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Impact of abiotic factors on the incidence of sorghum shoot fly *Atherigona soccata*

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Abstract
An experiment entitled "Impact of Abiotic factors on the Incidence of Sorghum shoot fly *Atherigona soccata*." was conducted at the Sorghum Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist: Ahmednagar (Maharashtra) during *rabi* 2021-22. During the course of study, sowing was done on 17th October 2021 for screening of different genotypes of sorghum against shoot fly, whereas for studying the effect of sowing dates on incidence of sorghum shoot fly on six dates at 15 days intervals starting 1st from 31st August 2021.Data on weather parameters were collected to correlate the influence of the abiotic factors with incidence of sorghum shoot fly. The results showed that most of the important rabi sorghum crops suffered heavily from the incidence of major insect pests resulting into reductions in their yields, when sowings were delayed. Correlation study indicated that rainfall in positively correlated with shoot fly infestation whereas maximum temperature negatively correlated with shoot fly infestation.

Keywords: Sorghum, shoot fly, weather parameters, genotypes, sowing dates

Introduction

Sorghum is the fifth most important cereal crop worldwide, behind wheat, rice, maize and barley and one of the most significant in the semi-arid tropics (SAT) (Bantilan *et al*., 2004) [2]
Sorghum is regarded as "One of the truly indispensable crops" because of its numerous applications and adaptations. It is one of the most efficient crops for using water and converting solar energy, as well as being highly energetic, drought-tolerant and environmentally benign. Because of its ability to withstand drought, Sorghum crop is a preferred in tropical, warmer and semi-arid regions of the world that experience extreme heat and water stress (Paterson, *et al*., 2009) [11].

About 150 distinct insect pests infest the sorghum crop during its entire life cycle, from seedling to harvest (Seshu Reddy and Davies 1978; Jotwani *et al*., 1980; Sharma, 1985) [13, 6, 14]. These insects, which can have several generations in a single season and injure sorghum in diverse ways at various stages of development, result in several unsustainable losses since they can have many generations in a single season.

Among the various sorghum pests, the Shoot Fly, *Atherigona soccata* (Diptera: Muscidae), is one of the main obstacles to sorghum production during the seedling stage of the crop (Nwanze *et al*., 1990; Sherwill *et al*., 1999) [9, 16]. Shoot fly infestations begin infesting sorghum seedlings seven days after emergence and lasts for 30 days after emergence (DAE) of the crop.

The sorghum shoot fly, *Atherigona soccata*, lays its eggs on the third to sixth basal leaves, which are parallel to the leaf midrib and have an elongated cigar shape. (Padmaja *et al*., 2010) [10]. In one to two days, an egg hatches into a maggot that descends down the leaf sheaths and crawls to the centre of the plant, where it slashes the central leaf, causing the whorl leaf to dry out and die, which causes the dead heart sign (Deeming, 1972) [4]. The core whorl's decomposing tissue serves as food for the maggot (Ponnaiya, 1951) [12]. The life cycle concludes in 17 to 21 days. It is the one of the most important pests of jowar in Maharashtra is the sorghum shoot fly. It produces dead hearts in the early seedling stage of the crop, which lowers plant population and results in a noticeable loss in output of up to 75.60% in grain and 68.90% in fodder (Khandare *et al*., 2013) [8].

Understanding the mechanisms underlying resistance as well as the elements involved in or linked to insect resistance is essential for the development of sorghum cultivars that are resistant to insects. When developing insect resistant varieties to fight emerging insect biotypes, knowledge of insect resistance mechanisms is helpful

Cultural techniques, resistant cultivars, natural enemies and insecticides are the main elements of pest management in an agro-ecosystem. Due to the low returns, farmers typically do not employ plant protection techniques, yet insecticides have a significant role in reducing the number of insect pests.

The creation of cultivars that are resistant to shoot flies, stem borers, midges, shoot bugs, aphids and head bugs has received significant attention. Significant progress has been achieved in the creation of methods for screening for insect resistance, locating the source of resistance and transferring resistance to high-yielding sorghum cultivars (Sharma *et al*. 1992) [15].

Certain insect species can be best controlled through cultural practices. The majority of sorghum pests can be avoided by changing the planting date, which will undoubtedly increase production and minimize shoot fly infestation. The timing of sowing and the choice of varieties are useful agronomic tools that can be utilized to reduce damage from insect pests. The diversity and severity of pests in a given area are significantly influenced by the selection of resistant or tolerant varieties. By creating synchronicity between host plants and pests or by synchronizing insect pests with their natural foes, plants have their own sophisticated defense systems that serve to reduce pest damage

There are no additional costs or pest management application skills required during planting time. Therefore, the current studies are being conducted to determine the relative impact of sowing dates on the prevalence of various insect pests and sorghum productivity under Maharashtra conditions. Considering seriousness of this pest, an effort has been made to research the meteorological conditions related to the incidence of the shoot fly and predict its occurrence.

Materials and Methods

A field trial was carried out in Randomized Block Design with six sowing dates of sorghum replicated four times having plot size 4 m x 2.7 m with inter and intra row spacing of 45cm &15 cm respectively. (Table 1), during *rabi* 2021-22 at Sorghum Improvement Project at MPKV, Rahuri. The seeds of sorghum variety ‘Phule Yashomati’ were sown on six dates at 15 days intervals starting 1st from 31st August 2021,whereas for screening of different genotypes of sorghum against shoot fly sowing of fourteen genotypes was done during 17th October 2021 in a plot size 4.0 x 2.7 m. with plant spacing 45 x 15 cm. The treatments are illustrated in (Table 1). The observations were registered at sowing intervals on physical traits such as plant population, number of eggs per ten plants, dead heart (%) at 14 as well as 28 DAE due to shoot fly infestation for studying the effect of sowing dates on incidence of sorghum shoot fly. In order to evaluate the different genotypes of sorghum against shoot fly, The observations were registered for each genotype on physical traits such as plant population (%), seedling vigour, leaf glossiness, days required to 50 per cent flowering, number of eggs per five plants, dead heart (%) at 14 as well as 28 DAE due to shoot fly infestation, dead heart (%) due to stem borer at 45 DAE, fall armyworm infestation (%) and yield. Data on weather parameters *viz*., temperature, relative humidity and rainfall were collected from the meteorological observatory, Sorghum Improvement Project, MPKV, Rahuri to correlate the influence of the abiotic factors with the incidence of sorghum shoot fly.

Table 1: Treatment details

Treatment No.	Treatments
T_1	31st August, 2021
T_2	15th September, 2021
T_3	30th September, 2021
T_4	15th October, 2021
T_5	31st October, 2021
T_6	15th November, 2021

Results and Discussion

To study the effect of sowing dates on incidence of sorghum shoot fly

The lowest oviposit ion rate (1.17) was recorded when the crop was sown on 31st August and maximum oviposit ion rate (3.01) was recorded when the sowing of the sorghum crop was delayed up to 15th November. The shoot fly attack increased with the delaying sowing.

In case of dead hearts, At 14 DAE, The minimum percentage of dead hearts were recorded in the plots sown on 31st August (1.71%) followed by 15th September (3.28%), 30th September (6.10%), 15th October (13.84%), 31st October (14.07%) and 15th November (17.08%). The dead heart formation increased as the sowing was delayed. At 28 DAE, The lowest dead heart percentage observed on sowing of 31st August 2021 (2.91%). The formation of dead hearts gradually increased with the subsequent sowings and reached its maximum level when the sorghum crop was sown on 15th November (18.58%). The shoot fly attack increased with the delay in sowing. The last sowing date i.e., 15th November was found very conducive to the development of shoot fly.

The highest grain yield observed in the plot sown on 31st August (414.67 gm), followed by 15th September (354 gm), 30th September (334.33 gm), 15th October (304.33 gm), 31st October (262.33 gm) and 15th November (249.47 gm). Similarly, the highest fodder yield observed in the plot sown on 31st August (0.75 kg), followed by 15th September (0.62 kg), 30th September (0.49 kg), 15th October (0.41 kg), 31st October (0.33 kg) and 15th November (0.28 kg).

The results of the present studies in respect to effect of sowing dates on shoot fly infestation, are in agreement with these findings. Gandhale *et al.* (1985) [5] reported significant increase in Number of eggs laid and dead hearts percentage due to delayed sowing. Shivpuje *et al.* (l976) [17] indicated that sowing up to middle September could be considered safe period under Parbhani condition. Gandhale *et al.* (1985) [5] reported significant increase in number of eggs laid and dead hearts percentage due to delayed sowing.

Similar results in respect of effect of sowing dates on yield was documented by Firke *et al*, (1972) [4] studied that as the sowing was delayed there was decrease in yield in all the sowings. Solanke, (1987) [18] revealed that the earlier sowings, 20th September and 30th September recorded higher yields. The relative study as documented could support the present results.

To evaluate the sorghum genotypes against major insect pests.

During the field screening, per plot highest plant population per cent was recorded by the genotypes RSV 1959 (92.30%), RSV 1996 (91.29%), RSV 1687 (90.73%), RSV 2176 (92.04) and by resistant check IS-18551 (92.01%), whereas the minimum plant population per cent was observed by test entry RSV 1918 (84.88%) and susceptible check DJ 6514

(83.62%).

Maximum seedling vigor at 12 days after emergence was recorded by test entry RSV 1959 and local check RSV 1188 (1.33), while the susceptible check DJ 6514 recorded lowest seedling vigour (4.00).

The leaf glossiness was highest i.e., 1.00 in resistant check IS 2205 as well as the resistant check IS-18551and the local check RSV1188, recorded higher leaf glossiness i.e., 1.33 glossiness The susceptible checks Swarna and DJ-6514 scored the lowest glossiness i.e., 3.33 out of all the entries.

The genotype RSV 1959 (90.66 days) recorded minimum days required for 50% flowering followed by RSV 1687 (94.33 days) Whereas RSV 1918 (95.32) and RSV 2397 (95.33 days). RSV- 1976 (104.32 days, RSV-1996 (103.66 days) and RSV 1188 (103.67)

The minimum numbers of eggs per five plants were observed on resistant checks IS-18551 (1.01). The IS-2205 (1.32) resistant check and RSV-1188 (1.32) also recorded minimum number of eggs indicating that they were at par with the genotypes RSV-2397 and RSV-2155 (2.34).

Among the fourteen test entries, resistant checks IS-18551 (6.81%) recorded the lowest dead hearts per cent at 14 DAE followed by IS-2205 (7.29%) and RSV 1188 (8.61%). Among the test entries RSV 1959 (8.81%) recorded the lower dead hearts which was at par with RSV 2155 (9.61%), RSV-2397 (11.01%) and these entries were considered to be promising.

Among the fourteen test entries, resistant check IS-18551 (11.98%) recorded the lowest dead hearts per cent at 28 DAE subsequently by IS-2205 (12.61%). The test entries RSV 1959 (14.42%), RSV-2155 (15.39%) and RSV-2397 (15.73%) were considered to be promising and recorded lowest dead heart percentage and these genotypes were at par with local check RSV-1188 (14.01%).

The incidence of stem borer was varied from 6.45 to 18.16 per cent in test entries while in checks it was ranged from 7.02 to 16.55 per cent. The lower percentage of dead hearts noticed in the genotype RSV 1959 (6.45%) and local check RSV 1188 (7.02%). The next lower per cent of dead heart was noticed in resistant check IS-18551 (7.62%) and was at par with test entries RSV 1687 (8.14) RSV 2155 (8.18%), RSV 2397 (9.00%) and these genotypes could be regarded as resistant lines.

Data recorded on fall armyworm per cent showed non-significant differences among test entries. The minimum fall armyworm percentage was observed in test entries RSV 1959 (4.01%), RSV- 2176 (4.18%), RSV-1996 (4.23%), RSV 1976 (4.29%) followed by RSV 2155 as well as RSV1687 which recorded 4.36 per cent and RSV 1410 as well as RSV 1918 which recorded 4.42 per cent.

Significantly maximum grain yield recorded in test entry RSV 2155 (299.68 g) followed by RSV 1959 (284.34 g), RSV-2397 (283.01g) which were at par with each other followed by RSV 1687 (221.00 g), RSV-1188 (213.34 g), RSV 2176 (202.68 g) which were at par with each other.

Significantly maximum fodder yield was observed in the test entry RSV 1959 (2.01 kg) and next higher fodder yield was observed in the test entries, RSV 2155 (1.97 kg), RSV 2397 (1.89 kg), local check RSV-1188 (1.87 kg) which were at par with each other, followed by RSV 2176 (1.59 kg), RSV 1996 (1.53 kg) and were also at par with one another.

To study the correlation of abiotic factors with incidence of sorghum shoot fly

In case of egg count, correlation analysis indicated that maximum temperature (r = - 0.217) and RH I (r = - 0.172) had negative correlation with egg count thereby an increase in maximum temperature and relative humidity at morning resulted in falling in egg count. However, the RH II (0.551) and rainfall (0.147) had a positive correlation with egg count. The minimum temperature (0.631) had a significant positive correlation with egg count.

In case of dead hearts caused by shoot fly, the result on correlation studies with weather variables indicated that maximum temperature (-0.200), minimum temperature (-0.286) and RH II (- 0.217) had a negative correlation with dead heart formation. There was decline in dead hearts when the maximum temperature and RH at 7 AM increased. Whereas, RH I (0.443) and rainfall (0.580) had a significant positive correlation with dead heart formation.

Result of present study in respect to correlation with egg count and weather parameters, found in agreement with this research findings. Chakravaty *et al*. (2020) [3], investigated that maximum temperature, RH 7 AM negatively influenced the count of *Atherigona pulla*. However, the RH at 2 PM had a significant high positive correlation with egg count and rainfall had positive correlation with egg count. Padmaja *et al*. (2010) [10], concluded that mean afternoon relative humidity and maximum temperature had a negative influence on egg count. Karibasavraja *et al.* (2006) [7], studied that maximum temperature with morning humidity had highly significant negative correlation with egg load. Whereas afternoon relative humidity and minimum temperature have together exerted highly significant positive correlation.

Similar results were obtained in respect to correlation with dead hearts and weather parameters such as, Chakravaty *et al*. (2020) [3], found that maximum temperature and at RH 2 PM had negative correlation with dead hearts caused by *Atherigona pulla.* Ballikai *et al.* (2019) [1] concluded that shoot fly dead hearts correlated negatively and significantly with minimum temperature at real time and at LT_1 to LT_3.

Table 2: Incidence of shoot fly on sorghum as affected by different sowing dates

Sr. No.	Date of Sowing	No. of Shoot fly Eggs/ 10 Plants**	Dead heart Percentage (%) *	
			14 DAE	28 DAE
1	31 August 2021	1.17	1.71	2.91
		(1.29)	(7.51)	(9.78)
2	15 September 2021	1.70	3.28	4.56
		(1.48)	(10.42)	(12.30)
3	30 September 2021	2.20	6.10	7.71
		(1.64)	(14.30)	(16.11)
4	15 October 2021	2.57	13.84	13.87
		(1.75)	(21.84)	(19.48)
5	31st October 2021	2.67	14.07	18.57
		(1.82)	(22.04)	(25.48)
6	15 November 2021	3.01	17.08	18.58
		(1.87)	(24.39)	(25.48)
	S.Em. (±)	0.02	0.49	0.45
	CD at 5%	0.05	1.59	1.47

**Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values.
*The values in parentheses indicate arcsine values.

Table 3: The average grain and fodder yield of sorghum sown on different dates

Sr. No.	Date of Sowing	Plant Population (%)*	Yield	
			Grain yield (gm/5 plants)	Fodder yield (kg/5 plants)
1	31 August, 2021	89.47 (71.27)	414.67	0.75
2	15 September, 2021	88.18 (68.19)	354.00	0.62
3	30 September, 2021	92.01 (71.97)	334.33	0.49
4	15 October, 2021	88.19 (68.04)	304.33	0.41
5	31st October, 2021	83.62 (65.97)	262.33	0.33
6	15 November, 2021	88.75 (70.52)	249.47	0.28
	S.Em.(±)	0.02	15.05	0.45
	CD at 5%	0.05	49.07	1.47

* The values in parentheses indicate arcsine values

Table 3: Screening of sorghum genotypes for morphological characters against shoot fly (*Atherigona soccata*)

Sr. No.	Genotypes	Plant Population* (%)	Seedling Vigour	Leaf Glossiness	Days Required to 50% Flowering
1	RSV 1410	89.47 (71.27)	1.67	3.00	101
2	RSV 1687	90.73 (72.37)	3.33	2.33	94.33
3	RSV 1918	84.88 (67.05)	1.67	2.00	95.32
4	RSV 1959	92.30 (78.75)	1.33	2.00	90.66
5	RSV 1976	87.15 (68.21)	2.67	1.67	104.32
6	RSV 1996	91.29 (73.20)	1.67	2.00	103.66
7	RSV 2155	88.19 (70.04)	2.00	2.00	97
8	RSV 2176	92.04 (73.62)	3.67	2.67	96
9	RSV 2397	89.47 (71.27)	2.67	3.00	95.33
10	RSV 1188	88.18 (68.19)	1.33	1.33	103.67
11	IS 18551	92.01 (71.97)	1.67	1.33	93
12	IS 2205	88.19 (68.04)	1.67	1.00	102 94
13	DJ 6514	83.62 (65.97)	4.00	3.33	94
14	Swarna	88.75 (70.52)	3.67	3.67	92
	S.Em. (±)	2.32	0.35	0.42	1.25
	C D 5%	6.80	1.03	1.24	3.65

The values in parentheses indicate arcsine values

Table 4: Screening of sorghum genotypes to oviposit ion and dead hearts caused by shoot fly (*Atherigona soccata*)

Sr. No.	Genotypes	Shoot fly Eggs/5	Dead heart percentage*	
1	RSV 1410	3.68 (2.17)	15.01 (22.76)	26.07 (30.66)
2	RSV 1687	2.68 (1.91)	12.01 (20.23)	22.05 (27.98)
3	RSV 1918	4.34 (2.32)	20.11 (26.62)	36.67 (42.25)
4	RSV 1959	2.01 (1.73)	8.81 (17.24)	14.42 (22.31)
5	RSV 1976	4.01 (2.24)	16.81 (24.18)	27.01 (31.28)
6	RSV 1996	3.68 (2.17)	16.01 (23.55)	26.01 (30.64)
7	RSV 2155	2.34 (1.83)	9.61 (18.01)	15.39 (23.09)
8	RSV 2176	3.01 (2.00)	14.01 (21.92)	24.73 (29.81)
9	RSV 2397	2.34 (1.83)	11.01 (19.37)	15.73 (23.36)
10	RSV 1188	1.32 (1.51)	8.61 (17.05)	14.01 (21.97)
11	IS 18551	1.01 (1.43)	6.81 (15.72)	11.98 (20.23)
12	IS 2205	1.32 (1.51)	7.29 (15.65)	12.61 (20.79)
13	DJ 6514	5.34 (2.53)	20.01 (26.55)	60.01 (50.77)
14	Swarna	6.01 (2.65)	24.99 (29.97)	64.01 (53.13)
	S.Em.(±)	0.11	0.74	0.79
	CD at 5%	0.33	2.15	2.30

*The values in parentheses indicate arcsine values.

*Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values

Table 5: Screening of sorghum genotypes against stem borer (*Chilo partellus* Swinhoe), fall armyworm (*Spodoptera frugiperda*) and yield

Sr. No.	Genotypes	Stem borer dead hearts (%) (45 DAE) *	Fall Armyworm Infestation*	Grain (g/5 plants)	Yield Fodder (kg/5 plants)
1	RSV 1410	12.66 (20.81)	4.42 (14.50)	187.00	1.64
2	RSV 1687	8.14 (16.55)	4.36 (24.96)	221.00	1.65
3	RSV 1918	18.16 (25.20)	4.42 (25.04)	154.68	1.35
4	RSV 1959	6.45 (14.70)	4.01 (24.96)	284.34	2.01
5	RSV 1976	16.28 (23.75)	4.29 (25.04)	171.68	1.46
6	RSV 1996	14.22 (21.32)	4.23 (15.75)	194.34	1.53
7	RSV 2155	8.18 (6.58)	4.36 (19.68)	299.68	1.97
8	RSV 2176	11.83 (20.10)	4.18 (24.06)	202.68	1.59
9	RSV 2397	9.00 (17.44)	4.49 (11.31)	283.01	1.89
10	RSV 1188	7.02 (15.36)	4.42 (11.31)	213.34	1.87
11	IS 18551	7.62 (16.02)	4.24 (14.50)	96.00	1.32
12	IS 2205	10.42 (18.82)	4.42 (12.91)	106	1.24
13	DJ 6514	16.55 (23.97)	4.54 (11.29)	53.01	1.28
14	Swarna	15.37 (23.04)	4.30 (22.01)	149.68	1.22
	S.Em. (±)	0.55	0.15	5.87	0.05
	CD	1.62	NS	17.11	0.14

*The values in parentheses indicate arcsine values.

*Figures in the parentheses are $\sqrt{X + 0.5}$ transformed values

Table 6: Correlation between shoot fly incidence and abiotic factors

Observation	Maximum temperature (0C)	Minimum temperature (°C)	Relative Humidity (%) RH I	Relative Humidity (%) RH II	Rainfall (mm)
Eggs / 10 plants	-0.217	0.631*	-0.172	0.551	0.147
Dead heart	-0.200	-0.286	0.443	-0.217	0.580*

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References
1. Ballikai RA, Venkatesh H. Weather based prediction models to forecast major pests of rabi sorghum in Karnataka, India. Journal of Experimental Zoology, India. 2019;22(1):131-134.
2. Bantilan MCS, Deb UK, Gowda CLL, Reddy BVS, Obilana AB, Evenson RE. Sorghum genetic enhancement: Research process dissemination and impacts. Patancheru 502 324, Andhra Pradesh, India. International Crops Research Institute for the Semi- arid tropics. 2004;43:37-45.
3. Chakravarty MK, Kamal Kartik Kenny Kundra, Alka Kumari. Influence of Abiotic Factors on the Shootfly (*Atherigona pulla* Wiede) infestation. International Journal of Current Microbiology and Applied Sciences. 2020, 9(6). ISSN: 2319-7706.
4. Deeming JC. Control of sorghum shoot fly. Oxford and IBH Publishing Co. New Delhi. Firke, P. V. and Kadam M. V.1979. Effect of sowing dates and seed rates on the incidence of *Atherigona soccata* Rond and grain yield of some sorghum varieties (India). Journal of Maharashtra Agricultural Universities. v. 1972;4(1):69-74.
5. Gandhale DN, Salunkhe SN, Naik LM. Relationship of sowing time and seed rate on shoot fly incidence in sorghum. Indian J Pl. Prot. 1985;10(1/2):67-69.
6. Jotwani MG, Davis JC. Insect resistance studies in sorghum at International Institutes and National Programs with special reference to India. In Proceeding of the short course Sharma 1985 in host plant resistance (ed M. K. Harris). Texas A and M University, College Station, Texas, USA; c1980. p. 224-236.
7. Karibasavaraja LR, Balikai RA. Seasonal incidences of sorghum shoot fly and correlations with weather parameters. International J Agric. Sci. 2006;2(2):381-384.
8. Khandare RP, Patil SP, Burghate SK, Kurhade Kalpana Screening of advanced breeding material of sorghum against shoot fly (*Atherigona soccata*). J Agric. Sci. 2013;3(8):305-307.
9. Nwazne KF, Reddy YVR, Soman P. The role of leaf surface wetness in larval behaviour of the sorghum shoot fly *Atherigona soccata*. Entomol. Exp. Appl. 1990;56:187-195.
10. Padmaja PG, Madhusudhana R, Seetharama N. Sorghum shoot fly, Directorate of sorghum Research, Rajendranagar, Hyderabad. 2010, 82.
11. Paterson AH, Bowers JE, Bruggmann R, Dubchak I, Grimwood J, Gundlach H, *et al*. The Sorghum bicolor genome and the diversification of grasses. Nature. 2009;457:551-556.
12. Ponnaiya BWX. Studies in the genus Sorghum II. The cause of resistance in sorghum to the insect pest *Atherigona soccata*. J Madras Univ. 1951;21:203-217.
13. Seshu Reddy KV, Devis JC. Species of Atherigonna. Andhra Pradesh. PANS. 1978;23:379-383.
14. Sharma HC. Future strategies for pest control in sorghum in India. Trop. Pest Manag. 1985;31:167-185.
15. Sharma HC, Taneja SL, Leuschner K, Nwanze KF. Techniques to screen the sorghum for resistance to insects. Information Bull. No. 32. Patancheru; c1992.

16. Sherwill T, Bryne M, Vanden J. Shoot fly species on sorghum in the Mpulanga subtropics of South Africa: relative abundance and infestation levels. Afr. J Plant Prot. 1999;5:31-35.
17. Shivpuje PR, Bapat DR, Kulkarni AV, Phadiivis AV. Seasonal incidence of shoot fly at Parbhani area. Sorghum Newsletter. 1976;19(2):51-52.
18. Solanke TF, Davey WW, Adeloye A. Stomach and duodenum. 6. Davey's Companion to Surgery in Africa. 1987:259-279.