The Pharma Innovation Journal 2023; SP-12(9): 359-363

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(9): 359-363

www.thepharmajournal.com
Received: 16-06-2023
Accepted: 22-08-2023

NV Radadiya
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

BK Davda
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

TV Ghevariya
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

KG Kanzariya
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

HN Der
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

AD Varma
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

Corresponding Author:
NV Radadiya
Main Sorghum Research Station, Navsari Agricultural University, Surat, Gujarat, India

Evaluation of insecticide and botanical combination for management of sorghum shoot fly and stem borer

NV Radadiya, BK Davda, TV Ghevariya, KG Kanzariya, HN Der and AD Varma

Abstract
To find out bio efficacy of combination of different insecticides with Neem based pesticides 1500 ppm for management of sorghum shoot fly and stem borer, the trial was conducted at Main Sorghum Research Station, Navsari Agricultural University, Athwa Farm, Surat, Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa and Krishi Vigyan Kendra, Navsari Agricultural University, Dediapada during *Kharif* 2015 to *Kharif* 2017. In pooled analysis over three locations and years from *Kharif* 2015 to *Kharif*2017, minimum percent of shoot fly dead heart were observed in treatment T_{10} (9.41%) and it was at par with treatment T_4 (10.40%) and T_2 (10.90%). In case of percent stem borer dead heart less damage was recorded in treatment T_{10} and it was found statistically at par with treatment T_4 (15.78%). Maximum yield was recorded in treatment T_{10} i.e. 2827.99 kg/ha.

Keywords: Insecticides, botanical, sorghum, shoot fly, stem borer, dead hearts

Introduction
Sorghum (*Sorghum bicolor* (L.) Moench), commonly known as Jowar, in the Indian sub-continent is native to Africa and one of the main staples for the world's poorest people. Sorghum mostly grows well in *Kharif* as well as *Rabi* season. Sorghum is mostly used for human food as grain, animal fodder and production of alcoholic beverages and biofuel. Most cultivated varieties are drought and heat tolerant and are especially important in arid regions, where the grain is one of the staples food for poor and rural people. These varieties form important components of forage in many tropical regions. *S. bicolor* is an important food crop in Africa, Central America and South Asia and is the fifth-most important cereal crop grown in the world after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.). In the early stages of the plant growth, sorghum can contain levels of hydrogen cyanide, hordenine and nitrates which are lethal to grazing animals. When stressed by drought or heat, plants can also contain toxic levels of cyanide and nitrates at later stages in growth (Anon., 2018) [2]. Sorghum [*Sorghum bicolor* (L.) Moench] is the 5th most important cereal in the world after wheat, maize, rice and barley. India contributes 9.45% of the world's sorghum production covering 5.82 million ha, producing 5.39 million tones with a productivity of 926 kg/ha (Gite *et al.*, 2015) [6]. The sorghum grain is used for food, preparation of beverages and biofuel, while the stalks are used for animal feed, fuel, and fence construction in some rural areas. Over 90% of sorghum grain is for food, being a staple diet in parts of Asia and Africa (Olabimpe *et al.*, 2021) [9].

The grain contains a very high amount of major nutrients *viz.*, carbohydrate (72.6%), protein (10.4%), fat (1.9%), crude fiber (1.6%) and minerals (1.6%) with a high digestibility. In India, Maharashtra, Karnataka, Madhya Pradesh, Andhra Pradesh, Rajasthan, Tamil Nadu, Gujarat, Uttar Pradesh and Haryana are the major sorghum growing states. Sorghum covering about 5.62 million hectares with 4.57 million tonnes of production under irrigated and unirrigated conditions while in Gujarat sorghum covering about 0.11 million hectares with 0.15 million tonnes of production (Anon., 2019) [3].

Introduction of hybrid and high yielding cultivars coupled with the use of high doses of fertilizers and irrigation has resulted in an increased susceptibility to pests and diseases hence plant protection is very essential to harvest good crop. So far, over 150 insect pests have been reported on sorghum (Abdisalam, 2017) [1] among them sorghum shoot fly (*Atherigona soccata*) and stem borer (*Chilo partellus*) are important. Damage due to insect pests is one of the major limitations for low grain yield of sorghum.

In India, nearly 32.1 percent of actual produce is lost due to insect and pests (Borad and Mital, 1983) [5].

The Sorghum Shoot fly, *A. soccata* an Antomycid fly, in the family Muscidae, order Diptera is the primary pest of economic importance of sorghum. Sukhani and Jotwani (1980) [13] reported that the losses due to shoot fly was 85.87 percent in grain and 44.86 percent in fodder yield. Singh *et al.*, (2017) [11] reported that Sorghum Shoot fly, *A. soccata* t is one of the most destructive pest at the seedling stage, which causes yield losses of 68.6 and 75.6 percent in terms of fodder and grain yield, respectively. Shoot fly (*Atherigona soccata*) is a major grain yield limiting factor that causes damage when sowings are delayed in rainy season. The early-sown crop escapes from shoot fly damage but the late-sown crop in most cases is affected. Agronomic practices, natural enemies, synthetic insecticides and host plant resistance have been employed for shoot fly management to minimize the losses. Early planting is not always feasible as the sowing window is short in rainfed situations and there exists a competition with other crops for sowing.

Stem borers belonging to Lepidoptera playing the most significant role. *Chilo partellus* is highly invasive, and has partially displaced some indigenous stem borers in India attacking all cereals (Kfir *et al*., 2002) [7].

Materials and Methods

To find out bio efficacy of combination of different insecticides with Neem based pesticides 1500 ppm for management of sorghum shoot fly and stem borer, the trial was conducted at Main Sorghum Research Station, Navsari Agricultural University, Athwa Farm, Surat, Sorghum Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa and Krushi Vigyan Kendra, Navsari Agricultural University, Dediapada during *Kahrif* 2015 to *Kharif* 2017. The experiment was conducted in randomised block design with eleven treatments including control and three replications. Normal tillage operation was carried out to bring the experimental plot to proper tilth and ridges. Treated seeds with different insecticides were sown except in control plot. The spray and whorl application of insecticides and botanicals was done at 30 days after sowing. The observations on sorghum shoot fly were recorded at 14, 21 and 28 days after treatment and stem borer were recorded at 35 and 45 days after treatment. The number of dead heart caused by Stem borer was counted from the net plots and the percent dead heart was estimated using following formula.

$$\% \text{ SFDH/SBDH} = \frac{\text{No. of SFDH/SBDH Plants}}{\text{Total no. of Plants}} \text{ X } 100$$

Table 1: Treatment Details

1	Seed treatment with Imidacloprid 48 FS @ 7g/ kg seed
2	Seed treatment with Thiamethoxam 30 FS @ 3g/ kg seed
3	T_1 + Neem based pesticides 1500ppm@ 35ml/10 lit. water
4	T_2 + Neem based pesticides 1500ppm@ 35ml/10 lit. water
5	T_1 + Quinalphos 25 EC @ 0.05%
6	T_2 + Quinalphos 25 EC @ 0.05%
7	T_1 + Methyl-o-dematon 25 EC@ 0.05%
8	T_2 + Methyl-o-dematon 25 EC@ 0.05%
9	T_1 + Whorl application with Phorate 10 CG @ 1.0 kg/ha
10	T_2 + Whorl application with Phorate 10 CG @ 1.0 kg/ha
11	Control

Results and Discussion

In pooled analysis over three locations and years from *Kharif* 2015 to *Kharif* 2017, minimum percent of shoot fly dead heart were observed in treatment T_{10} and it was at par with treatment T_4 (10.40%) and T_2 (10.90%). In case of percent stem borer dead heart less damage was recorded in treatment T_{10} (14.08%) and it was at par with treatment T_4 (15.78%). Maximum yield was recorded in treatment T_{10} i.e. 2827.99 Kg/ha.These findings are in accordance with data reported by Balikai (2006) [4], Kumar and Praburaj (2007) [8], Sridhar *et al.*, (2016) [12], Singh *et al.*, (2017) [11] and Ravindra Kumar and Tiwana (2018) [10].

Table 2: Bio efficacy of different insecticides and botanicals against shoot fly in sorghum (Over three Years pooled data)

Sr. No	Treatment	SFDH% at 14 DAE				SFDH% at 21 DAE				SFDH% at 28 DAE			
		Surat	Deesa	Dediapada	Pooled	Surat	Deesa	Dediapada	Pooled	Surat	Deesa	Dediapada	Pooled
1	T_1	22.03 (14.50)	20.46 (13.06)	20.22 (12.35)	20.90 (13.30)	25.34 (18.44)	22.83 (15.84)	25.40 (18.70)	24.52 (17.66)	27.19 (20.98)	25.05 (18.75)	26.91 (20.69)	26.38 (20.14)
2	T_2	17.22 (9.07)	15.15 (7.21)	15.66 (7.92)	16.02 (8.07)	20.32 (12.10)	17.54 (9.35)	20.02 (11.85)	19.29 (11.10)	22.62 (14.92)	19.94 (11.95)	21.60 (13.71)	21.39 (13.53)
3	T_3	23.62 (16.34)	21.05 (13.80)	19.90 (12.00)	21.53 (14.05)	25.51 (18.71)	22.55 (15.42)	24.58 (17.34)	24.21 (17.16)	28.85 (23.63)	24.88 (18.36)	25.55 (18.78)	26.43 (20.26)
4	T_4	16.93 (8.73)	14.83 (7.04)	14.66 (7.34)	15.48 (7.71)	19.28 (10.94)	17.29 (9.23)	19.21 (11.03)	18.59 (10.40)	22.50 (14.69)	19.74 (11.64)	20.99 (12.93)	21.08 (13.09)
5	T_5	22.28 (14.79)	21.19 (14.41)	15.86 (8.91)	19.78 (12.70)	24.04 (16.60)	21.63 (14.17)	23.06 (15.71)	22.91 (15.49)	26.27 (19.67)	23.53 (16.45)	24.41 (17.35)	24.74 (17.82)
6	T_6	17.92 (9.76)	18.63 (11.19)	16.29 (8.44)	17.62 (9.79)	21.43 (13.55)	20.44 (13.10)	21.55 (13.61)	21.14 (13.42)	23.56 (16.04)	23.04 (16.10)	22.91 (15.24)	23.17 (15.79)
7	T_7	23.12 (16.01)	22.06 (15.61)	19.74 (11.96)	21.64 (14.53)	25.37 (18.46)	22.02 (14.67)	24.20 (16.90)	23.86 (16.67)	27.81 (21.89)	24.42 (17.85)	25.44 (18.58)	25.89 (19.44)
8	T_8	17.57 (9.39)	16.57 (8.62)	16.00 (8.14)	16.72 (8.72)	20.73 (12.71)	18.69 (10.82)	20.31 (12.41)	19.91 (11.98)	23.39 (15.84)	20.52 (12.79)	22.25 (14.45)	22.05 (14.36)
9	T_9	20.22 (12.32)	19.08 (11.56)	19.36 (11.70)	19.56 (11.86)	23.16 (15.70)	20.70 (13.02)	22.94 (15.42)	22.27 (14.71)	25.36 (18.39)	22.66 (15.31)	24.56 (17.41)	24.20 (17.04)
10	T_{10}	15.94 (7.84)	14.26 (6.49)	13.77 (6.24)	14.66 (6.86)	18.30 (9.99)	16.21 (8.13)	18.50 (10.41)	17.67 (9.51)	20.76 (12.69)	18.79 (10.69)	20.34 (12.17)	19.97 (11.85)
11	T_{11}	24.91 (17.87)	23.30 (16.81)	22.88 (15.46)	23.70 (16.71)	30.64 (26.36)	28.18 (22.77)	28.67 (23.11)	29.16 (24.08)	36.78 (36.33)	31.33 (27.45)	33.31 (30.34)	33.81 (31.37)
S. Em. (T)		0.82	1.79	1.18	0.61	0.70	1.10	0.61	0.42	1.34	1.24	0.78	0.6
C.D. at 5%		2.32	5.27	3.32	1.70	1.97	3.26	1.72	1.15	3.95	3.65	2.19	1.68

S. Em. (TXS)	1.46	1.52	2.18	1.75	1.16	1.37	1.13	1.23	1.55	1.47	1.41	1.48
C.D. at 5%	NS	4.29	NS	NS	NS	3.89	NS	NS	4.39	4.15	NS	4.1
CV%	12.52	13.99	21.4	16.07	8.71	11.48	8.66	9.59	10.37	11.02	10.02	10.46

Note: Figures in parenthesis are original values while outside are arcs in transformed value

Table 3: Bio efficacy of different insecticides and botanicals against stem borer in sorghum and yield performance. (2015-16 to 2017-18)

Sr. No.	Treatment	SBDH% at 35 DAE				SBDH% at 45 DAE				Yield (Kg/ha.)			
		Surat	Deesa	Dediapada	Pooled	Surat	Deesa	Dediapada	Pooled	Surat	Deesa	Dediapada	Pooled
1	T_1	26.93 (20.71)	23.60 (16.42)	23.87 (16.54)	24.80 (17.89)	28.79 (23.32)	25.26 (30.97)	25.85 (19.25)	20.40 (24.52)	880.66	1906.07	1935.82	1574.18
2	T_2	21.54 (13.70)	21.18 (13.47)	21.16 (13.55)	21.29 (13.57)	23.68 (16.25)	22.61 (27.42)	23.02 (15.62)	15.70 (19.76)	1454.73	2309.73	3244.99	2336.49
3	T_3	27.90 (22.13)	24.51 (17.53)	23.40 (16.51)	25.27 (18.72)	29.64 (24.63)	25.52 (31.41)	25.89 (19.28)	20.93 (25.11)	914.61	1799.57	2041.06	1585.08
4	T_4	21.21 (13.33)	20.67 (12.81)	19.45 (11.73)	20.44 (12.63)	23.18 (15.60)	22.06 (26.87)	21.88 (14.32)	14.79 (18.93)	1563.79	2391.82	3058.57	2338.06
5	T_5	24.68 (17.61)	23.13 (15.81)	22.68 (15.10)	23.50 (16.18)	27.40 (21.25)	24.75 (29.73)	25.05 (18.19)	19.14 (23.06)	1061.73	1943.00	2405.05	1803.26
6	T_6	23.09 (15.50)	22.15 (14.55)	21.77 (14.06)	22.34 (14.70)	25.37 (18.45)	23.37 (28.77)	22.91 (15.55)	16.68 (20.93)	1319.96	2193.15	2786.89	2100.00
7	T_7	26.28 (19.82)	24.01 (16.98)	24.27 (17.05)	24.85 (17.95)	28.49 (22.88)	25.48 (31.09)	25.76 (19.28)	20.39 (24.42)	1036.22	1698.19	2318.42	1684.28
8	T_8	22.11 (14.29)	21.55 (13.64)	21.34 (13.54)	21.67 (13.82)	24.46 (17.23)	23.56 (28.19)	23.37 (16.01)	16.48 (20.48)	1397.12	2248.81	3085.16	2243.69
9	T_9	23.91 (16.61)	22.50 (15.02)	22.01 (14.22)	22.81 (15.28)	26.17 (19.63)	24.32 (29.20)	23.33 (15.99)	17.66 (21.61)	1156.38	1848.83	3090.14	2031.78
10	T_{10}	20.32 (12.30)	19.48 (11.41)	17.17 (9.89)	18.99 (11.20)	22.49 (14.75)	20.83 (23.31)	20.57 (12.82)	13.48 (16.96)	1640.95	2941.97	3901.06	2827.99
11	T_{11}	32.01 (28.37)	29.12 (23.91)	27.84 (21.91)	29.66 (24.73)	37.25 (36.99)	33.10 (29.97)	32.61 (29.13)	32.03 (32.03)	706.79	1374.13	1673.57	1251.50
S. Em. (T)		0.78	1.06	0.95	0.53	1.31	1.00	0.78	0.5	86.28	66.05	177.19	89.46
C.D. at 5%		2.21	2.98	2.67	1.48	3.87	2.83	2.20	1.39	254.40	186.18	522.70	252.20
S. Em. (TXS)		1.25	1.99	1.57	1.63	1.04	1.86	1.37	1.46	54.97	114.83	170.19	122.71
C.D. at 5%		NS	NS	NS	NS	2.95	NS	NS	NS	155.463	NS	481.37	340.13
CV%		8.81	15.03	12.2	12.15	6.69	13.09	9.64	9.98	7.97	9.66	10.98	10.74

Table 4: Bio efficacy of different insecticides and botanicals against shoot fly in sorghum. (Pooled over location and years)

Sr. No.	Treatment	SFDH%							
		Surat		Deesa		Dediapada		Pooled	
1	T_1	24.85 (17.97)		22.78 (15.88)		24.18 (17.25)		23.94f (17.03)	
2	T_2	20.05 (12.03)		17.54 (9.51)		19.10 (11.16)		18.90ab (10.90)	
3	T_3	25.99 (19.56)		22.83 (15.86)		23.35 (16.04)		24.06f (17.16)	
4	T_4	19.57 (11.46)		17.29 (9.30)		18.29 (10.43)		18.38ab (10.40)	
5	T_5	24.19 (17.02)		22.12 (15.01)		21.12 (13.99)		22.48ef (15.34)	
6	T_6	20.97 (13.12)		20.71 (13.46)		20.25 (12.43)		20.64cd (13.00)	
7	T_7	25.43 (18.79)		22.83 (16.04)		23.13 (15.81)		23.80f (16.88)	
8	T_8	20.56 (12.65)		18.60 (10.74)		19.52 (11.67)		19.56bc (11.69)	
9	T_9	22.91 (15.47)		20.82 (13.30)		22.29 (14.85)		22.01de (14.54)	
10	T_{10}	18.33 (10.17)		16.42 (8.44)		17.54 (9.61)		17.43a (9.41)	
11	T_{11}	30.77 (26.85)		27.60 (22.34)		28.29 (22.97)		28.89g (24.05)	
		S. Em. ±	CD (5%)	S. Em. ±	CD (5%)	S. Em. ±	CD (5%)	S. Em. ±	CD (5%)
Treatment(T)		0.46	1.28	0.48	1.32	0.61	1.70	0.56	1.65
Period(P)		0.24	0.67	0.25	0.69	0.32	0.89	0.62	2.45
Location (L)								2.25	NS
Year(Y)		0.36	1.42	0.58	2.29	0.25	0.96	0.41	NS
T x P		0.80	2.21	0.82	NS	1.06	NS	0.50	1.39
T x L								0.89	NS

T x Y	0.42	1.15	0.43	1.19	0.56	NS	0.50	1.39
P x L							0.68	NS
P x Y	0.80	2.21	0.82	2.28	1.06	2.95	0.41	1.17
L x Y							0.41	1.17
T x P x L							0.87	NS
T x P x Y	1.38	NS	1.43	NS	1.84	NS	0.87	NS
T x L x Y							0.87	2.40
P x L x Y							0.71	2.02
T x P x L x Y							1.50	NS
C. V. %	10.37		11.84		14.81		11.91	

Note: 1) Letters in common are statistically at par with 5% level of significance within a column.

Table 5: Bio efficacy of different insecticides and botanicals against stem borer in sorghum. (Pooled over location and years)

Sr. No.	Treatment	SBDH%							
		Surat		Deesa		Dediapada		Pooled	
1	T_1	27.86 (22.02)		24.29 (23.70)		24.86 (17.90)		25.72ef (21.20)	
2	T_2	22.61 (14.97)		22.88 (20.44)		22.09 (14.58)		22.20bc (16.67)	
3	T_3	28.77 (23.38)		24.78 (24.47)		24.65 (17.90)		26.14f (21.91)	
4	T_4	22.19 (14.47)		22.31 (19.84)		20.67 (13.02)		21.41ab (15.78)	
5	T_5	26.04 (19.43)		23.87 (22.77)		23.87 (16.65)		24.62def (19.62)	
6	T_6	24.23 (16.97)		23.04 (21.66)		22.34 (14.81)		23.11bcd (17.81)	
7	T_7	27.38 (21.35)		24.85 (24.04)		25.02 (18.16)		25.72ef (21.18)	
8	T_8	23.28 (15.76)		22.96 (20.92)		22.35 (14.77)		22.73bcd (17.15)	
9	T_9	25.04 (18.12)		22.91 (22.11)		22.67 (15.11)		23.71cde (18.44)	
10	T_{10}	21.41 (13.52)		21.08 (17.36)		18.87 (11.35)		20.14a (14.08)	
11	T_{11}	34.63 (32.68)		30.60 (26.94)		30.22 (25.52)		31.99g (28.38)	
		S. Em. ±	CD (5%)	S. Em. ±	CD (5%)	S. Em. ±	CD (5%)	S. Em. ±	CD (5%)
Treatment (T)		0.46	1.28	0.77	2.15	0.60	1.67	0.68	2.01
Period (P)		0.20	0.55	0.33	0.92	0.25	0.71	0.26	1.57
Location (L)								2.10	NS
Year (Y)		0.25	0.96	0.47	1.86	0.33	1.31	0.13	0.37
T x P		0.75	NS	1.33	NS	1.03	NS	0.52	NS
T x L								0.63	NS
T x Y		0.34	0.95	0.57	NS	0.44	1.23	0.63	1.75
P x L								0.18	NS
P x Y		0.65	1.82	1.09	NS	0.84	NS	0.18	0.52
L x Y								0.22	0.64
T x P x L								0.89	NS
T x P x Y		1.12	NS	1.88	NS	1.46	NS	0.89	NS
T x L x Y								1.10	NS
P x L x Y								0.31	NS
T x P x L x Y								1.55	NS
C. V. %		7.55		13.73		10.81		11.03	

Conclusion

For effective management of shoot fly and stem borer infesting to sorghum crop, seeds should be treated with Thiamethoxam 30 FS @ 3g/ kg seed before sowing and followed by Whorl application with Phorate 10 CG @ 1.0 kg/ha or application of Neem based pesticides 1500ppm @ 35ml/ 10 lit. of water after 30 days of sowing.

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