Sustainable management of shoot fly in sorghum: A comprehensive review

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Abstract

Sorghum [Sorghum bicolor (Linnaeus)] also known as Jowar is an important food and fodder crop of dryland agriculture with wide range of adaptability to various agro-ecological conditions in the semi-arid tropics and cultivated on marginal, fragile, and drought-prone environments. Sorghum is attacked by around 150 insect pest damage from seedling stage to maturity, of which sorghum shoot fly, Atherigona soccata (Rondani) is a notorious pest which is responsible for causing a loss of 80–90% of grain, and 68% of fodder yield in sorghum due to its regular occurrence. To manage pest problem, farmers still rely on pesticides use, but excessive use of chemical has resulted many problems. Hence, integration of all these approaches in a unified manner has exposed more good results for eco-friendly management of shoot fly and consequently high yield of sorghum obtained.

Keywords: Sorghum, shoot fly, resistant varieties, loss, cultural control and management

Introduction

Sorghum crop [Sorghum bicolor (Linnaeus) Moench, 2n = 2x = 20)] is belong to family Poaceae also known as jwari, jowar, cholam, jonna, jola, jondhalaa, Guinea corn in West Africa, Mtama in Eastern Africa, Kafir corn in South Africa, Milo or Milo-maize in North America and Kaoliong in China. It is a globally important food and fodder security crop cultivated in almost all regions and marginal, fragile, and drought-prone environments in the semi-arid tropics by subsistence farmers for wide use particularly in arid and semi-arid environments (Ashok et al., 2011) [3]. Sorghum is used in various ways in our country as edible starchy seeds used for food to human and major ingredients in poultry and cattle feed in USA, China and Australia (Bramel-Cox et al., 1995) [15], leaf and stalk are used as animal feed for green chop, silage or hay and fodder, broomcorn used in making brooms, brushes and sweet sorghums for forage, syrup and ethanol production as liquor and beer. The reclaimed stalks of the sorghum plant are used as decorative millwork material marketed as Kirei board and construction of houses and fences and as fuel wood (Mastresha and Belay, 2020) [41]. Sorghum is widely used in various culinary preparations viz., unleavened flat breads (roti) (Murty and Subramanian, 1981) [44], infant food, syrup, popped grain as similar to popcorn, Indian bread, bhakri, jowar roti, or jolada rotti, used as wheat substitutes in gluten-free recipes and products in India. In Korea, it is cooked with rice, or its flour is used to make cake called susu bakkumi, droo, tortillas in Tunisia, Honduras in Central America, injera, porridge, Nifro, “Tella” in USA, Arekie in Ethiopia and flour as an alternative to wheat in Northern China. Nutritionally, 100grams of sorghum contain 339kcal energy, 74.63g carbohydrates, 11.30g protein, 6.3g dietary fiber, 3.30g fat and amino acids is around 126.72 and 168.42 mg/g in red sorghum and white sorghum, respectively (Linko et al., 2005) [40]. Sorghum also contains less starches, sugars and diverse phenolic compounds viz., simple phenolic acids, flavonoids, and tannins compared to other major cereal crops confers sorghum with a number of health benefits such as reducing oxidative stress, cancer prevention obesity, oxidative stress, inflammation, dyslipidemia and hypertension and Celiac Disease (CD) and diabetes in sorghum (Gonzalez-Montilla et al., 2012) [30]. Sorghum is the fifth most important and oldest cereal crop in the world after rice, wheat, corn and barley. Besides, it is also the main staple cereal food for over 750 million people living in semi-arid tropical regions of Africa, Asia and Latin America (CCCF, 2011) [17].
In India, sorghum is an important dual-purpose crop grown extensively by resource-poor farmers in the states of Maharashtra, Karnataka, Telangana, and Andhra Pradesh indicates lifeline for resource-poor farmers in drylands as it tolerates water deficit stress. Globally, sorghum is grown over an area of 40.98 million hectares with a production of 59.77 MT (metric ton) and productivity of 1.46 MT per hectare (USDA, 2020) [8]. Region wise, production share of sorghum is highest in Africa accounting for overproduction 50.2% followed by America (32.4%), Asia 13.4% Oceania (2%) and Europe (1.8%) (FAOSTAT, 2018) [23]. According to USDA (2020) [8], India ranks 6th in sorghum production (4.40 MT) after US (8.92 MT), Nigeria (6.90 MT), Ethiopia (5.20 MT) Sudan (5MT) and Maxico (4.40MT) at global level and in area cultivation under sorghum, India ranks 3rd with a land of 4.80 Million Hectares after Nigeria (5.90 MH) and Sudan (7.00MH). In India, sorghum is cultivated over an area of 4960000 hectare and production of 4800000 tons with productivity of 10.33 tons/hectare (FAOSTAT, 2018) [23]. Sorghum is attacked by 150 insects and right from the nursery stage to till harvesting including the major ones being sorghum shoot fly (Atherigona soccata Rondani), spotted stem borer (Chilo partellus), pink borer (Sesamia inferens), Eldana saccharina, and Diatraea spp (Jotwani et al., 1971) [55], armyworms (Mythimna separata, Spodoptera frugiperda and S. exempta), Shoot bug, or plant hopper (Peregrinus maidis), sorghum midge (Contarinia sorghicola) and a complex of earhead bugs (Calocoris angustatus and Eurystylus oldii), and head caterpillars (Helicoverpa, Eablimma, Cryptoblabes, Pyroderces and Nola sp.), white grub (Holotrichia serrata) and Lachnosterna consanguinea), Flea beetle (Chaetornema indica, Longitarrae sp., and Phyllotreta chotanica), cutworms, grasshoppers and locusts (Hieroglyphus, Oedaleus, Aiolopus, Stictocerca and Locusta sp.) and leaf-eating beetles and spiders mite, Oligonychus indicus) and stored grain pests including Sitotroga cerealella, Corcyra cephalonica, Euphestia cautella, Sitophilus oryzae, Rhyzopertha dominica, Tribolium castaneum, Trogoderma granarium, Oryzaephilus surinamensis, Lathetics oryzae and Lasioderma serricorne (ICRISAT, 1985) [29]. Out of these, A. soccata has attained noxious pest status in Asia and other countries (Atwall and Dhalwali, 2008) [5] that reduces sorghum production in the semi-arid tropics. Several biotic and abiotic constraints influence the production and productivity of sorghum. Among the biotic constraints, insect pests are one of the major factors influencing the grain yield in sorghum and result in losses of over $1000 million in grain and forage yield (ICRISAT, 2007) [28]. Nearly 32% of the actual production of sorghum is lost because of insect pests in India (Barad and Mittal, 1983) [12]. This notorious pest is considered a limiting factor in sorghum cultivation causing average yield loss of 50% in India (Jotwani, 1982) [33], 80–90% of grain and 68% of fodder losses (Kahate et al., 2014) [35] and yield losses up to 90% (Jotwani and Srivastava 1970) [31] but the infestations at times may be over 90% was recorded in India by its attack. Atwall (1976) [4] reported 75.6% grain loss and 68.6% in fodder loss due to shoot fly attack. Shoot fly causes nearly loss of 20% actual produce in Africa and Latin America, 9% in USA reported by Wiseman and Morrison (1981) [69]. Identifying sorghum genotypes with stable shoot fly resistance is highly important as it will help to reduce the cost of cultivation and stabilize the yields. Economic threshold level for sorghum shoot fly is 5-10% dead heart appearance in the plant (Atwall and Dhalwali, 2008) [5].

Nature of damage
The maggots crawl inside the sheath and bore into the heart of the young shoot killing the growing point and the youngest leaf, which turns brown and withers and the resulted damage is known as “dead heart”. The damaged seedling is killed but may produce side tillers. In weak plant, repeated infestation may cause serious losses. Sometimes the damage is so severe that many seedlings die and the field has to be replanted. Older plants may also be attacked, but they do not produce the dead-heart symptoms. Instead, the damaged leaf becomes thin and papery, and wraps around the other leaves. As a result, the plants may fail to grow normally. Late infestations may also damage the panicle in the formative stage, resulting in rotting or drying up of the panicle portion (Biradar and Sajjan, 2018) [14].

Management strategies:
Different management practices reported by different workers for sorghum shoot fly have been reviewed under different headings.

Cultural control
Sorghum shoot fly can be effectively controlled by modifying the cultural practices like sowing time, seed rate, fertilization etc. have been used for many years to control pest. Shoot fly infestation can be avoided by suitable adjustment of planting time so that the vulnerable stage of the crop does not coincide with its active period. Young (1981) [70] pointed out that continuous cropping over several months favors population buildup and fly injury. Delobel (1982) [21] found that in low density plots (22 plants/m²), plants received 3.35 times more eggs than in higher density plots (704 plants/m²). In India, several authors from different localities have studied the effects of sowing dates and seed rates on the incidence of the shoot fly and found that early sowing helped to avoid and reduce damage (Mote, 1983) [43]. Early sowing (second week of June) with high seed rate @ 10 kg/ha and thinning dead heart plants at 28 days after emergence was found superior for checking the infestation of shoot fly and obtaining maximum yield (Shekarappa and Bhuti, 2007) [58]. As the sowing was delayed, infestation of shoot fly increased and it adversely affected the plant height, weight and length of head, number of primaries and spikelets, grain and stover yield (Ameta and Sumeria, 2004) [2]. During the rainy season, if planting is done within 7-10 days of the onset of the monsoon rains, the crop can escape from shoot fly infestation. In the post-rainy season, planting from September last week to October first week relatively reduced the shoot fly damage (Balikai, 1999) [6]. Under delayed plantings in the rainy season, increased seed rate, followed by thinning and destroying the dead hearts to maintain the optimum plant stand can be adopted. Application of nitrogen and phosphorous @ 80 and 40 kg/ha, respectively reduced the shoot fly infestation than the lower doses (Bhandari and Patel, 2016) [13]. Shoot fly infestation can also be reduced by creating water stress conditions during young seedling stage (7-28 days after emergence) for different lengths of time (Nwanze et al., 1996) [48]. Intercropping also plays an important role in reducing the population of sorghum shoot fly. Garlic or onion intercrops can be used for the management of shoot fly with paired row planting of sorghum without affecting plant population (Karibasavaraja et al., 2005) [37]. Sorghum-cowpea intercrop also increased the parasitism by Neotrichoporidae nyemitaus compared to...
sole crop and recorded less number of eggs and per cent dead heart (Spurthi et al., 2007) [60]. Shoot fly damage is found reduced when sorghum is intercropped with leguminous crops (Nagesh, 2007) [65]. Seed treatment with thiamethoxam 70 WS @ 2g/kg seeds which in turn was on par with imidacloprid 70 WS @ 5g/kg seeds (Balkai, 2011).

| Location               | Biocontrol agents used                                  | Predatory/parasitism on | Reference |
|------------------------|---------------------------------------------------------|-------------------------|-----------|
| **Predators**          |                                                         |                         |           |
| Burkina Faso           | *Tapinoma* sp. Forster (Formicidae)                     | Egg                     | (Zongo et al., 1993) [71] |
|                        | *Thysanopteran sp.* (Phlaethripidae Haplothripinae), Cecidomyiid (Dicrodiplosis sp) Mite (Histiotomidae and Suidasia pontifica) | Egg                     | (Zongo et al., 1993) [71] |
| India                  | *Abrolophus* sp.                                        | Egg and larva           | (Reddy and Davies, 1979) [52] |
| Kenya                  | *Spider*                                                | Egg                     | (Delobel and Lubega, 1984) [22] |
| Uganda                 | *Dasyproctus bipunctatus*                                | Adult                   | (Deeming, 1983) [19] |
| **Parasitoid**         |                                                         |                         |           |
| India, Ily Nigeria Burkina Faso | *Trichogramma chilonis* Ishii and *T. japonicum* Ashmead*T. evanescens* *T. kalkae* Sch. & Feij. | Egg                     | (Taley and Thakare, 1979) [67], (Deeming, 1971) [18], (Brenerie, 1972) [16], (CIPE, 1982) [27] |
| Kenya                  | *Trichogramma* sinimondi                                 | Egg                     | (Zongo et al., 1993) [71] |
| India                  | *Neotropicporoides nyentavus* *Bracon* sp. and *Hockeria* sp. | Larvae                  | (Rohwer, 1921) [53], (Zongo et al., 1993) [71] |
| Ily                    | *Trichoplata* Benoit                                     | Pupae                   | (Del Bene, 1986) [20] |
| India                  | *Aprostocetus* sp., *Callitula bipartitus* *Farouqui*, *Neotropicporoides* sp. and *N. Nyentavus* | Pupae                   | (Jotwani, 1981) [32] |
| India                  | *Monella* sp. and *Rhoptromeris* sp.                    | Pupae                   | Taley & Thakare, 1979) [67] |
Integrated control

Management of this pest through integrated approach will play a key role in the sustainable production of sorghum. It was reported that three sprays (7th, 14th and 21st day after germination) of neem oil 2% and karanj oil 2% recorded lower oviposition and reduced the dead heart formation, considerably (Joshi et al., 2016) [30]. Similarly, neem oil 2% treated plots produced the yield at par with plant mixture and NSKE 5 per cent (Sable, 2009) [33]. Also NSKE 5% alone sprayed at 21st day after germination reduced egg laying of shoot fly and per cent dead heart formation at par with carbofuran (Shrinivasan and Shekharappa, 2009) [60, 61]. Maximum grain yield and highest Cost Benefit ratio were recorded from neem oil 13 per cent (Gautam et al., 2014) [25]. NSKE in combination with panchagavya and cow urine could be equally effective to chemical insecticides apart from being environmentally safe and eco-friendly in nature (Shrinivasan et al., 2009) [60, 61]. Another neem product, Azadirachtin 1500 ppm also resulted in lowering the egg lying of sorghum shoot fly and reduction of dead heart formation (Parteti et al., 2014) [49]. Likewise, Vitex negundo spray recorded significantly least per cent dead hearts caused by shoot fly. It was also reported that at 14 days after germination (DAG) the extract from mint and tulsi leaves and neem seed kernel suspension may be used to reduce the shoot fly infestation, considerably. Balikai (2003) [30] reported that treatment with Carbofuran 3G @ 2 g/meter row + High seed rate of 10 kg/ha and thinning at 28 days after germination + Release of egg parasitoid, Trichogramma chilonis Ishi @ 5 lakh adults on 7, 14 and 21 days after germination recorded the lowest shoot fly incidence of 11.5 per cent and highest grain yield of 30.0 q/ha. Six insecticides viz; thiamethoxam, imidacloprid, acetamiprid, profenofos 40 per cent + cypermethrin 4 per cent, endosulfan @ 0.07 per cent and carbofuran with various concentrations were evaluated against shoot fly of Sorghum by Aghav et al. (2007) [1]. Out of these insecticides imidacloprid gave the good control of this pest followed by thiamethoxam. The shoot fly infestation was recorded less with the seed treatment of imidacloprid 70 WS @ 10 ml/kg seed followed by quinalphos 25% EC spray @ 20 ml/10 lit water 15 days after emergence found significantly most effective (Sonalkar et al., 2018) [65].

Conclusion

The various control techniques have been practiced by different workers and among them cultural control, host plant resistance, biological control and chemical control are more effective against sorghum shoot fly. High rainfall after first week of emergence of the crop leading to mortality of eggs leading to less dead heart in the later growth stage of the crop and humidity in the morning and rainfall found important during oviposition but rainfall has no significance during dead heart formation. Genotypes with diverse shoot fly resistance and morphological traits can be effectively utilised as parents in developing high yielding shoot fly-resistant sorghums. We conclude that an integrated approach is the most effective for long-term sustainable and eco-friendly management programs for shoot fly.

References

1. Aghav ST, Baheti HS, Tambe AB. Evaluation of new insecticides against sorghum shoot fly, Atherigona soccata Rondani. Indian J Agri. Res 2007;2:119-121.
2. Ameta OP, Sumeria HK. Effect of sowing dates on the incidence of insect pests and productivity of sorghum {Sorghum bicolar (L.) Moench}. Indian J Agri. Res 2004;38:278-282.
3. Ashok KA, Reddy BVS, Sharma HC, Hash CT, Srinivasan RP, Ramaiah B, et al. Recent advances in sorghum genetic enhancement research at ICIRSAT. Am J Plant Sci 2011;2:589-600.
4. Atwal AS. Agricultural pests of India and Southeast Asia. Kalyani Publishers. New Delhi, India 1976, pp. 159-165.
5. Atwal AS, Dhaliwal GS. Agricultural pest of South Asia and their management. Kalyani publisher, New Delhi 2008, pp. 332.
6. Balikai RA. Effect of different dates of sowing on shoot fly incidence and grain yield of sorghum. Insect Environ 1999;15(2):57-58.
7. Balikai RA, Biradar BD. Field evaluation of sorghum parental lines for resistance to shoot fly and aphid. Agric. Sci. Digest 2007;27:291-292.
8. Balikai RA. Integrated pest management for shootfly (Atherigona soccata Rondani) in rabi sorghum. Agric Sci Digest 2003;23(4):291-29.
9. Balikai RA. Seed treatment, an eco-friendly management tactic for the suppression of insect pests in sorghum. Int J PI Prot 2011;4:381-384.
10. Balikai RA, Biradar BD. Performance of sorghum germplasm lines against shootfly in rabi sorghum. Agric Sci Digest 2004;24(1):63-64.
11. Banger MS, Patel CC, Kher HR, Parmar HP. Biochemical basis of resistance in forage sorghum to shoot fly Atherigona soccata (Rondani). Indian J Entomol 2012;74:125-131.
12. Barad PK, Mittal VP. Assessment of losses caused by pest complex to sorghum hybrid, CSH 5. In: B. H. Krishnamurthy Rao, and K. S. R. K. Murthy (eds), crop losses due to insect pests. Indian J Entomol 1983, pp 271-278.
13. Bhanderi GR, Patel KA. Fertilizer levels vs. shoot fly and stem borer in grain sorghum. Indian J Entomol 2016;27:270-271.
14. Biradar A, Sajjan S. Management of Shoot Fly in Major Cereal Crops. Int. J Pure App Biosci. 2018;6(1):971-975.
15. Bramel-Cox PJ, Kumar KA, Hancock JD, Andrews DJ. Sorghum and millets for forage and feed, In: Sorghum and Millets Chemistry and Technology, ed Dendy D. A. V. (St. Paul, MN: American Association Cereal Chemists, Inc.) 1995, 325-364.
16. Breniere J. Sorghum shoot fly in West Africa, in Control of Sorghum Shoot fly (Jowwani, M.G. & Young, W.R., Eds). Oxford & IBH Pub. Co., New Delhi, India 1972, pp. 129-136.
17. CCCF. Working paper on mycotoxin in sorghum. Joint FAO/ WHO food standard codex committee on containment of food 2011.
18. Deeming JC. Some species of Atherigona Rondani (Diptera: Muscidae) from Northern Nigeria, with special reference to those injurious to cereal crops. Bulletin Entomol Res 1971;61:133-190.
19. Deeming JC. Atherigona spp, as prey of Dasyproctus bipunctatus Lepeletier and Brulle in Uganda. Entomologists Monthly Magazine 1983;119:83.
20. Del Bene G. Note sur la biologia di Atherigona soccata Rondani (Diptera: Muscidae) in Toscano e Lazio. Redia 1986;69:47-63.
21. Delobel AGL. Effects of sorghum density on oviposition and survival of the sorghum shoot fly, Atherigona soccata. Entomol Exp Appl 1982;31:170-174.
22. Delobel AGL, Lubega MC. Rainfall as a mortality factor in the sorghum shoot fly, Atherigona soccata Rondani (Diptera: Muscidae) in Kenya. Insect Sci Appl 1984;2:67-71.
23. FAO FAOSTAT data 2018. (Available at: http://www.fao.org)
24. Gahukar RT. Population dynamics sorghum shoot fly Atherigona soccata (Diptera: Muscidae) in sonegal. Environ Ent 1987;16:910-916.
25. Gautam N, Mansuri MA, Singh K, Swaminathan R. Bioefficacy of different botanicals against shoot feeding insect pests of sorghum. Indian J Appl Entomol 2014;28:30-34.
26. Gonzalez-Montilla FM, Chavez-Santoscoy RA, Guti JA, Serna-Saldivar SO. Isolation and identification of phase II enzyme inducers obtained from black Shawaya sorghum [Sorghum bicolor (L.) Moench] bran. J Cereal Sci 2012;55(2):126-131.
27. ICIPE (International Centre of Insect Physiology and Ecology). 1982. ICIPE Ninth Annual Report. International Centre of Insect Physiology and Ecology, Nairobi, Kenya 1981.
28. ICRISAT. The Productivity and Livelihoods of Success in the SAT Nourished, Archival Report. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Andhra Pradesh, India 2007.
29. ICRISAT. Proceedings of the International Sorghum Entomology Workshop, 15-21 July 1984, Texas A&M University, College Station, TX, USA. Patancheru, A.P. 502 324, India: ICRISAT 1985.
30. Joshi S, Hussain T, Kirar VS, Nagar R. Management of sorghum shoot fly, Atherigona soccata Rondani (Diptera: Muscidae) through botanicals. J Biopest 2016;9:23-26.
31. Jotwani MG, Srivastava KP. Studies on sorghum lines resistant against shoot fly (Atherigona soccata Rondani). Indian Entomol 1970;32:1-3
32. Jotwani MG. Integrated approach to the control of the sorghum shoot fly. Insect Science and its Application 1981;2:123-127.
33. Jotwani MG. Factors reducing sorghum yields: insect pests. In: Sorghum in the Eighties: Proc. of the International Symposium on Sorghum, 2-7 Nov 1981, ICRISAT Center, India 1982. pp. 251-255.
34. Jotwani MG, Chandra D, Young WR, Sukhani PR, Saxena PN. Estimation of avoidable losses caused by insect complex on sorghum hybrid CSH-1 and percentage increase in yield over treated control. Indian J Entomol 1971;33:375-383.
35. Kahate NS, Raut SM, Ulemale PH, Bhogave AF. Management of Sorghum Shoot Fly. Popular Kheti 2014;2:72-74.
36. Kalpande HV, More AW, Ambilwade PP, Aundhekar RL, Mundhe AG, Abubakar SYD, et al. Evaluation of sorghum genotypes for shoot fly resistance: Morphophysiological characters. J Ent Res 2015;139:105-109.
37. Karibasavaraja LR, Balikai RA, Deshapane VP. Interrogating for the management of sorghum shoot fly. Ann Pl Protoc Sci 2005;13:237-238.
38. Kishore P, Kishore P. Resistance to shoot fly, Atherigona soccata Rondani and stem borer, Chilo partellus (Swinhoe) in new germplasm of sorghum. J Ent Res 2001;25:273-282.
39. Kumar AA, Reddy BVS, Sharma HC. Shoot fly (Atherigona soccata) resistance in improved grain sorghum hybrids. An Open Access Journal published by ICRISAT 2008:6:1-4.
40. Liniko AM, Katri SJ, Mykkkenen MM, Herman A. Whole-grain rye bread consumption by women correlates with plasma alkyl resorcinol and increases their concentration compared with low-fiber wheat bread. The J nutrition 2005;135(3):580-583.
41. Masresha MT, Belay GG. Characterization of nutritional, anti-nutritional, and mineral contents of thirty-five sorghum varieties grown in Ethiopia. Int J Food Sci 2020. Article ID 8243617:1-11.
42. Mohan S. Only female sorghum shoot flies in fish meal traps. Indian J Plant Prot 1991;11:77-78.
43. Mote UN. Relation between the shootfly damage and sorghum yields during rainy season. Indian J Plant Prot 1983, 145-147.
44. Murty DS, Subramanian V. Sorghum roti: A traditional methods of consumption and standard procedures for evaluation. In: ICRISAT Proc. of the International Symposium on Sorghum Grain Quality, Hyderabad, India. 28-31 October 1981, 73-78.
45. Nagesh C. Studies on multiple resistance and management of sorghum pests in Rabi. M.Sc. thesis, Univ. Agric, Sci, Dharwad (India) 2007.
46. Narkhede BN, Karad SR, Akade JH, Kachole UG. Screening of rabi sorghum local germplasm of Maharashtra tract against shoot fly reaction. J Maharashtra Agric Univ 2002;27:60-61.
47. Natarajan K, Chellaiah S. A new method to sorghum shoot fly. Pesticides 1983;17:37
48. Nwanze KS, Reddy YVR, Nwilene FE, Soman P, Laryea KB, Jayachandran R, et al. Reduction of shoot fly damage in irrigated post-rainy season sorghum by manipulating irrigation. Ann. Appl. Bio 1996;129:390-403.
49. Parteti SR, Kalinika AS, Gurve SS, Gawe RW. Efficacy of botanicals for the management of sorghum shoot fly. Trends Biorosci 2014;7:2566-2569.
50. Prasad GS, Srinivasa K Babu, Subbarayudu B, Bhagwat VR, Patil JV. Identification of sweet sorghum accessions possessing multiple resistance to shoot fly (Atherigona soccata Rondani) and Spotted Stem Borer (Chilopartellus Swinhoe). Sugar Tech, Apr-June 2015;17(2):173-180.
51. Reddy KVS, Skinner JD, Davies JC. Attractants for Atherigona spp. including sorghum shoot fly, Atherigona soccata Rond. (Muscidae: Diptera), Insect Sci. Appl 1981:2:83-86.
52. Reddy KVS, Davies JC. Pests of sorghum and pearl millet and their parasites and predators recorded at ICRISAT center up to August, 1979. Cereal Entomology Progress Report II, ICRISAT, Patancheru, Andhra Pradesh, India 1979.
53. Rohwer SA. Descriptions of new chalcidid flies from Coimbatore (S. India). Annual Magazine, Natural History 1921;7:123-135.
54. Ruesink WG, Kogan M. The quantitative basis of pest management: Sampling and measuring, pp. 315-352. In Metcalf, R.L. and W. H. Luckman. (eds.). Introduction to insect pest management. John Wiley and Sons, New York 1982.
55. Sable VA, Non-chemical approaches for the management of shoot fly Atherigona soccata (Rondani) in kharif
sorghum. M.Sc. thesis, University of Agricultural Sciences, Dharwad. Sciences 2009;13:85-87.

56. Sandhu GS. Evaluation of management components against shoot fly in sorghum. Ann Pl Protec Sci 2016;24:67-70.

57. Sharma HC. Crop Protection Compendium: Sorghum shoot fly, Atherigona soccata. Electronic Compendium for Crop Protection. Wallingford, U.K., CAB International 1996.

58. Shekharappa S, Bhuti SG. Integrated management of sorghum shoot fly, Atherigona soccata Rondani. Karnataka J Agric. Sci 2007;20:535-536.

59. Shrma HC, Dhillon MK, Reddy VS. Expression of resistance to Atherigona soccata in F1 hybrids involving shoot fly- resistant and susceptible cytoplasmic male- sterile line and restorer lines of sorghum. Plant Breeding 2006;125:473-477.

60. Shrinivasan M, Shekharappa. Evaluation of plant products against sorghum shootfly, Atherigona soccata Rondani. J Pl Protec Sci 2009;1:66-68.

61. Shrinivasan M, Shekharappa, Balikai RA. Evaluation of plant products in combination with cow urine and panchagavya against sorghum shoot fly, Atherigona soccata Rondani. Karnataka J Agric. Sci 2009;22:618-620.

62. Singh BU, Sharma HC. Natural enemies of sorghum shoot fly, Atherigona soccata Rondani (Diptera: Muscidae). Biocont Sci Technol 2002;12:307-323.

63. Sonalkar VU, Pagire KS, Gulhane AR, Ghorade RB. Management of Shoot Fly, Atherigona soccata (Diptera: Muscidae) in Kharif Sorghum in Vidarbha. Int J Curt Microbiol Appl Sci 2016;7:2192-2206.

64. Spurthi GS, Shekharappa R, Patil K, Puttanavar MS, Ramegowda GK, Effect of intercropping on incidence of shoot fly, Atherigona soccata Rondani in sorghum. J Ent. Res 2007;31:319-321.

65. Subbarayudu B, Prasad GS, Kalaisekar A, Bhagwat VR, Elangovan M. Evaluation of sorghum genotypes for multiple resistance to shoot pests. Indian J Pl Protec 2011;39:116-120.

66. Taddi S, Polavarapu B, Kishor K, Sharma HC. Identification of diverse sources of resistance to shoot Fly (Atherigona soccata) in sorghum. Int J Agric Innovations and Res 2019;7:413-419.

67. Taley YM, Thakare KR. Biology of seven new hymenopterous parasitoids of Atherigona soccata (Rondani). Indian J Agri Sci 1979;49:344-354.

68. USDA. Classification, plants database, natural resources conservation service 2020. http://plants.usda.gov/java/ClassificationServlet?source=display&classid=SOME

69. Wiseman BR, Morrison WP. Components for management of field corn and grain sorghum insects and mites in the United States. USDA Agricultural Research Service ARMS- 18, Government Printing Office, Washington, DC, USA 1981.

70. Young WR. Fifty-five years of research on the sorghum shoot fly. Insect Sci Appl 1981;2:3-9.

71. Zongo JO, Vincent C, Stewart RK. Effects of intercropping sorghum-cowpea on natural enemies of the sorghum shoot fly, Atherigona soccata Rondani (Diptera: Muscidae) in Burkina Faso. Biol Agric HORTI 1993;9:201-213

72. USDA. Classification, plants database, natural resources conservation service 2020. http://plants.usda.gov/java/ClassificationServlet?source=display&classid=SOME