rendani) is one of the serious pests attacking sorghum in India. Shoot fly causes 23.3 to 36.5% grain losses and 37.5% fodder losses. Stem borer causes between 20-60% losses (Prem Kishore, 1987). *Chile par Tellus* causing 90-95 percent of the total damage in *Kharif* season (Prakash *et al.*, 2017) [16] The loss in grain and fodder yields due to aphid infestation varied from 11.74 to 26.13 percent and 9.83 to 31.43 percent with an overall average loss of 16.09 and 14.99 percent, respectively (Balikai and Lingappa, 2004) [3].

Materials and Methods

The experiment was conducted at the research farm of department of Argil. Entomology College of agriculture Latur (MS) during *Rabi* 2021-22 on sorghum variety Parbati Moti (SPV-1411). The experiment was laid out in Randomized Block Design with four replications and nine treatments including untreated control. The field was prepared following the recommended packages of practices with spacing of 45 X 15 cm with plot size 2.7 X 3 m. The observation on dead hearts due to shoot fly recorded per plot. The pretreatment observations were recorded one day before insecticidal spray and post treatments observations were taken on 1, 3, 7 and 14 days after each spray. The volume of spray water was worked out before insecticidal spray by spraying plain water on control plot. Spraying was done in early morning hours to avoid mid-day heat. Spraying was done by using knapsack sprayer with hollow cone nozzle.

Observations

Three rows of 1 m length will be selected randomly. From those rows total plants and plants showing dead heart symptoms will be counted. From this count, percent dead heart will be worked out. Dead heart incidence due to shoot fly was recorded from each treatment and expressed in percentage by using below formula. The observations on parameters were noted a day before spraying and at 1, 3,7 and 14 days after spraying. Plotwise harvesting will be carried out and the yield will be expressed as q/ha.

$$\text{Dead heart (\%)} = \frac{\text{Number of plants showing dead heart}}{\text{Total number of plants in 1 meter row}} \times 100$$

Table 1: Details of insecticides used in experiment.

Sr. No	Treatments	Doses
T1	Imidacloprid 48%FS (seed treatment)	5 ml/kg
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg
T3	Chlorantraniliprole-18.5% SC	3 ml/10 *l*
T4	Abamectin Benzoate 5% SG	4 g/10 *l*
T5	Imidacloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	5 ml/kg fob 3 ml/10 *l*
T6	Imidacloprid 48%FS (seed treatment) followed by Abamectin Benzoate 5% SG	5 ml/kg fob 4 g/10 *l*
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	10 ml/kg fob 3 ml/10 *l*
T8	Thiamethoxam 30FS (seed treatment) followed by Abamectin Benzoate 5% SG	10 ml/kg fob 4 g/10 *l*
T9	Untreated (control)	-

Results and Discussion

First spray

The results revealed that all the insecticides found to be significantly superior over untreated control in reducing population of sorghum dead heart by shoot fly at 1, 3, 7 and 14 days after first application of insecticides.

At one day after first spray, significantly minimum population of dead heart (8.89%) was registered from the plots treated with Thiamethoxam 30FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* followed by Imidacloprid 48%FS seed treatment 5 ml/kg Ph.B. Abamectin Benzoate 5% SG 4 g/10 *l* (9.09%), Imidacloprid 48% FS seed treatment 5 ml/kg fob Chlorantraniliprole-18.5%SC 3 ml/10 *l* (9.55%), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (9.66%), Imidacloprid 48% FS seed treatment 5 ml/kg (10.43%) Thiamethoxam 30FS seed treatment 10 ml/kg (10.54%), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (12.09%) and Abamectin Benzoate 5% SG 4 g/10 *l* (12.57%). All these treatments were found to be equally effective in reducing dead heart population.

Similar trend of results were obtained at three days after first spray, Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* recorded significantly lowest population of dead heart to the tune of (11.01%), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (11.11%), Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (12.13%), Thiamethoxam 30 FS seed treatment 10 ml/kg (12.39%), Imidacloprid 48%FS seed treatment 5 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (12.69%), Imidacloprid 48% FS seed treatment 5 ml/kg (13.07%), Abamectin Benzoate 5% SG 4 g/10 *l* (14.08%) and Chlorantraniliprole-18.5% SC 3 ml/10 *l* (14.10%).

At seven days after first spray, Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (13.12%), Imidacloprid 48% FS seed treatment 5 ml/kg fib Abamectin Benzoate 5% SG 4 g/10 *l* (13.90%), Imidacloprid

48% FS seed treatment 5 ml/kg f.b.Chlorantraniliprole-18.5% SC 3 ml/10 *l* (14.10%), Thiamethoxam 30FS seed treatment 10 ml/kg fib Chlorantraniliprole-18.5% SC 3 ml/10 *l* (14.37), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (15.03%), Abamectin Benzoate 5% SG 4 g/10 *l* (15.33%), Thiamethoxam 30 FS seed treatment 10 ml/kg (16.61%) and Imidacloprid 48% FS seed treatment 5 ml/kg (17.42%). All these treatments were found to be statistically at par with each other.

At 14 days after first spray, significantly minimum population of dead heart (17.99%) was registered from the plots treated with Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* followed by Imidacloprid 48% FS seed treatment 5 ml/kg f.b.Chlorantraniliprole-18.5% SC 3 ml/10 *l* (18.39%), Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (18.89), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (19.16%), Chlorantraniliprole-18.5%SC 3 ml/10 *l* (20.24%), Abamectin Benzoate 5% SG 4 g/10 *l* (20.94%), Imidacloprid 48%FS seed treatment 5 ml/kg (22.74%) and Thiamethoxam 30FS seed treatment 10 ml/kg (23.08%). All these treatments were statistically at par with each other.

Second spray

At one day after second spray, significantly minimum population of dead heart (18.04%) was recorded from the plots treated with Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* followed by Imidacloprid 48% FS seed treatment 5 ml/kg f.b.Chlorantraniliprole-18.5% SC 3 ml/10 *l* (18.78%), Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (19.31), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (19.76%), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (21.93%) and Abamectin Benzoate 5% SG 4 g/10 *l* (22.34%). All these treatments were statistically at par with each other. The next effective treatments were Imidacloprid 48% FS seed treatment 5 ml/kg (26.58%), Thiamethoxam 30FS seed treatment 10 ml/kg (26.34%).

At three days after second spray, Imidacloprid 48% FS seed treatment 5 ml/kg f.b.Chlorantraniliprole-18.5% SC 3 ml/10 *l* (19.07%), Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (19.72), Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (19.94%), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (20.11%), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (22.01%) and Abamectin Benzoate 5% SG 4 g/10 *l* (23.13%). All these treatments were statistically at par with each other. The next effective treatments were Thiamethoxam 30FS seed treatment 10 ml/kg (29.00%) and Imidacloprid 48%FS seed treatment 5 ml/kg (29.07%).

At seven day after second spray, significantly minimum population of dead heart (20.22%) was registered from the plots treated with Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* followed by Imidacloprid 48% FS seed treatment 5 ml/kg f.b.Chlorantraniliprole-18.5% SC 3 ml/10 *l* (20.26%), Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (21.18%), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (21.75%), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (25.18%) and Abamectin Benzoate 5% SG 4 g/10 *l* (26.28%). All these treatments were found to be equally effective in reducing dead heart population. Subsequently effective treatments were Imidacloprid 48%FS seed treatment 5 ml/kg (32.01%), Thiamethoxam 30FS seed treatment 10 ml/kg (31.52%).

At 14 days after spraying, significantly lowest population of dead heart was noted in Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* recorded significantly lowest population of dead heart to the tune of (24.24%). Subsequently effective treatments were Imidacloprid 48% FS seed treatment 5 ml/kg f.b.Chlorantraniliprole-18.5% SC 3 ml/10 *l* (24.78%), Imidacloprid 48%FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (25.02%), Thiamethoxam 30 FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (26.01%), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (28.25%) and Abamectin Benzoate 5% SG 4 g/10 *l* (29.49%).All these treatments were statistically at par with each other. The next effective treatments were Thiamethoxam 30FS seed treatment 10 ml/kg (38.21%), Imidacloprid 48%FS seed treatment 5 ml/kg (38.98%).

The dead hearts due to shoot flies were recorded up to 14 days after spray of different insecticides. Meena (2021) noticed the dead hearts along with *A. soccata*, fruit flies (*Osceola* sp). Wakeli *et al* (2011) [25] Fruit flies were commonly observed causing dead hearts for long period in wheat. The present findings are in close agreement with the earlier reports of Shid *et al.* (2022) [22] who exhibited that least dead hearts due to shoot fly was noted in the plots with the seed treatments with Thiamethoxam 30 FS @ 10 ml/kg seed (19.76%), Cyantraniliprole 19.8% + Thiamethoxam 19.8% FS (21.00%) and Imidacloprid 17.8 SL 3 ml/kg (21.46%). However, Saxena *et al.* (2022) observed maximum reduction dead hearts due to shoot fly was recorded in the seed treatments with Thiamethoxam (19.8 w/w) + Cyantraniliprole (19.8 w/w) (1.36 to 15.95%) followed by seed treatment wih Thiamethoxam 30 FS ((1.61 to 21.76%) Analogously, Kumar and Tiwana (2018) [9] reported that seed treatment with thiamethoxam 30 FS @ 10 ml per kg seed was the most superior to reduce dead hearts due to soot fly (7.71%) followed by Imidacloprid 70 WS @ 7 ml per kg seed (9.47%) compared to untreated check (17.08%).

Similar trends of results were also pointed out by many authors in different crops as discussed below. Sridhar *et al.* (2016) indicated least dead hearts due to shoot fly in sweet sorghum at 30 days after emergence in the seed treatment with Imidacloprid 70 WS followed by Thiamethoxam 25 WG. While Jambagi *et al* (2022) [6] that at 15 DAS, thiamethoxam 30 FS @ 5 ml/kg seed f. b. a spray of cypermethrin 10 EC @ 0.5 ml/*l* recorded least shoot fly dead hearts (9.12%) and the plot with the treatment thiamethoxam 30 FS @ 5 ml/kg seed f. b. a spray of abamectin benzoate 5 SG 0.2 gm/*l* of was on par with it (9.25%). Only the seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed was less effective (21.86%). In the same way, Siddique *et al* (2011) [23] reported that Thiamethoxam 25 WG @ 0.005% spray was most effective in reducing shoot fly dead-hearts followed by imidacloprid 10 g/kg and thiamethoxam 5 gm/kg seed treatments. Patil and Bagde (2017) [14] recorded significantly lower no of shoot fly dead hearts in sorghum sprayed with chlorantraniliprole 18.5 SC.

Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* highest grain yield (32.19 q per ha) of sorghum followed by Imidacloprid 48% FS seed treatment 5 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (31.01 q per ha), Thiamethoxam 30FS seed treatment 10 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* (30.67 q per ha), Thiamethoxam 30FS seed treatment 10 ml/kg fob Chlorantraniliprole-18.5% SC 3 ml/10 *l* (28.61 q per ha), Chlorantraniliprole-18.5% SC 3 ml/10 *l* (26.29 q per ha), Abamectin Benzoate 5% SG 4 g/10 *l* (25.71 q per ha), Thiamethoxam 30FS seed treatment 10 ml/kg (23.17 q per ha) and Imidacloprid 48% FS seed treatment 5 ml/kg (22.68 q per ha). The highest incremental cost benefit ratio (1:25.1) was attained by Imidacloprid 48%FS (seed treatment) which was followed by (1:24.3), Thiamethoxam 30FS (seed treatment), Imidacloprid 48%FS (seed treatment) fib Abamectin Benzoate 5% SG (1:13.2), Thiamethoxam 30FS (seed treatment) fib Abamectin Benzoate 5% SG (1:11.3), Abamectin Benzoate 5% SG (1:7.0), Imidacloprid 48%FS (seed treatment) fib Chlorantraniliprole-18.5%SC (1:4.8), Thiamethoxam 30FS (seed treatment) fib Chlorantraniliprole-18.5% SC (1:3.7) and Chlorantraniliprole-18.5% SC (1:2.8). According to Rawat *et al*. (2020) all the treatments also revealed superiority of imidacloprid 600 FS @ 5 ml/kg of seed amongst all the treatments as imidacloprid 600 FS @ 5 ml/kg of seed proved to be the best treatment. Jambagi *et al* (2022) [6] recorded higher grain yield (32.22 and 31.27 q/ha) and straw yield (76.30 and 74.78 q/ha) was obtained in the plots characterized with seed treatment of thiamethoxam 30 FS (5 ml/kg seed) followed by a spray of cypermethrin 10 EC (0.5 ml/l). Khandare *et al* (2017) [8] indicated that the treatment with thiamethoxam 35 FS @ 5 ml/kg seed produced highest grain yield (3462 kg/ha). Shid *et al* (2022) [22] recorded highest yield in seed treatment with Thiamethoxam 30 FS @ 10 ml/kg of seed (15.70 q/ha). The maximum net monetary returns 1:56.25 (ICBR) were realized by the treatment thiamethoxam 35 FS @ 5 ml/kg seed. Shid *et al*. (2022) [22] recorded maximum ICBR 1:43.80 was obtained in seed treatment with Imidacloprid 17.8 SL @ 3 ml/kg of seeds.

Table 2: Effect of different insecticides on number of dead heart caused by shoot fly on *rabi* sorghum (first spray)

Sr. No	Treatments	Dosage	Mean dead hearts due to shoot fly (%)				
			1 DBS	1 DAS	3 DAS	7 DAS	14 DAS
T1	Imidacloprid 48%FS (seed treatment)	5 ml/kg	8.00 (16.34)	10.43 (18.79)	13.07 (21.14)	17.42 (24.61)	22.74 (28.46)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	7.41 (15.69)	10.54 (18.90)	12.39 (20.38)	16.61 (24.02)	23.08 (28.68)
T3	Chlorantraniliprole-18.5% SC	3 ml/10 *l*	11.77 (20.91)	12.09 (20.26)	14.10 (21.98)	15.03 (22.77)	20.24 (26.69)
T4	Abamectin Benzoate 5% SG	4 g/10 *l*	11.99 (21.10)	12.57 (20.72)	14.08 (21.99)	15.33 (23.02)	20.94 (27.12)
T5	Imidacloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	5 ml/kg fob 3 ml/10 *l*	7.24 (11.55)	9.55 (17.92)	12.69 (20.79)	14.10 (21.98)	18.39 (25.37)
T6	Imidacloprid 48%FS (seed treatment) followed by Abamectin Benzoate 5% SG	5 ml/kg fob 4 g/10 *l*	8.08 (16.39)	9.09 (17.50)	11.01 (19.35)	13.90 (21.85)	17.99 (25.06)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	10 ml/kg fob 3 ml/10 *l*	8.14 (16.54)	9.66 (18.07)	12.13 (20.35)	14.37 (22.17)	18.89 (25.68)
T8	Thiamethoxam 30FS (seed treatment) followed by Abamectin Benzoate 5% SG	10 ml/kg fob 4 g/10 *l*	7.21 (15.53)	8.89 (17.30)	11.11 (19.42)	13.12 (21.09)	19.16 (25.91)
T9	Untreated (control)	-	13.18 (21.26)	17.26 (24.53)	19.40 (26.09)	24.31 (29.50)	31.08 (33.37)
	SE±		1.17	1.25	1.40	1.41	1.57
	CD 5%		3.40	3.65	4.09	4.11	4.58
	CV %		9.30	9.16	9.31	8.49	8.11

Table 3: Effect of different insecticides on number of dead heart caused by shoot fly on *rabi* sorghum (second spray)

Tr. No	Treatments	Dosage	Mean dead hearts due to shoot fly (%)				
			1 DBS	1DAS	3 DAS	7 DAS	14 DAS
T1	Imidacloprid 48%FS (seed treatment)	5 ml/kg	22.74 (28.46)	26.58 (31.02)	29.07 (32.61)	32.01 (34.40)	38.98 (38.62)
T2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	23.08 (28.68)	26.34 (30.82)	29.00 (32.53)	31.52 (34.11)	38.21 (38.17)
T3	Chlorantraniliprole-18.5% SC	3 ml/10 *l*	20.24 (26.69)	21.93 (27.91)	22.01 (27.92)	25.18 (30.08)	28.25 (32.00)
T4	Abamectin Benzoate 5% SG	4 g/10 *l*	20.94 (27.12)	22.34 (28.06)	23.13 (28.60)	26.28 (30.79)	29.49 (32.77)
T5	Imidacloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	5 ml/kg fob 3 ml/10 *l*	18.39 (25.37)	18.78 (25.44)	19.07 (25.88)	20.26 (26.72)	24.78 (29.80)
T6	Imidacloprid 48%FS (seed treatment) followed by Abamectin Benzoate 5% SG	5 ml/kg fob 4 g/10 *l*	17.99 (25.06)	18.04 (25.13)	19.94 (26.45)	21.18 (27.37)	25.02 (29.94)
T7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	10 ml/kg fob 3 ml/10 *l*	18.89 (25.68)	19.31 (26.05)	19.72 (26.32)	20.22 (26.65)	24.24 (29.45)
T8	Thiamethoxam 30FS (seed treatment) followed by Abamectin Benzoate 5% SG	10 ml/kg fob 4 g/10 *l*	19.16 (25.91)	19.76 (26.34)	20.11 (26.63)	21.75 (27.76)	26.01 (30.64)

T9	Untreated (control)	-	31.08 (33.37)	33.80 (35.52)	35.46 (36.54)	39.43 (38.88)	46.66 (43.07)
	SE±		1.57	1.74	1.74	1.81	1.97
	CD 5%		4.58	5.10	5.08	5.29	5.76
	CV %		8.11	8.68	8.41	8.34	8.25

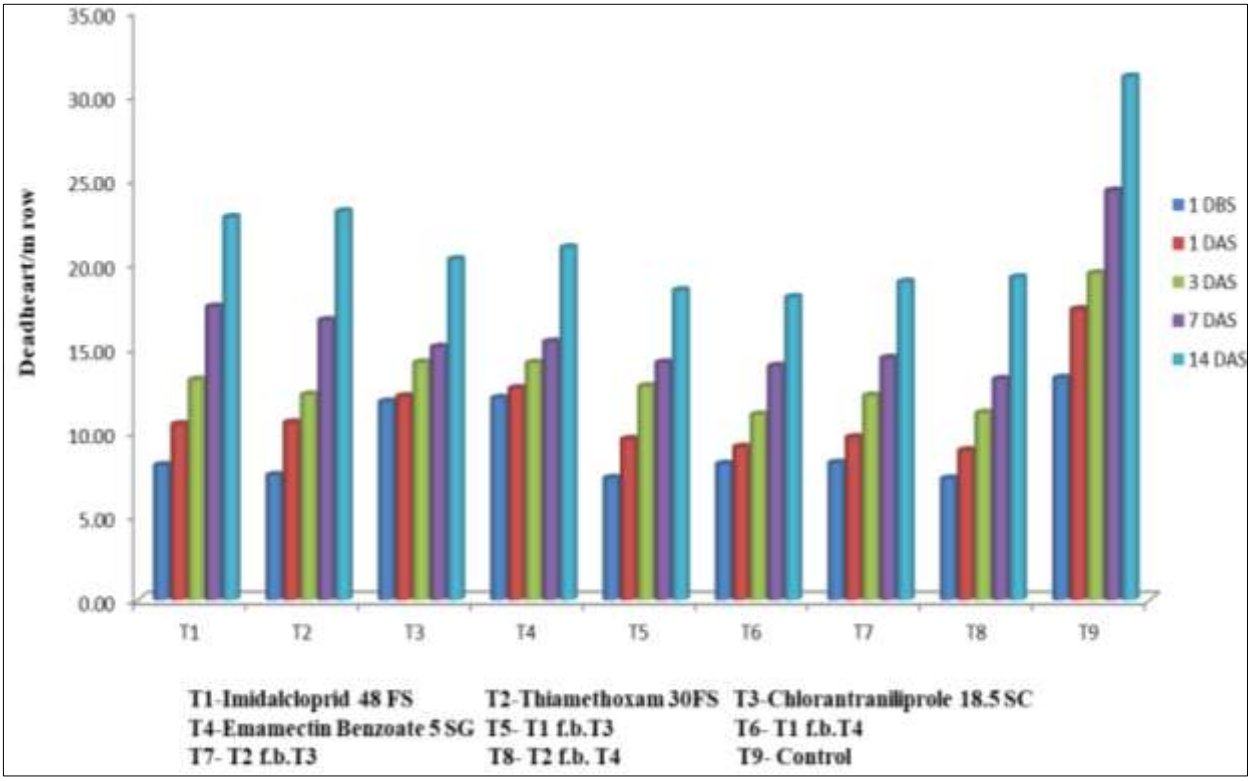

Fig 1: Effect of different insecticides on number of dead hearts caused by shoot fly on *rabi* sorghum (first spray)

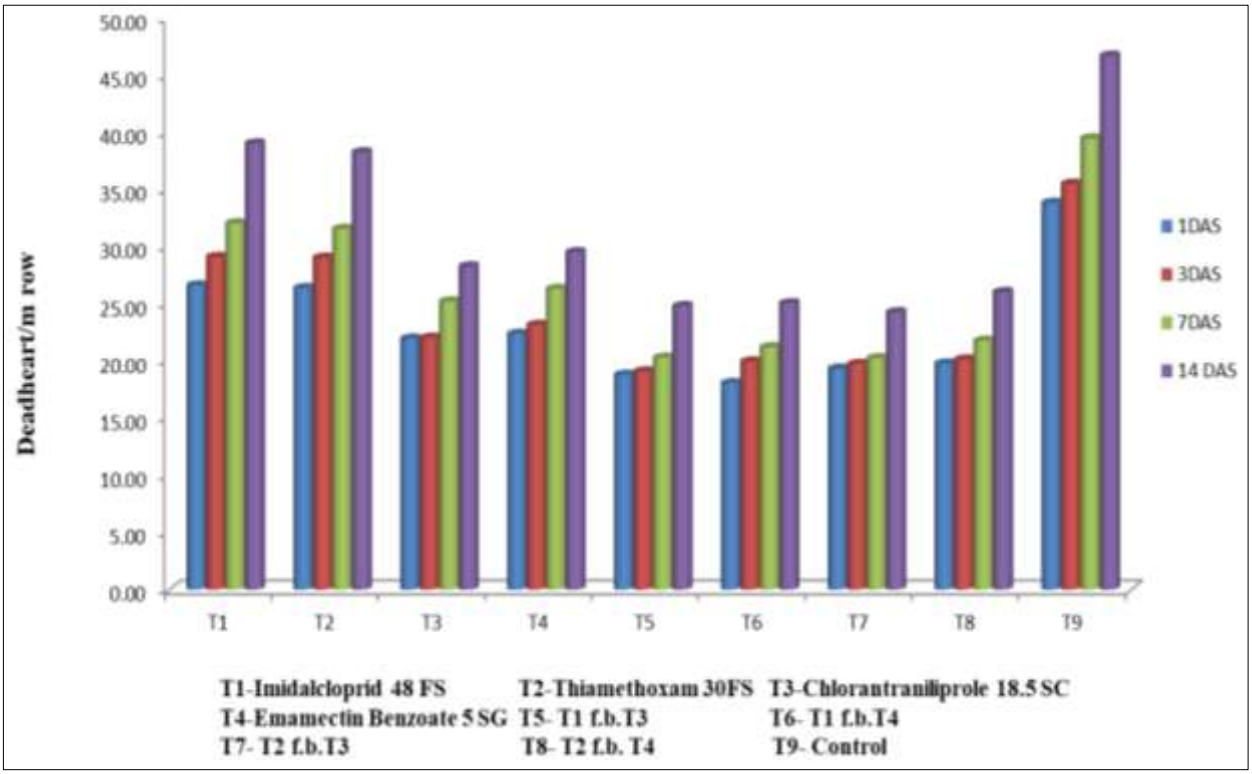

Fig 2: Effect of different insecticides on number of dead heart caused by shoot fly on *rabi* sorghum (second spray)

Table 4: Effect of different insecticides on grain yield of *rabi* sorghum

Sr. No.	Treatments	Dosage	Grain Yield (kg/ha)	Grain Yield (q/ha)	Increased yield over control
T1	Imidacloprid 48% FS (seed treatment)	5 ml/kg	2268.52	22.68	4.60
T2	Thiamethoxam 30 FS (seed treatment)	10 ml/kg	2317.90	23.17	5.09
T3	Chlorantraniliprole-18.5% SC	3 ml/10 *l*	2629.63	26.29	8.21
T4	Abamectin Benzoate 5% SG	4 g/10 *l*	2570.99	25.71	7.63
T5	Imidacloprid 48% FS (seed treatment) fob Chlorantraniliprole-18.5% SC	5 ml/kg fob 3 ml/10 *l*	3101.85	31.01	12.93
T6	Imidacloprid 48%FS (seed treatment) fob Abamectin Benzoate 5% SG	5 ml/kg fob 4 g/10 *l*	3219.14	32.19	14.11
T7	Thiamethoxam 30FS (seed treatment) fob Chlorantraniliprole-18.5% SC	10 ml/kg fob 3 ml/10 *l*	2861.11	28.61	10.53
T8	Thiamethoxam 30FS (seed treatment) fob Abamectin Benzoate 5% SG	10 ml/kg fob 4 g/10 *l*	3067.90	30.67	12.59
T9	Untreated (control)	-	1808.64	18.08	-
	SE±		80.82		
	CD 5%		235.91		
	CV %		6.10		

Table 5: Incremental cost benefit ratio (ICBR) of different insecticides used against major insect-pests of *rabi* sorghum.

Sr. No.	Treatment details	Dose (ml or kg/ha)	Yield (q/ha)	Increased yield over control (q/ha)	Additional income (Rs. /ha)	Insecticide cost (Rs.)	Labor charges (Rs.)	Total costs (Rs.)	Incremental benefit	ICBR	Rank
1	Imidacloprid 48%FS (seed treatment)	5 ml/kg	22.68	4.60	12609	120	350	470	12139	1:25.8	1
2	Thiamethoxam 30FS (seed treatment)	10 ml/kg	23.17	5.09	13961	200	350	550	13411	1:24.3	2
3	Chlorantraniliprole-18.5% SC	3 ml/10 *l*	26.29	8.21	22496	4500	1400	5900	16596	1:2.8	8
4	Abamectin Benzoate 5% SG	4 g/10 *l*	25.71	7.63	20891	1200	1400	2600	18291	1:7.0	5
5	Imidacloprid 48%FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	5 ml/kg fob 3 ml/10 *l*	31.01	12.93	35426	4620	1400	6020	29406	1:4.8	6
6	Imidacloprid 48%FS (seed treatment) followed by Abamectin Benzoate 5% SG	5 ml/kg fob 4 g/10 *l*	32.19	14.11	38637	1320	1400	2720	35917	1:13.2	3
7	Thiamethoxam 30FS (seed treatment) followed by Chlorantraniliprole-18.5% SC	10 ml/kg fob 3 ml/10 *l*	28.61	10.53	28834	4700	1400	6100	22734	1:3.7	7
8	Thiamethoxam 30FS (seed treatment) followed by Abamectin Benzoate 5% SG	10 ml/kg fob 4 g/10 *l*	30.67	12.59	34496	1400	1400	2800	31696	1:11.3	4
9	Untreated (control)	-	18.08	-						-	

Conclusion

The present study brought out the significant difference among the insecticides against sorghum dead heart. Among different insecticides, Imidacloprid 48% FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* and Imidacloprid 48% FS seed treatment 5 ml/kg Ph.B. Chlorantraniliprole-18.5% SC 3 ml/10 *l* exhibited highest efficacy against percent dead heart. The present investigation exhibited better response of Imidacloprid 48%FS seed treatment 5 ml/kg fob Abamectin Benzoate 5% SG 4 g/10 *l* with higher grain yield of sorghum. The highest incremental cost benefit ratio (1:25.1) was attained by Imidacloprid 48%FS (seed treatment).

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