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SEASONAL INCIDENCE AND MANAGEMENT OF SORGHUM SHOOT FLY, *ATHERIGONA SOCCATA* RONDANI - A REVIEW

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SUMMARY

Sorghum [*Sorghum bicolor* (Linn.) Moench] is an important cereal crop of the world. This crop is vulnerable to over 150 insect species from sowing to final harvest. Among the insect pests, the shoot fly (*Atherigona soccata* Rondani) is one of the most important and destructive pest which causes considerable losses in fodder as well as grain yield. Due to introduction of improved sorghum varieties and hybrids susceptible to this insect and continuous cropping, it has become a principal pest of the sorghum. This pest attacks on the sorghum crop at seedling stage causing maximum damage during the rainy season. The larva of this pest attacks on central whorl of the plant and causes 'dead heart' formation. Various methods have been suggested to control this pest. Use of resistant genotypes is the simplest method to control any pest without polluting the environment. A number of genotypes have been screened by various workers depicting resistance against the shoot fly. The sorghum crop grown early or timely can easily escape the incidence of this pest. So, the modification of date of sowing can also prove to be an effective method for management of this pest. The sorghum shoot fly can also be managed by using various types of traps. The fish meal and hanging type traps can be used for catching the adults of this pest. For each insect pest, there is also available parasitoid or predator in the crop ecosystem. Natural enemies also play an important role in reducing the shoot fly population, considerably. Intercropping of sorghum with other crops attractive to this pest can also be used as trap crop to reduce the shoot fly incidence on main crop. The intercropping also enhances the degree of parasitism. The seed treatment and foliar spray of recommended insecticides can also be used for effective management of sorghum shoot fly. Botanicals like neem oil, NSKE, karanj oil, *Azadirachtin* etc are also used widely against sorghum shoot fly which can reduce the pest population to a considerable level without causing any harm to non target organisms. The combination of two or more control practices may be used to suppress the sorghum shoot fly population below economic threshold level.

Key word : Sorghum, *Atherigona soccata*, seasonal incidence, management

Sorghum [*Sorghum bicolor* (Linn.) Moench] is an important crop in the world, used for food (as grain or sorghum molasses), fodder, the production of alcoholic beverages and biofuels. Most varieties are drought and heat tolerant, and are especially important in arid regions, where the grain is one of the staples for poor and rural people. *Sorghum bicolor* is an important food crop in Africa, Central America, and South Asia and is fifth most important cereal crop grown in the world. It is an important food and fodder crop grown in India, and among cereals, it is the fourth most important crop after rice, wheat and maize (Dehinwal *et al*., 2016). The major sorghum growing areas are in the states of Maharashtra, Andhra Pradesh, Karnataka, Gujarat, Tamil Nadu and Rajasthan. In Haryana, it is grown mainly for fodder purpose (Satpal *et al*., 2016).

Sorghum crop is attacked by different groups of insect pests one after another which lower the yield of sorghum in terms of fodder as well as grain. More than 150 insect species have been reported as pests on sorghum (Sharma, 1993), of which sorghum shoot fly (*Atherigona soccata*), stem borers (*Chilo partellus, Busseola fusca, Eldana saccharina*, and *Diatraea* spp), armyworms (*Mythimna separata*, *Spodoptera frugiperda* and *S. exempta*), shoot bug (*Peregrinus maidis*), aphids (*Schizaphis graminum* and *Melanaphis sacchari*), spider mites (*Oligonychus* spp), grasshopper (*Hieroglyphus sp.*), sorghum midge (*Stenodiplosis sorghicola*), earhead bugs (*Calocoris angustatus* and *Eurystylus oldi*), and head caterpillars (*Helicoverpa armigera* and *Eublemma* sp.) are the major pests worldwide. The early stage of the crop i.e. seedling stage was mainly attacked by shoot fly and flea beetle wherein the shoot fly was predominant

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(Patel and Purohit, 2015).

The shoot fly (*Atherigona soccata* Rondani) is considered to be the most severe pest in India causing tremendous damage at the seedling stage by killing the central shoot. Severe infestation at the boot stage results in the twisting of top leaves and preventing the emergence of panicles resulting in losses up to 41 per cent in India (Subbarayudu *et al.*, 2002). It has attained the status of a principle pest because of the introduction of improved sorghum varieties and hybrids susceptible to this insect, continuous cropping, ratooning, and reduced genetic variability (Singh and Rana, 1986). Further, its high fecundity and shorter generation span result in rapid population build up. It is also able to feed on several other plant species including other cereal crops and weeds. In view of its effects on plant stand and losses in grain yield, considerable research efforts have been made to develop strategies for the management of this pest. The growers must be prepared to scout and prevent injury from insects. There are various method used to manage sorghum shoot fly like early planting, increased seed rate, thinning and destroying the seedlings with dead hearts, seed treatment or soil application of insecticides, intercropping, crop rotations, and fallowing etc. However, a proper insect pest management program will minimize the losses due to the pest and ensure appropriate insecticide use. Here, an attempt has been made to review the various management practices suggested by different workers for effective control of the sorghum shoot fly.

Biology and Seasonal Incidence

The adult is a grey-colored small fly, which oviposits at early dawn, and each female lays up to 75 cigar-shaped eggs singly on the abaxial leaf surface of the seedlings parallel to midrib between the first and fourth week after seedling emergence. After hatching in 1-2 days, the maggots enter the seedling base through the whorl and cut the growing point resulting in wilting and drying of the central leaf, known as a ‘dead heart’. The larva feeds on the decaying plant tissue in the shoot. There are 4- 5 instars, and the larval development is completed in 8-10 days. Grown up larva is yellowish and about 6 mm in length. Pupation takes place either at the base of the damaged seedling or in the soil and lasts for 8 days. Adults survive for 12 days on sorghum seedlings. The entire life cycle is completed in 17 to 21 days (Sharma and Nwanze, 1997) but can be as long as 45 days, with up to 10 generations per year. The shoot fly population exhibits considerable variation, normally very low from April to June; tend to increase in July and reaches peak in August. From September onwards the population gradually declines and with slight increase there will be a small peak in October and thereafter remains at a moderate level till March (Balikai, 2000). Thus, the activities of shoot fly increased during the initial stages of crop growth, remain at high level during grand growth phase and decreased at crop reaching to cessation stage of crop (Rai and Mulatu, 2012). The peak incidence of shoot fly in *kharif* season was in the month of August while in *rabi* season it was in the month of October – November (Pawar *et al*., 2015). Shoot fly infestation is normally high in the post-rainy season crop planted in September-October. Its activity is influenced by extreme temperatures and frequency of rainfall also. Temperature above 35°C and below 18°C, and continuous rainfall reduced shoot fly abundance (Taneja *et al*., 1986). It was observed that the pest was active from 27th to 44th standard week. Further, studies on the shoot fly catches in fish meal trap revealed that highest peak catch of 488 flies per trap was recorded during 35th standard week (Karibasavaraja *et al.*, 2005a). Similarly, Maximum per cent dead hearts were recorded during 36th meteorological week, when prevailing maximum, minimum temperature and morning and evening relative humidity were 32.7, 22.1^{o}C, and 78.7 and 54.7 per cent, respectively (Aghav *et al*., 2007). It was reported that rainfall received at one week and higher day temperature at two weeks after seedling emergence reduced shoot fly infestation, whereas lower afternoon relative humidity at 4 weeks after emergence increased shoot fly infestation (Balikai and Venkatesh, 2001).

Extent of Losses

Sorghum shoot fly is one of the most destructive pest at the seedling stage, which causes yield losses of 68.6 and 75.6 per cent in terms of fodder and grain yield, respectively (Pawar *et al.*, 1984). The estimate of the annual loss comes to the tune of 5,25,200 tonnes, valued about five crore rupees. Total plant stand loss is not uncommon in delayed sorghum plantings in India.

Nature of Damage

Infestation normally occurs in the 1st to 4th weeks after seedling emergence. Maggot causes injury to the growing tip, which results in withering of central leaf popularly known as ‘dead heart’. The damaged seedling is killed but may produce side tillers. However, the side tillers are also attacked under high shoot fly pressure; some of them produce productive panicles, which often are subjected to the ravages of panicle feeding insects and birds. Early crop infestation may result in loss of plant stand.

Alternate Hosts

During the off-season, the shoot fly survives on alternate hosts (*Echinochloa colonum* Link., *E. procera* Hubb, *Cymbopogon* sp., *Paspalum scrobiculatum* Linn., and *Pennisetum glaucum* (L.) R. Br.).

Economic Threshold

The economic threshold levels (ETLs) vary over cultivars, locations, and seasons, and are influenced by variation in input costs, value of produce, productivity potential of the crop, as well as other socioeconomic factors. The ETL of 4-10, 3-9, and 6-15 per cent dead hearts in sorghum cultivars CSH-1, CSH-5 and Swarna, respectively has been estimated (Rai *et al*., 1978). For every 1 per cent increase in infestation lead to 89.1 and 30.5 kg per ha reduction in grain yield in CSH-5 and M 35-1, respectively (Mote, 1986).

Management

Various management practices suggested by different workers for sorghum shoot fly have been reviewed under following headings.

- Cultural control
- Host plant resistance
- Physical control
- Biological control
- Use of botanicals
- Chemical control
- Integration of various practices

Cultural control

Sorghum shoot fly can be effectively controlled by modifying the cultural practices like sowing time, seed rate, fertilization, intercropping etc. 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. 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 (Shekharappa and Bhuti, 2007). As the sowing was delayed, infestation of shoot fly increased and it adversely affected the plant height, weight and length of earhead, number of primaries and spikelets, grain and stover yield (Ameta and Sumeria, 2004). 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). 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 (Bhanderi and Patel, 2016). 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). Intercropping also plays an important role in reducing the population of sorghum shoot fly. Sorghum intercropped with garlic or onion reduced the shoot fly incidence on main crop. These intercrops can be used for the management of shoot fly with paired row planting of sorghum without affecting plant population (Karibasavaraja *et al*., 2005b). Sorghum-cowpea intercrop also increased the parasitism by *Neotrichoporoides nyemitawus* compared to sole crop (Singh and Sharma, 2002) and recorded less number of eggs and per cent dead heart (Spurthi *et al*., 2007).

Host plant resistance

Use of resistant genotypes against any pest is the best method to avoid the pest incidence. There are so many genotypes of sorghum which exhibit resistance against sorghum shoot fly. The genotypes viz., ICSB 425, ICSB 42 and IS 2312 showed resistance against sorghum shoot fly due to the leaf glossiness which acts as non-preference mechanism for oviposition (Kalpande *et al.*, 2015). Similarly, the genotypes S-1049, AFS-14, CVS-21F (Bangar *et al.*, 2012), ICVS 745, IS 2205 (Subbarayudu *et al.*, 2011), IS-2191, IS-4481, IS-4516, IS-17596, IS-18366, IS-33714, IS-33717, IS-33722, IS-33740, IS-33742, IS-33756, IS-33761, IS-33764, IS-33810, IS-33820, IS-33839, IS-33843, IS-3388 (Balikai and Biradar, 2004), KC-1, PGN-8, PGN-19, PGN-20, PGN-64, SEH-2, PFGS-2, PFGS-57 and PFGS-8 (Kishore and Kishore, 2001) were reported resistant and AFS-15, AFS-18 (Bangar *et al.*, 2012), SR-1247-1, SR 2126, ICSV 705, SPV 839, CSV 15, SR 2135, RS 29, CSH 5, GSSV 251, NSS 103, SR 1115-1, CSH 6, CSH 9 and SPV 462 (Subbarayudu *et al.*, 2011) as moderately resistant to sorghum shoot fly. Some other resistant sources are IS-1055, IS-2123, IS-2146, IS-2165, IS-2312, IS-3962, IS-4646, IS-4664, IS-5469, IS-5470, IS-5480, IS-5604, IS-5613, IS-5619, and IS-18551. Genotype PSC 2, PSC 3 and PSC 6 were also found promising against shoot fly (Sandhu, 2016). The genotypes RSV-175, RSV- 176, RSV-182 and RSV-290 were also reported as resistant sources stable across several locations (Narkhede *et al.*, 2002). Sorghum parental line 104A, 104B, RR 9817, RR 585 and RS 653 were found to be resistant (Balikai and Biradar, 2007) which can be used for effective control of shoot fly. Further, genotypes SR 770-2, SR 970-2, SR 833 and GFS 261 (Subbarayudu *et al.*, 2011) and forage sorghum lines Katakhatav, Ramkel, Rampur Local depicted multiple resistance to sorghum shoot fly (Prasad *et al*., 2015).

Physical Control

There are various types of traps used for controlling the sorghum shoot fly. Fishmeal trap is one of the most commonly used for trapping the adults of this pest. It was found effective bait for *A. soccata* and related species on sorghum. In fishmeal trap, about 80 to 97 per cent females of *A. soccata* were trapped (Gahukar, 1987). Further, sometimes only females were observed in fishmeal traps in catch studies, accounting 49.78 per cent gravid females (Mohan, 1991). The fish meal yeast ammonium sulphide was found the most potent mixture for trapping the maximum females (about 85 per cent) of shoot fly (Reddy *et al*., 1981). A hanging trap consisted of a plastic jar (11 cm diameter and 14 cm length) with entry holes (2 cm diameter), a dispenser with a fish meal and a small tube holding an insecticide to kill the trapped flies can also be used for attracting the shoot flies. These traps caught up to 342 adults daily and were more effective than pan type of water traps (Natarajan and Chellaiah, 1983).

Biological Control

Parasitoids : The natural enemies also play an important role in managing the sorghum shoot fly. The levels of egg parasitism vary widely across seasons and locations. In Burkina Faso, *Trichogrmmatoidea simmondsi* was observed on the sorghum crop between 17 and 38 days after planting and caused 8.8 to 12.3 per cent egg parasitism in sorghum cowpea intercrop. Further, the numbers of exit holes (1, 2, and 3) by *T. simmondsi* on each shoot fly egg have been observed in the proportion of 44.9, 53.5 and 1.6 per cent, respectively, indicating super-parasitism (Zongo *et al*., 1993). It was observed that *Aprostocetus* sp. may be one of the major parasites of shoot fly (Jotwani, 1978). In India, *Aprostocetus* sp., *Callitula bipartitus* Farooqui, *Neotrichoporoides* sp., and *N. nyemitawus* have been recorded from a number of locations. The maximum parasitism was found during the first week of August (Jotwani, 1981). Although, *N. nyemitawus* cannot prevent dead heart formation, it may be of potential use in reducing population build up of shoot fly in the first generation, which is quite low in early plantings. Parasitism levels increase by the second generation, coinciding with delayed plantings during the rainy season (Zongo *et al*., 1993). Intercropping of sorghum with cowpea has a beneficial effect in increasing the levels of parasitism by *N. nyemitawus*. There was a nearly 2-fold and 1.4-fold increase in larval parasitism in sorghum cowpea intercrop over mono crop sorghum.

Other larval parasitoids such as *Bracon sp*. and *Hockeria sp*. have also been recorded from shoot fly larvae (Zongo *et al*., 1993). *Hockeria sp*. is distributed worldwide and contains 30 described species (Halstead, 1990). It was also suggested that *T. simmondsi* was more effective than *N. nyemitawus* in reducing shoot fly populations. Subsequently, other parasites such as *Callitula sp*. (Eucoilidae), *Psilus sp*. (Diapriidae), *Hemiptarsenus sp*. and *Diaulinopsis sp*. (Eulophidae) from Delhi (Jotwani, 1978) and *Scoliopthalmu s nicans* Lamb. (Chloropidae) from Parbhani, India (Chopde, 1978) and *S. micantinpennis* Duda from Burkina Faso (Zongo *et al*., 1993) have been recorded. *Abrolophus* spp. (Acari: Erythraeidae) were also observed feeding on eggs and larvae of *A. soccata* in India (Reddy and Davies, 1979). An endo-parasite, *Trichoplasta sp*. Benoit has been recorded from shoot fly pupae in Italy (Del Bene, 1986).

Predators : The spider population plays an important role in reducing the shoot fly population as its population increased in about 31 days after crop planting which coincides with the susceptible stage of sorghum to shoot fly (Bailey and Chada, 1968). Several unidentified species of spiders from Kenya have been reported as predators on shoot fly eggs (Delobel and Lubega, 1984). In Uganda, *Dasyproctus bipunctatus* was reported as predator of shoot fly adults (Deeming, 1983). It was observed that saltids, thomisids, and aranaeids were predominant in a mono crop of sorghum, but the number of spider species such as *Araneus* sp., *Latrodectus geometricus* C.L. Koch (Theridiidae), *Meioneta prosectes* Locket (Linyphiidae), *Misumenops* sp., *Neoscona* sp., *Pardosa injuncta* P.P.Cbr. (Lycosidae) and *Steatoda badia* Rohwer (Theridiidae) increased in sorghum-cowpea intercrop (Zongo *et al*., 1993).

Use of botanicals : Management of this pest through botanicals can play a vital role in the organic production of sorghum. It was reported that three sprays (7th, 14th and 21st day after germination) of neem oil 2 per cent and karanj oil 2 per cent recorded lower oviposition and reduced the dead heart formation, considerably (Joshi *et al.*, 2016). Similarly, neem oil 2 per cent treated plots produced the yield at par with plant mixture and NSKE 5 per cent (Sable, 2009). Also NSKE 5 per cent alone sprayed at 21st day after germination reduced egg laying of shoot fly and per cent dead heart formation at par with carbofuran (Shrinivas Mudigoudra and Shekharappa, 2009). Maximum grain yield and the highest Cost Benefit ratio were recorded from neem oil l3 per cent (Gautam *et al*., 2014). 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 (Shrinivas Mudigoudra *et al*., 2009). 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). Likewise, *Vitex negundo* spray recorded significantly least per cent dead hearts caused by shoot fly (Anonymous, 2001). 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. Also at 28 DAG and at the ear head stage, the mint extract resulted in the lowering the level of shoot fly infestation (Juneja *et al*., 2004). Application of bioinoculants like *Azospillum* and *Azotobactor* as seed treatment are newly emerging trends which can be utilized in integrated control for suppressing sorghum shoot fly population (Kishore, 2000).

Chemical Control : Seed treatment with thiamethoxam 30 FS @ 5 ml/kg seed and imidacloprid 600 FS @ 7 ml/kg seed were found effective in reducing shoot fly incidence (Sandhu, 2016). Similarly, seed treatment with thiamethoxam 70 WS @ 3g/kg seed was found very effective against sorghum shoot fly (Daware *et. al*., 2012). Further, seed treatment even with lower dose of thiamethoxam 70 WS and imidacloprid 70 WS i.e. 2g and 5g, respectively (Kumar and Prabhuraj, 2007) or thiamethoxam @ 2.10 g a.i./kg seed (Daware *et al*., 2011) also performed better in reducing shoot fly incidence. Under late plantings, the shoot fly can be effectively controlled by the application of either carbofuran 3G or phorate 10 G @ 20 kg per ha at the time of planting in the seed furrows (Balikai, 1998). Application of cypermethrin @ 0.05 kg a.i. per ha at 6 and 12 days after emergence provided adequate control of this pest. Spray of carbaryl 50 WP, imidacloprid 17.8 SL, indoxacarb 15.8 SC, chlorantraniliprole 18.5 SC and fipronil 5 SC @ 375 g/ha, 75 ml/ha, 125 ml/ha, 100 and 175 ml/ha, respectively at 3–4 leaf stage also reduced the shoot fly incidence (Sandhu, 2016).

Integration of Various Practices : It was found that incidence of *A. soccata* was lowered and sorghum grain yield increased through the manipulation of management practices such as genotype selection, fertilizer and insecticide application (Obonyo *et al*., 2008). In an IPM package, soil application of carbofuran 3G @ 2 g/meter row + high seed rate of 10 kg/ha and thinning at 20 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 and highest grain yield (Balikai, 2003). Intercropping of sorghum with chickpea (2:2) + seed treatment with thiamethoxam 70 WS @ 3 g/kg seed or thiamethoxam 70 WS @ 3 g/kg seed + spray of NSKE 5 per cent at 45 DAE of crop or seed treatment with thiamethoxam 70 WS @ 3 g or /kg seed alone were effective in reducing the shoot fly population (Balikai and Bhagwat, 2009). Similarly**,** seed treatment with thiamethoxam 70 WS @ 3 g/kg followed by one spray of NSKE 5 per cent at 35 DAE of the crop, were effective in reducing the incidence of shoot fly (Daware and Ambilwade, 2014).

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