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Management of insect pests in *Rabi* Sorghum [*Sorghum bicolor* (L.) Moench]

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Abstract
A field experiment was conducted at Regional Agricultural Research Station, Vijayapura University of Agricultural Sciences, Dharwad during 2015-16 to assess the efficacy of different pesticides. The results revealed that application of Carbofuran 3G (30 kg/ha) was found superior over the other treatments (7.9 % dead hearts), followed by fipronil 5 SC (0.5 ml/litre), NSKE 5 %, imidacloprid 17.8 SL (0.3 ml/l), and phorate 10 G (40 kg/ha) for shoot fly management. Acephate 75 SP, fipronil 5 SC, Imidacloprid 17.8 SL and NSKE were promising insecticides for shoot bug and aphid management in sorghum.

Keywords: sorghum, pesticides, shoot fly, shoot bug, aphid

1. Introduction
The demand for sorghum as a staple food is growing in recent years [1]. Though, sorghum is known for its versatile use, hardiness dependability, stability of yield and adaptability over a wide range of cultures and climatic conditions, pests and diseases prevailing in sorghum growing areas of the world limit the crop production [2].

Sorghum is vulnerable to over 150 insect species from sowing to the final crop harvest [3]. In northern dry zone of Karnataka (zone-3), three insect pests namely, shoot fly *Atherigona soccata* Rondani (Diptera: Muscidae), shoot bug *Peregrinus maidis* (Ashmead) and aphids *Melanaphis sacchari* (Zehntner) are the important regular pests.

The sorghum shoot fly, *A. soccata* causes severe damage in the early stage and lasts up to four weeks causing severe reduction in plant population. Maximum yield losses of 75.6 per cent in grain and 68.6 per cent in fodder have been reported by Pawar *et al*. (1984) [4]. Its incidence is greater in late sown crop in rainy and post rainy seasons in India.

The shoot bug, *P. maidis* previously considered to be of minor importance, but now with the introduction of new sorghum genotypes of different maturity periods in certain parts of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu has become a serious pest. The shoot bug is a major hurdle in *rabi* sorghum production by causing dual problem of direct loss by sucking the sap and indirect damage by transmitting sorghum stripe virus disease. Hence, it comes in the way of harvesting potential yield of grain and fodder. In India shoot bugs can cause 41 per cent loss [5].

In shoot bug, both macropterous and brachypterous nymphs and adults suck the sap from the leaves by congregating in the plant whorl and inner sides of the leaf sheath. Severe attack of shoot bug results in leaf chlorosis, stunted growth, shriveled and chaffy grains [6]. The top leaves start drying first, later leaf death gradually extends to older leaves and some times, death of the whole plant occurs [7].

Severe infestation at boot leaf stage results in twisting of top leaves, thus preventing the emergence of panicles [8]. Further, the honey dew excreted by nymphs and adults favours the growth of sooty mould fungus (*Capnodium* sp.) which inhibits the photosynthetic activity. It was also reported as a vector of sorghum stripe disease (SStD). The other hosts of shoot bug include maize, bajra, sugarcane, ragi and other grasses [9].

Sorghum aphid, *M. sacchari* is distributed in Asia, Africa and America. It prefers to feed on the under surface of older leaves, resulting in premature drying of leaves, non-filling of grains and deterioration of fodder quality. Rensburg and Hamberg (1976) [10] have highlighted the severity of aphid damage by reporting 77 per cent reduction in sorghum grain yield. Spraying or dusting of several insecticides are being recommended for its management.

Keeping these points in view, the present investigation was undertaken.

2. Materials and Methods

This experiment was conducted during 2015-16, in a Randomized Block Design (RCBD) with 16 treatments and two replications, using M 35-1 variety of sorghum in a plot size of 3.15 m x 4.0 m (7 rows of 4m length) for each treatment. The crop was raised with a spacing of 45 x 15 cm by following all recommended package of practices of UAS Dharwad, except plant protection methods.

Table I: List of pesticides evaluated along with their dosage.

Treatments	Pesticides	Dosage
1.	Acephate 75 SP	1 g/litre
2.	Malathion 50 EC	2 ml/litre
3.	Profenophos 50 EC	1 ml/litre
4.	Methomyl 40 SP	0.6 g/litre
5.	Chlorpyriphos 20 EC	2.5 ml/litre
6.	Cypermethrin 10 EC	0.5 ml/litre
7.	Alphamethrin 10 EC	0.25 ml/litre
8.	Fipronil 5% SC	0.5 ml/litre
9.	Carbofuran 3 G	30 kg/ha
10.	Phorate 10 G	40 kg/ha
11.	Imidacloprid 17.8 SL	0.3 ml/litre
12.	Chlorantraniliprole18.5 SC	0.15 ml/litre
13.	Emamectin benzoate 0.5 SG	0.2 g/litre
14.	Spiromesifen 240 SC	2 ml/litre
15.	NSKE	5%
16.	Control	

The treatments were imposed at an age of 25, 60 and 90 days after sowing of the crop by using knapsack sprayer. The insect pest observations were recorded by following the standard procedures for individual pests separately as mentioned below.

Shoot fly (*Atherigona soccata*)

The observations were made on per cent dead heart damage by counting total number of plants and the plants showing dead hearts in each treatment [11].

$$\text{Percent dead heart (\%)} = \frac{\text{Number of plants showing dead heart symptoms}}{\text{Total no. of plants in each treatment}} \times 100$$

Shoot bug (*Peregrinus maidis*)

Shoot bug population density

The shoot bug population density were recorded as number of adults or nymphs/plant on five randomly selected tagged plants in each treatment.

Shoot bug damage

Total number of plants in each treatment was recorded and number of plants showing yellowing, girdling and stunted growth were recorded at 90 days after emergence and percentage of plant damage was worked out. The data were subjected to arcsin transformations before statistical analysis and also rated using (0-9) scale as detailed below.

Table 2: Shoot bug damaging scale

Per cent of plant damage by shoot bug	Score
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-90	8
>81	9

Aphid (*Melanaphis sacchari*)

Aphid population density

The aphid population was recorded as number of aphid/sq.cm/leaf on all the five randomly selected plants in each treatment.

Per cent aphid index

For calculating per cent aphid index, the aphid population density was recorded on five randomly selected plants in each treatment. Six leaves in each plant from apex to downward excluding flag leaf as well as dried leaves at the bottom were observed for aphid colonies and rated using 0-9 scale as detailed below [12].

Table 3: Aphid damaging scale

Per cent leaf area covered by aphids	Score
0	0
1-10	1
11-20	2
21-30	3
31-40	4
41-50	5
51-60	6
61-70	7
71-90	8
>81	9

Based on the scores (0-9 scale), the per cent aphid index (PAI) was worked out by the following formula generally used for computing per cent disease index [13].

$$\text{PAI} = \frac{\text{Sum of all numerical ratings}}{\text{Number of plants observed x Number of leaves per plant x Maximum rating}} \times 100$$

Statistical analysis of data

The data collected from the experiment were analyzed statistically following the procedure described by Gomez and Gomez (1976) [14]. The level of significance used in 'F' and t' tests was P=0.05. Critical difference values were calculated wherever the 'F' test was significant.

3. Results and discussion

Shoot fly *(Atherigona soccata)*

Study on bio efficacy of pesticides against shoot fly on 30 days after sowing revealed that significant difference between the treatments. Carbofuran 3G (30 kg/ha) showed least per cent dead hearts (4.15%), followed by imidacloprid 17.8 SL (0.3 ml/l), fipronil 5 SC (0.3 ml/litre) were found on par with each other (5.25, 6.15 per cent dead hearts, respectively). However, highest per cent dead hearts (21.35%) was recorded in control plot (Table 4).

On 45 days after sowing the crop carbofuran 3G (30 kg/ha) was found superior over the other treatments (7.9 % dead hearts), followed by fipronil 5 SC (0.5 ml/litre), NSKE 5 %, imidacloprid 17.8 SL (0.3 ml/l), phorate 10 G (40 kg/ha), malathion 50 EC (2 ml/litre), chlorpyriphos 20 EC (2.5 ml/litre) and cypermethrin 10 EC (0.5 ml/litre) were found on par with each other (9.99, 10.3, 10.55, 11.2, 12.9 and 13.8% dead hearts, respectively). The highest per cent dead hearts (27.6%) was recorded in control plot (Table 4).

These results are in agreement with reports placed on records by Thirumurthi *et al.* (1973) [15] Shivpuje and Thombare (1983) [16] and Subhedar *et al.* (1992) [17], who reported that the application of carbofuran granules was the best chemical insecticide in mitigating the shoot fly, *A. soccata.* The results with respect to imidacloprid 17.8 SL (0.3 ml/l) are in line with Balikai *et al.* (2001) [18] reported that imidacloprid 70 WS at both rates was the best control treatment in terms of controlling the pest and increasing the yield.

Table 4: Bio-efficacy of pesticides on shoot fly, *Atherigona soccata* (Rondani)

S. No	Pesticides	Dosage	30 DAS	45 DAS
			Percent dead hearts	
1	Acephate 75 SP	1 g/litre	12.1 (20.1)^{bc}	16.4 (23.8)^{b}
2	Malathion 50 EC	2 ml/litre	13.6(21.6)^{b}	12.9(21.0)^{bc}
3	Profenophos 50 EC	1 ml/litre	11.25(19.4)$^{b-d}$	16.2 (23.7)^{b}
4	Methomyl 40 SP	0.6 g/litre	10.8(19.0) $^{b-d}$	15.85(23.4)^{b}
5	Chlorphyriphos 20 EC	2.5 ml/litre	8.3(16.7)$^{b-e}$	13.8(21.7)^{bc}
6	Cypermethrin 10 EC	0.5 ml/litre	9.85(18.3)$^{b-d}$	13.95(21.7)^{bc}
7	Alphamethrin 10 EC	0.25 ml/litre	9.55(18.0)$^{b-e}$	14.5(22.3)^{bc}
8	Fipronil 5% SC	0.5 ml/litre	6.15(14.3)$^{c-e}$	9.99(18.4)^{bc}
9	Carbofuron 3 G	30 kg/ha	4.15(11.7)^{e}	7.9(16.1)^{c}
10	Phorate 10 G	40 kg/ha	8.5(16.9)$^{b-e}$	11.2(19.5)^{bc}
11	Imidacloprid 17.8 SL	0.3 ml/litre	5.25(13.2)^{de}	10.55(18.9)^{bc}
12	Chlorantraniliprole18.5 SC	0.15 ml/litre	9.8(18.2)$^{b-d}$	15.35(22.9)^{bc}
13	E. benzoate 0.5 SG	0.2 g/litre	9.75(18.19)$^{b-d}$	15.35(23.04)^{bc}
14	Spiromesifen 240 SC	2 ml/litre	9.85(18.25)$^{b-d}$	15(22.72)^{bc}
15	NSKE	5%	7.8 (16.18)$^{b-e}$	10.3 (18.66)^{bc}
16	Control	-	21.35 (27.52)^{a}	27.6 (31.66)^{a}
	SEm±		1.89	2.09
	C.D. (P= 0.05)		5.69	6.29
	CV (%)		14.87	13.51

Figures in the parentheses are arcsine transformations; DAS - days after sowing

Shoot bug *(P. maidis)*

Shoot bug population per plant

Study on bio efficacy of pesticides against shoot bug on 90 days after sowing revealed that significant difference between the treatments. The least number of population per plant was recorded in the treatment fipronil 5 SC (0.5 ml/litre) (0.65/plant), followed by acephate 75 SP (1 g/litre), imidacloprid 17.8 SL (0.3 ml/litre) and NSKE 5% were found on par with each other (1.2, 1.3 and 0.8, respectively), However, highest number of population (25.8) was recorded in control plot (Table 5).

Table 5: Bio-efficacy of pesticides on shoot bug, *Peregrinus maidis* (Ashmead)

S. No	Pesticides	Dosage	Shoot bug population/plant* at 90 DAS	Shoot bug damage** at 90 DAS
1	Acephate 75 SP	1 g/litre	1.2 (1.3)^{fg}	1.96 (7.8)^{g}
2	Malathion 50 EC	2 ml/litre	2.15(1.6)$^{d-g}$	5.85(13.8)^{e}
3	Profenophos 50 EC	1 ml/litre	2.6(1.8)$^{d-f}$	4.15 (11.7)^{f}
4	Methomyl 40 SP	0.6 g/litre	7.4(2.8)^{c}	10.57(18.7)^{c}
5	Chlorphyriphos 20 EC	2.5 ml/litre	2.25(1.7)$^{d-f}$	5.67(13.8)^{e}
6	Cypermethrin 10 EC	0.5 ml/litre	2.25(1.7)$^{d-f}$	6.35(14.4)^{de}
7	Alphamethrin 10 EC	0.25 ml/litre	3.85(2.1)^{d}	7.32(15.6)^{de}
8	Fipronil 5% SC	0.5 ml/litre	0.65(1.1)^{g}	4.07(11.5)^{f}
9	Carbofuron 3 G	30 kg/ha	15.7(4.0)^{b}	15.35(23.0)^{b}
10	Phorate 10 G	40 kg/ha	7.3(2.8)^{c}	6.7(14.8)^{de}

11	Imidacloprid 17.8 SL	0.3 ml/litre	1.3(1.3)^{fg}	3.87(11.3)^{f}
12	Chlorantraniliprole18.5 SC	0.15 ml/litre	2.7(1.8)$^{d-f}$	6.6(14.8)^{de}
13	E. benzoate 0.5 SG	0.2 g/litre	3.5(1.99)^{de}	8.05(16.38)^{d}
14	Spiromesifen 240 SC	2 ml/litre	13.75(3.77)^{b}	16.15(23.65)^{ab}
15	NSKE	5%	0.8(1.44)$^{e-g}$	2.95(9.73)^{f}
16	Control	-	25.8(5.11)^{a}	18.3(25.17)^{a}
	SEm±		0.17	0.61
	C.D. (P= 0.05)		0.51	1.85
	CV (%)		10.70	5.65

*- Figures in parentheses indicates √ x + 0.5 transformed values; ** - Figures in the parentheses are arcsine transformations; DAS - days after sowing.

Shoot bug per cent plant damage

The lowest per cent plant damage was recorded in the treatment acephate 75 SP (1 g/litre) (1.96%) followed by NSKE 5%, imidacloprid 17.8 SL (0.3 ml/litre), fipronil 5 SC (0.5 ml/litre) and profenophos 50 EC (1 ml/litre) were found on par with each other (2.95, 3.87, 4.07, 4.15 per cent plant damage, respectively) However, highest percentage plant damage (18.3%) was recorded in control plot (Table 5).

Shoot bug damaging scale

Among the different pesticides tested, methomyl 40 SP (0.6 g/litre), carbofuron 3 G (30 kg/ha), spiromesifen 240 SC (2 ml/litre) and control plot were shown more than 10 per cent (grade 2) plant damage and other pesticides such as acephate 75 SP (1 g/litre), malathion 50 EC (2 ml/litre), profenophos 50 EC (1 ml/litre), chlorpyriphos 20 EC (2.5 ml/litre), cypermethrin 10 EC (0.5 ml/litre), alphamethrin 10 EC (0.25 ml/litre), fipronil 5 SC (0.5 ml/litre), phorate 10 G (40 kg/ha), imidacloprid 17.8 SL (0.3 ml/litre), chlorantraniliprole 18.5 SC (0.15 ml/litre), emamectin benzoate 0.5 SG (0.2 g/litre) and NSKE 5% treated plots shows less than 10 per cent plant damage (grade 1) (Table 5).

The present results are agreement with the findings of Kumar and Prabhuraj (2007) [19] reported that seed treatment with thiamethoxam 70 WS at 2 g/kg recorded lower infestation of shoot bug population (5.83/5 plants), and higher grain yield (31.93 q/ha), besides higher fodder yield (56.92 q/ha), imidacloprid 70 WS at 5 g per hectare was the next best treatment and was on par with each other. Similarly, Vijaykumar (2004) [20] reported that thiamethoxam 70WS @ 2 g/kg seeds to be highly effective against reducing the shoot bug population in sorghum. And Anaji and Balikai (2007) [21] reported that thiamethoxam 70 WS @ 3 g/kg seeds to be highly effective against reducing the shoot bug population in sorghum.

Aphid (*M. sacchari)*

Aphid population/cm^2/leaf

Study on bio efficacy of pesticides against aphid on 90 days after sowing revealed that significant difference between the treatments. The least number of aphids were recorded in the treatment imidacloprid 17.8 SL (0.3 ml/litre) (6.2), followed by fipronil 5 SC (0.5 ml/litre), chlorpyriphos 20 EC (2.5 ml/litre) and NSKE 5% were found on par with each other (7.9, 9.15 and 10.1 respectively) and the highest population (31.00) was recorded in the control plot (Table 6).

Per cent aphid index

Among the different pesticides tested the lowest per cent aphid index was recorded in the treatment fipronil 5 SC (0.5 ml/litre) (0.52%), followed by imidacloprid 17.8 SL (0.3 ml/litre) and chlorpyriphos 20 EC (2.5 ml/litre) (0.65, and 0.61%, respectively) and the highest per cent aphid index (4.62%) was recorded in the control plot (Table 6).

The present results are agreement with the findings of Balikai and Lingappa (2003) [22], reported that dimethoate 30 EC @ 1.7 ml/l recorded 95.25 per cent reduction in aphid population at 10 days after spraying, followed by endosulfan (93.22%) and chlorpyriphos (91.13%). Dimethoate also gave significantly higher grain yield (27.17 q/ha), fodder yield (6.66 t/ha) and 1000 grain weight (31.88 g) followed by endosulfan (26.43 q/ha, 6.46 t/ha and 31.42 g, respectively). Similarly, Balikai (2001) [23] reported that, seed dressing with imidacloprid 70 WS @ 10g/kg was highly effective in lowering aphid population in sorghum.

Table 6: Bio-efficacy of pesticides on sorghum aphid, *Melanaphis sacchari* (Zehntner)

S. No	Pesticides	Dosage	Aphid population/ cm^2/leaf* at 90 DAS	Percent aphid index (PAI)** at 90 DAS
1	Acephate 75 SP	1 g/litre	11.1(3.4)$^{e-i}$	0.95(5.6)$^{b-d}$
2	Malathion 50 EC	2 ml/litre	20.95(4.6)$^{b-d}$	2.06(8.2)$^{a-d}$
3	Profenophos 50 EC	1 ml/litre	21.2(4.7)$^{a-d}$	2.69(9.2)^{ab}
4	Methomyl 40 SP	0.6 g/litre	18.9(4.4)$^{b-d}$	2.15(7.8)$^{b-d}$
5	Chlorphyriphos 20 EC	2.5 ml/litre	9.15(3.1)$^{g-i}$	0.61(4.5)^{cd}
6	Cypermethrin 10 EC	0.5 ml/litre	13.85(3.8)$^{d-h}$	1.07(5.9)$^{b-d}$
7	Alphamethrin 10 EC	0.25 ml/litre	17.5(4.2)$^{c-f}$	2.32(8.88)$^{a-c}$
8	Fipronil 5% SC	0.5 ml/litre	7.9(2.9)^{hi}	0.52(4.2)^{d}
9	Carbofuron 3 G	30 kg/ha	20.95(4.6)$^{b-d}$	2.08(8.3)$^{a-d}$
10	Phorate 10 G	40 kg/ha	24.5(5.0)$^{a-c}$	2.32(8.8)$^{a-c}$
11	Imidacloprid 17.8 SL	0.3 ml/litre	6.2(2.6)^{i}	0.65(4.3)^{d}
12	Chlorantraniliprole18.5 SC	0.15 ml/litre	15(3.9)$^{d-g}$	1.25(6.2)$^{b-d}$
13	E. benzoate 0.5 SG	0.2 g/litre	28.3(5.36)^{ab}	3.0(9.86)^{ab}
14	Spiromesifen 240 SC	2 ml/litre	18.05(4.30)$^{c-e}$	1.8(7.60)$^{b-d}$
15	NSKE	5%	10.1(3.25)$^{f-i}$	1.22(6.34)$^{b-d}$

16	Control	-	31(5.61)[a]	4.62(12.39)[a]
	SEm±		0.29	1.27
	C.D. (P= 0.05)		0.88	3.83
	CV (%)		10.01	23.72

*-Figures in parentheses indicates √ x + 0.5 transformed values; * *- Figures in the parentheses are arcsine transformations, DAS - days after sowing

4. Conclusion

Sorghum is a hardy plant grown majorly under rainfed conditions. Farmers unknowingly loss the yield majorly due to insect pests, Hence the application of pesticides such as Carbofuran 3G, Acephate 75 SP, Fipronil 5 SC, Imidacloprid 17.8 SL and NSKE 5 % were found to be effective management of insect pests in sorghum. Other pesticides such as Profenophos 50 EC, Malathion 50 EC, Chloropyriphos 20 EC, Alphamethrin 10 EC and Spiromesifen, also control the insect pests to some extent but they are produced adverse effect to the sorghum plants (phytotoxic) symptoms like chlorosis, white blotches and bronzing.

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