Original Research Article

Innovative Strategies for Controlling Sorghum Shoot Fly: Seed Treatments and Botanical Insecticides

ABSTRACT

Aim: To assess the efficacy of various treatments for managing sorghumshoot fly, *Atherigonasoccata*Rondani, and their effects on plant vigour, growth, yield, and Incremental Cost-Benefit Ratio (ICBR).

Study Design: A field experiment with a Randomized Block Design, involving three replications and nine treatments.

Place and Duration of Study: Chaudhary Charan Singh Haryana Agricultural University, Hisar (29.1492° N, 75.7217° E), during the *Kharif* season of 2020.

Methodology: Sorghum variety Swarna was sown in August 2020. Treatments included Imidacloprid 70WS, Thiamethoxam 30FS, Neem oil, Karanj oil, and their combinations. Treatments were applied at 7 and 17 days after emergence. Data on plant stand, egg counts, dead hearts (%), plant height, green fodder yield, and ICBR were analyzed.

Results: Thiamethoxam 30FS @ 10ml/kg + neem oil @ 2% showed the best performance, significantly reducing shoot fly infestation (19.98%)and enhancing plant vigour (1.00), height (86.93 cm), and yield (309.60 q/ha). Neem oil @ 2% was more effective than Karanj oil @ 2%. Imidacloprid 70WS had the highest Incremental Cost Benefit Ratio (ICBR) (1:21), while Karanj oil @ 2% had the lowest (1:0.78).

Conclusion: Thiamethoxam 30FS @ 10ml/kg + neem oil @ 2% was the most effective for managing shoot fly and improving crop performance. Imidacloprid 70WS offered the highest economic benefit, indicating its cost-effectiveness in pest management.

Keywords: Atherigonasoccata, Sorghum, plant vigour, Incremental Cost-Benefit Ratio (ICBR), pest management

1. INTRODUCTION

Sorghum [*Sorghum bicolor* (L.) Moench], commonly known as Jowar, originates from Northeast Africa and is a crucial crop for the poorest populations, particularly in semi-arid regions [1]. In India, sorghum is the fourth most important cereal crop, cultivated extensively in states such as Maharashtra, Andhra Pradesh, Karnataka, Gujarat, Tamil Nadu, and Rajasthan. In Haryana, it is predominantly grown for fodder purposes [2]. Despite its significance, the crop faces substantial threats from pests, notably the sorghum shoot fly, *Atherigonasoccata*. This pest can inflict up to 80% grainyield loss and devastate more than 50% of the crop within just 7 to 30 days of seedling emergence [3, 4, 5].

The sorghum shoot fly attacks the crop during the crucial early stages of growth, specifically between 7 and 28 days after seedling emergence. The pest lays eggs on young leaves, and the larvae subsequently feed on the growing tips, causing the formation of "dead hearts" and significant reductions in yield. Effective management of this pest is challenging, as conventional chemical pesticides, while effective, pose environmental risks and potential harm to non-target organisms. In contrast, plant-derived oils present a promising nontoxic alternative for controlling shoot fly populations. This research aims to evaluate the efficacy of various plant oils applied both as sprays and seed treatments in managing shoot flyinfestations in sorghum. By exploring these alternative methods, the study seeks to provide sustainable and environmentally friendly solutions for mitigating the impact of this devastating pest on sorghum crops.

2. MATERIALS AND METHODS

A comprehensive field experiment was conducted at Chaudhary Charan Singh Haryana Agricultural University (29.1492° N, 75.7217° E) in Hisar. The experiment was laid out in the Randomized Block Design in three replications and nine treatments with a plot size of 3.6 × 4 m, leaving a gangway of 1m all around the plots. The susceptible sorghum variety Swarna was sown during the second week of August 2020 by following the recommended package of practices except for protection measures. The treatments were imposed with seed treatment and a knapsack sprayer. The first spray was given at 7 DAE and the second spray after 10 days of the first application. To compare the efficacy of treatments, an untreated control plot was maintained. The experimental treatments comprised Imidacloprid 70WS @ 3 ml/kg of seed, thiamethoxam 30FS @ 10 ml/kg of seed, neem oil @ 2%, karanj oil @ 2%, and various combinations of these treatments. Each treatment was administered with sprays applied at 7 and 17 days after emergence (DAE), with a control plot included for comparative analysis.Seeds were initially treated with a gum solution combined with the respective insecticides before being shade-dried and sown. Neem and karanj oil sprays were prepared at a concentration of 2% and applied using a sprayer. The efficacy of various treatments, was recorded in terms of mean number of plants with shoot fly eggs, plant vigour rating at 12 days after germination, plant stand, mean per cent plants with dead heart formation at 14, 21, and 28 DAE, plant height, fodder yield, and Incremental Cost-Benefit Ratio (ICBR)at harvest during*Kharif* 2020, in order to determine the most effective treatment against sorghum shoot fly. The collected data were rigorously analyzed statistically to evaluate the effectiveness of each treatment in managing sorghum shoot fly infestations and improving crop performance.

$$\text{Per cent dead hearts due to shoot ly} = \frac{\text{Number of plants with dead hearts per plot}}{\text{Total number of plants per plot}} \times 100$$

Plate 1: Seed treatment of sorghum

Plate 2: Experimental field

3. RESULTS AND DISCUSSION

3.1 Plant standand Plant vigour

Plant stand was assessed at 12 days after emergence (DAE) on two 2-meter rows. Findings revealed significant differences among treatments, with all but neem oil @ 2% and karanj oil @ 2% outperforming the control in managing sorghum shoot fly infestations (Table 1). Seed treatments consistently resulted in higher plant populations compared to botanical sprays, corroborating the work of Jayanthi et al. [6] and Sharma and Nwanze [7], who demonstrated that increased plant vigor in sorghum confers greater resistance to *Atherigonasoccata*. This study highlighted that seed treatments significantly enhanced plant vigor, with thiamethoxam 30FS + neem oil achieving the highest vigor rating of 1.00,

followed by thiamethoxam + karanj oil at 1.33, and thiamethoxam alone at 1.67. In contrast, sprays with karanj oil and neem oil had the lowest vigor ratings of 3.67 and 3.33, respectively, while imidacloprid treatments showed moderate effectiveness with a rating of 2.00. These results underscore the critical role of plant vigor in enhancing resistance to *A. soccata*(Table 1).

Table 1: Impact of various treatments on plant stand and vigour in controlling *A. soccata* in forage sorghumvariety swarna during*Kharif* 2020 at Hisar, Haryana

Treatment	Plant stand at 12 DAE*	Plant vigour (1-5)*
Imidacloprid 70WS S.T.* @ 3ml/kg	309.00	2.00
Thiamethoxam 30FS S.T. @ 10ml/kg	311.66	1.67
Neem oil @ 2% spray	264.00	3.33
Karanj oil @ 2% spray	260.33	3.67
Imidacloprid 70WS S.T. @ 3ml/kg + Neem oil@ 2% spray	289.66	2.00
Imidacloprid 70WS S.T. @ 3ml/kg + Karanj oil @ 2% spray	300.33	2.00
Thiamethoxam 30FS S.T. @ 10ml/kg + Neem oil @ 2% spray	305.66	1.00
Thiamethoxam 30FS S.T. @ 10ml/kg + Karanj oil @ 2% spray	302.33	1.33
Control	256.00	4.67
C.D. (P=0.05)	(23.82)	(0.98)
SE(m)±	(7.87)	(0.30)
C.V. %	(4.72)	(15.66)

**Mean of three replications, DAE: Days after emergence*

3.2 Number of eggs and dead heart (%)

At 7 days after emergence (DAE), the number of shoot fly eggs per five sorghum plants ranged between 5.67 and 8.00, with no statistically significant differences observed among the treatments. The highest egg count of 8.00 eggs was recorded in the control plot and with karanj oil at 2%, while thiamethoxam 30FS, both alone and in combination with karanj oil, exhibited the lowest egg count of 5.67 eggs.By 14 DAE, all treatments had significantly reduced shoot fly oviposition compared to the control. Egg counts at this stage ranged from 11.67 with neem oil @ 2% to 22.34 in the control plot. Neem oil spray and thiamethoxam + neem oil treatments resulted in the lowest egg counts, whereas the control exhibited the highest counts (Table 2). These observations align with previous studies by Subbarayudu et al. [8] and Joshi et al. [9], which found that botanical treatments effectively reduced egg numbers, highlighting their potential for managing shoot fly infestations in sorghum.

At 14 days after emergence (DAE), all treatments significantly reduced dead heart formation compared to the control, with thiamethoxam 30FS + neem oil showing the lowest rate at 11.07%, followed closely by thiamethoxam 30FS + karanj oil at 11.45%. The control plot had the highest dead heart formation (22.87%). By 21 DAE, thiamethoxam 30FS + neem oil continued to be the most effective treatment, reducing dead hearts to 14.44%, while the control plot exhibited 28.48% dead hearts. Thiamethoxam 30FS + karanj oil was also effective, with a dead heart rate of 15.21%. At 28 DAE, the combination of thiamethoxam 30FS + neem oil remained superior, minimizing dead hearts to 19.98%, compared to 47.35% in the control plot. Thiamethoxam 30FS + karanj oil also performed well, reducing dead hearts to 22.14%. Overall, the combination of thiamethoxam 30FS with neem oil consistently outperformed other treatments in reducing dead heart formation (Table 2). The research supports previous findings that thiamethoxam and imidacloprid seed treatments effectively reduce shoot fly damage in sorghum, with comparable results reported by Dawareet al. [10], Sandhu [11]and Saxena [12]. Botanicals like neem and karanj oil also showed significant reductions in dead heart formation, as observed by Joshi et al. [9]. These treatments consistently minimized shoot fly injury across various studies.

Table 2: Effect of various treatments on the oviposition by the shoot fly in sorghum variety swarna during *Kharif* 2020 at Hisar, Haryana

Treatment	Number of eggs per five plant		Per cent dead hearts		
	7 DAE	14 DAE	14 DAE	21 DAE	28 DAE
Imidacloprid 70WS S.T.* @ 3ml/kg	6.34 (2.70)*	15.07 (22.82)**	15.07 (22.82)**	19.91 (26.48)**	30.16 (33.28)**
Thiamethoxam 30FS S.T. @ 10ml/kg	5.67 (2.57)	14.45 (22.32)	14.45 (22.32)	19.28 (26.03)	28.99 (32.55)
Neem oil @ 2% spray	7.67 (2.92)	17.31 (24.57)	17.31 (24.57)	21.41 (27.52)	31.41 (34.05)
Karanj oil @ 2% spray	8.00 (2.99)	18.26 (25.29)	18.26 (25.29)	22.53 (28.29)	33.08 (35.07)
Imidacloprid 70WS S.T. @ 3ml/kg + Neem oil @ 2% spray	6.67 (2.75)	12.58 (20.76)	12.58 (20.76)	17.00 (24.33)	24.67 (29.77)
Imidacloprid 70WS S.T. @ 3ml/kg + Karanj oil @ 2% spray	7.00 (2.81)	12.76 (20.92)	12.76 (20.92)	18.21 (25.25)	26.14 (30.73)
Thiamethoxam 30FS S.T. @ 10ml/kg + Neem oil @ 2% spray	6.00 (2.64)	11.07 (19.41)	11.07 (19.41)	14.44 (22.32)	19.98 (26.512)
Thiamethoxam 30FS S.T. @ 10ml/kg + Karanj oil @ 2% spray	5.67 (2.58)	11.45 (19.77)	11.45 (19.77)	15.21 (22.93)	22.14 (28.05)
Control	8.00 (2.99)	22.87 (28.55)	22.87 (28.55)	28.48 (32.24)	47.35 (43.46)
C.D. (P=0.05)	N/A	(1.18)	(1.18)	(1.96)	(2.79)
SE(m)±	(0.15)	(0.40)	(0.40)	(0.67)	(0.88)
C.V. %	(9.47)	(3.10)	(3.10)	(4.03)	(5.60)

**Figures in parentheses are (√x+1) transformed values **Figures in parentheses are arc sine transformed values, DAE: Days after emergence*

3.3 Plant height and Green fodder yield

All treatments significantly outperformed the control in both plant height and green fodder yield. The combination of thiamethoxam 30FS @ 10ml/kg + neem oil @ 2% produced the highest mean plant height of 86.93 cm, followed closely by thiamethoxam 30FS + karanj oil @ 2% at 83.66 cm. In contrast, the control plot recorded the lowest height at 58.06 cm, while neem oil @ 2% and karanj oil @ 2% reached 74.46 cm and 70.6 cm, respectively. The remaining treatments showed plant heights ranging between 79.73 cm and 82.00 cm (Table 3). These results challenge the findings of Sridhar et al. [13] and Birangal et al. [14], who observed the greatest plant height in plots treated with imidacloprid.

In terms of green fodder yield (GFY), thiamethoxam 30FS @ 10ml/kg + neem oil @ 2% achieved the highest yield of 309.60 q/ha, closely followed by the combination of thiamethoxam + karanj oil @ 2% at 305.55 q/ha. The lowest yield was recorded with karanj oil @ 2%, at 225.64 q/ha. Treatments combining imidacloprid 70WS @ 3ml/kg with either neem or karanj oil yielded 295.74 q/ha and 290.83 q/ha, respectively (Table 3). These findings align with those of Daware et al. [10], who reported comparable results with thiamethoxam seed treatments, as well as the work of Sable [15] and Joshi et al. [9], who observed significant yields with neem oil treatments. The synergy between thiamethoxam and neem oil proved to be the most effective in optimizing both plant height and green

fodder yield, highlighting its potential as a superior treatment for sorghum shoot fly management.

Table 3: Effect of different treatments on the height and green fodder yield of sorghum swarna during *Kharif* 2020 at Hisar, Haryana

Treatment	Plant Height (cms.)	GFY (q/ha)
Imidacloprid 70WS S.T.* @ 3ml/kg	79.73	273.14
Thiamethoxam 30FS S.T. @ 10ml/kg	80.73	278.77
Neem oil @ 2% spray	74.46	232.26
Karanj oil @ 2% spray	70.60	225.64
Imidacloprid 70WS S.T. @ 3ml/kg + Neem oil @ 2% spray	82.00	295.74
Imidacloprid 70WS S.T. @ 3ml/kg + Karanj oil @ 2% spray	81.56	290.83
Thiamethoxam 30FS S.T. @ 10ml/kg + Neem oil @ 2% spray	86.93	309.60
Thiamethoxam 30FS S.T. @ 10ml/kg + Karanj oil @ 2% spray	83.66	305.55
Control	58.06	162.63
C.D. (P=0.05)	(5.35)	(10.88)
SE(m)±	(1.77)	(3.59)
C.V. %	(3.96)	(2.36)

3.4 Incremental cost-benefit ratio

The highest cost-benefit ratio of 1:21 was achieved with imidacloprid 70WS treatment, which resulted in a yield of 273.14 q/ha. Thiamethoxam 30FS at 10 ml/kg followed with a cost-benefit ratio of 1:11.5 and a yield of 278.77 q/ha. Other treatments exhibited lower ratios, ranging from 1:1.6 to 1:0.78 (Table 4). These results align with Anita [16], who reported enhanced net returns with imidacloprid 70WS (2 g/kg), and Chikkarugi et al. [3], who observed improved returns with imidacloprid 70WS (5 g/kg). Additionally, Gautam et al. [17] found that neem oil offered a competitive cost-benefit ratio of 1:1.48.

Table 4: Economics of different treatments against *A.soccata* in forage sorghum swarna during *Kharif* 2020 at Hisar, Haryana

Treatment	GFY (q/ha)	Increase yield over the control (q/ha)	Cost of the increased yield (Rs/ha)	Cost of the treatment (Rs/ha)	Incremental cost-benefit ratio (ICBR)
Imidacloprid 70WS S.T.* @ 3ml/kg	273.14	110.50	13813.62	660	1:21
Thiamethoxam 30FS S.T. @ 10ml/kg	278.77	116.13	14516.75	1260	1:11.5
Neem oil @ 2% spray	232.26	69.63	8703.75	10220	1:0.9
Karanj oil @ 2% spray	225.64	63.00	7876.12	10120	1:0.78

Imidacloprid 70WS S.T. @ 3ml/kg + Neem oil @ 2% spray	295.74	133.10	16637.75	10680	1:1.5
Imidacloprid 70WS S.T. @ 3ml/kg + Karanj oil @ 2% spray	290.83	128.19	16024.25	10780	1:1.4
Thiamethoxam 30FS S.T. @ 10ml/kg + Neem oil @ 2% spray	309.60	146.96	18371	11380	1:1.6
Thiamethoxam 30FS S.T. @ 10ml/kg +Karanj oil @ 2% spray	305.55	142.91	17864.62	11380	1:1.5
Control	162.63	_	_	_	_

** S.T. = Seed treatment,*
Costs of inputs based on prevailing market prices: Fodder sorghum Rs 125/q
Imidacloprid 70WS Rs 2000/l, Thiamethoxam 30FS Rs 1800/lNeem oil Rs 465/l, Karanj oil Rs 460/lLabour cost Rs 360/day/ha, Water/ha 500 l

4. CONCLUSION

Thiamethoxam 30FS @ 10ml/kg + neem oil @ 2% emerged as the most effective treatment, significantly reducing shoot fly infestation while enhancing plant vigour, height, and green fodder yield. This combination minimized egg laying and dead heart formation, outperforming other treatments. Imidacloprid 70WS showed the highest ICBR, highlighting its cost-effectiveness. The integration of seed treatments and botanicals offers a potent strategy for improving pest control and crop productivity.

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