Forage Res., **50**(4) : pp. 447-453 (2025) **http://forageresearch.in**

PLANT VIGOUR, GLOSSINESS OF LEAF AND CANOPY ARCHITECTURE: MORPHOLOGICAL INDICATORS OF SHOOT FLY, *ATHERIGONA SOCCATA* RESISTANCE IN SORGHUM GENOTYPES

RAJ KUMAR[1], DALIP KUMAR[1]*, BAJRANG LAL SHARMA[1], TARUN VERMA[1], PAVITRA KUMARI[2], VIVEK KUMAR SAINI[3], POOJA YADAV[1] AND SUMIT MEHLA[1]

[1]Department of Entomology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125004, Haryana (India)
[2]Department of Plant Pathology, Chaudhary Charan Singh Haryana Agricultural University, Hisar-125004, Haryana (India)
[3]Department of Zoology, Government College, Hisar-125001, India
**(e-mail: dshroff@hau.ac.in)*

(Received: 14 January 2025; Accepted: 22 March 2025)

SUMMARY

In *Kharif*, 2021, a comprehensive study was conducted at CCS Haryana Agricultural University, Hisar, to determine the response of 40 sorghum genotypes against sorghum shoot fly under field condition, replicated thrice in randomized block design. 24 sorghum genotypes exhibited ovipositional preference (ovipositional mean 1.76eggs laid/plant with deadheart infestation of 18.95%) while, 16 sorghum genotypes shown ovipositional preference (2.37eggs laid/plant with deadheart 25.81%) and same trend was evident at 14 days after seedling emergence indicating higher the oviposition, higher of numbers of deadheart (%) in sorghum lines. As the glossiness of leaves (scale 1-5) declined, per cent deadheart infestation increased caused by shoot fly sand vice versa in different sorghum genotypes. On the basis of glossiness of leaves (scale 1-5), two sorghum genotypes fell in the range of 0.0–1.0 (deadheart 9.77%), five in a range of 1.1–2.0 (deadheart 14.75%), nine in a range of 2.1-3.0 (deadheart 22.82%), 20 in a range of 3.1–4.0 (deadheart 23.93%) and four genotypes fallen in a range of 4.1–5.0 (deadheart 28.70%). Sorghum genotypes (11) with closed canopy type of plants preferred more (deadheart 23.18%) by sorghum shoot fly over genotypes (29) having open canopy (deadheart 21.21%). Thus, traits associated with plants can be used as markers for developing shoot fly-resistant sorghum varieties.

Key words: Morphological**,** Resistance, screening, shoot fly, sorghum genotypes

Sorghum bicolor (L.) Moench, sometimes known as Jowar, belongs to the Poaceae family. Originating in North East Africa, it is a staple crop grown worldwide for food and fodder. Short-day; C4 tillering grass sorghum has fibrous roots and grows swiftly, reaching a maximum height of five meters (Badigannavar *et al.*, 2018). Sorghum crop is climate change compliant because to its resilience to high temperatures and water constraint (Abreha *et al.*, 2022). Sorghum ranks fourth in importance among cereals, behind rice, wheat, and maize in India (Dehinwal *et al*., 2016). The United States of America leads the world in sorghum production with 9.4 million tons (15%), followed by Ethiopia, Sudan, and Nigeria. India produces 3.47 million tons of sorghum annually, placing it fifth in the world (Anonymous, 2023). In 2020, India produced 4.15 million tons of sorghum grains on 4.15 million hectares of land, with a productivity of 1082.0 kg/ha (FAO, 2022), significantly less than the global average of 1412.6 kg/ha.

The Indian states of Maharashtra, Andhra Pradesh, Karnataka, Gujarat, Tamil Nadu, and Rajasthan are the main sorghum-growing regions. Grains of sorghum are used in many forms as roti or bhakri, malted, popped with several local preparations (Kumar *et al.*, 2024). According to Verma and Singh (2000), about 150 insect pest species can harm sorghum plants from the time of germination till the crop harvest. This is one of the significant factor to achieve the desired levels of productivity and production for sorghum. Within this heterogeneous group of insect pests, the sorghum spotted stem borer, *Chilo partellus* Swinhoe, shoot fly, *Atherigona soccata*

Rondani, ear head bug, *Calocoris angustatus* Leth. and ear head worm, *Cryptoblebes gnidiella* Mab. are some of the few quintessential insect pests that attack sorghum crop at different stages of the crop development (Patidar *et al.*, 2019). However, because adult shoot flies are active in the morning and evening, sorghum is more susceptible to damage during the early stages of crop growth, specifically the late-planted crop, which is 5 to 25 days after germination (Patil and Bagde, 2017). In India, *Atherigona soccata* can cause losses to the tune of 80-90 per cent in grain yield and 68 per cent in fodder yield (Kahate *et al.*, 2014). A radical change in pest management strategies from a unidirectional chemical approach to non-chemical alternatives like ecological management, biological control, and host plant resistance has, therefore, become imperative (Kumar et al, 2018). Keeping in the view of importance of resistance in sorghum crop, a field experiment carried out to estimate the reaction of 40 sorghum genotypes against sorghum shoot fly, *Atherigona soccata* on the basis of, Plant Vigour, Glossiness of Leaf and Canopy Architecture, morphological characteristics.

MATERIALS AND METHODS

Experiment was conducted during *Kharif*, 2021 at the research area of Forage Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar, situated at 29.1492°N, 75.7217°E at an elevation of 215 metres above sea level. It falls under agro-climatic zone II where summer temperature prevails as high as 46 degrees Celsius and temperature falls in winter up to1.5 degree Celsius. Southwest monsoon usually brings showers from July to September with an average of 450 mm. Recommended agronomic practices were followed to raise the healthy crop as per package of practices of CCSHAU for *Kharif* crop except plant protection measures.

Forty sorghum genotypes were collected from Forage section, Department of Genetics and Plant Breeding, CCSHAU, Hisar as availed under All India Coordinated Sorghum Improvement Project (AICSIP), International Crop Research Institute for semi-arid tropics (ICRISAT), Hyderabad.

Plant vigour (visual basis)

Five randomly selected and tagged plants were assessed for vigour in morning hours between 6 to 9 A.M. at 12 days after emergence and vigour rating (1-5) were ascribed to them per method suggested by Sharma and Nwanze, 1997.

Glossiness of leaves (visual basis)

Five randomly selected and tagged plants from each genotype were evaluated to assess the glossiness of leaves at 12th DAE in morning hours between 6 to 9 A.M. and glossiness rating were ascribed to them as per method suggested by Sharma and Nwanze, 1997.

Shape of canopy (visual basis)

Five tagged plants per replication were selected randomly to record the observations on plant canopy (open/ close) at maturity.

Plant vigour Scale	Plant characteristics
1	Highly vigorous, plant showing maximum height, more number of fully expanded leaves, good adaptation, and robust seedlings
2	Vigorous, good plant height, good number of fully expanded leaves, good adaptation and good seedlings growth
3	Moderately vigorous, moderate plant height with moderate number of fully expanded leaves and fairly good seedlings growth
4	Less vigorous, less plant height with poor leaf expansion and poor adaptation
5	Poor seedling vigour, plant showing poor growth and weak seedlings

Glossiness of leaves	Leave characteristics
1	Highly glossy, light green, shining, narrow and erect leaves
2	Glossy, light green, less shining, narrow and erect leaves
3	Moderate glossy, fair green, light shining, medium leaf width and less dropping leaves
4	Moderate non glossy, green, pseudo-shine, broad and drooping leaves
5	Non-glossy, dark green, dull, broad and drooping leaves

Number of egg/plant

Numbers of eggs laid by sorghum shoot fly underneath the leaves of five randomly selected and tagged plants per replication were recorded at 7 and 14 days after emergence.

Deadheart (%)

Observations on deadheart were made at 21 and 28 days after emergence (DAE) in the experimental plots. Based on total number of plants per replication, numbers of plants having deadhearts caused by shoot fly and deadheart (%) was calculated as per following formula.

$$\text{Deadheart (\%) due to shoot fly} = \frac{\text{Number of plants with deadheart}}{\text{Total number of plants observed}} \times 100$$

Statistical analysis

Data of different treatments were analyzed by using OPSTAT software (Sheoran *et al.*, 1998).

RESULT AND DISCUSSIONS

Forty sorghum genotypes were screened during *Kharif* 2021 to determine source of resistance against sorghum shoot fly, *Atherigona soccata* under the field infestation conditions, on the basis of deadheart (%) formation at 21 and 28 DAE and it's relation with number of eggs laid per plant at 7 and 14 DAE, glossiness of leaves, seedling vigour on 12 DAE and shape of canopy at the time of harvest.

Ovipositional preference of sorghum shoot fly at 7 and 14 days after emergence (DAE)

Mean value of number of eggs laid by sorghum shoot fly (average values of egg laid per plant at 7 and 14 days after crop emergence) ranged from 1.0 to 5.8 with a mean of 3.3 in screened sorghum genotypes. Resistant check IS 2312 recorded least egg laying *i.e.*, 1.0 followed by IS 2205 (1.3), test entries; SH 2026 and 467 x SSG each recorded 1.8 eggs per plant and SH 1603 (2.0) found statistically at par with each other. Egg laid by sorghum shoot fly, *A. soccata* ranged from 0.33 to 4.67 with the mean of 2.37 per plant (Fig. 1) at 7 days after emergence. Resistant checks IS 2312

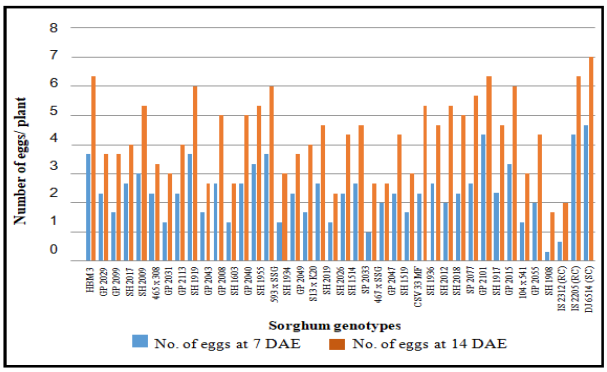

Fig. 1. Shoot fly eggs/plant on sorghum genotypes at 7 and 14 DAE.

recorded the least number of eggs per plant *i.e.*, 0.33 followed check IS 2205 (0.7) were statistically at par, also test entries; 467x SSG (1.0), GP 2055, SH 2026, SH 1934, SH 1603 and GP 2031each having 1.3 eggs per plant with each other. At 14 days after emergence, eggs laid by sorghum shoot fly varied from 1.7 to 7.0 with mean 4.3 per plant across the sorghum lines tested (Fig. 1). Again at 14 days after crop emergence resistant check *i.e.*, IS 2312 (1.7) and IS 2205 (2.0) recorded least number of eggs per plant followed by sorghum lines *viz.*, SH 2026 (2.3), GP 2047 (2.67), 467xSSG (2.67), SH 1603 (2.6), GP 2043 (2.6), GP 2031 (3.0), SH 1934 (3.0), GP 2055 (3.0) and CSV33MF (3.0). Forty sorghum genotypes were categorized into two categories on the basis of mean of number of eggs *i.e.*, 2.37/per plant laid by *A. soccata* at 7 days after seedling emergence (Table 1). 24 sorghum genotypes were having the cumulative ovipositional preference mean value (1.76eggs/plant) less than the mean (2.37eggs/plant) having deadheart infestation rate 18.95 per cent. 16 sorghum genotypes had an aggregated ovipositional preference mean (3.29eggs/plant) that was higher than the mean of eggs laid per plant *i.e.*, 2.37 having cumulative deadheart percentage of 25.81 per cent. At 14 days after seedling emergence, 18 genotypes had an ovipositional preference mean value of 3.06 eggs/plant less than the average eggs laid per plant (4.32) with deadheart infestation 17.83 per cent (Table 2) while, 24 sorghum genotypes aggregated ovipositional preference mean 5.35 eggs per plant with a cumulative deadheart percentage of 24.97 per cent indicating higher the oviposition resulted in higher number of deadheart in sorghum germplasm lines. Present findings are in accordance with the Subbaraydu *et al.* (2011) that observed eggs of shoot fly per plant ranged from 1.5 (IS 2312) to 9.3 (DJ 6514) and test entries, IS 2205, GFS 261, SR 1247-1 and SR 115-1 recorded 1.5 eggs/

TABLE 1
Categorisation of sorghum genotypes on the basis of ovipositional preference at 7 DAE against sorghum shoot fly, *Atherigona soccata* during *Kharif*, 2021

S. No.	Ovipositional preference (no. of eggs/plant) (Mean)	Deadheart (%)	No of genotypes	Sorghum genotypes
1.	1.76 (≤2.37)	18.95	24	GP 2029, GP 2099, 465 x 308, GP 2031, GP 2113, GP 2043, SH 1603, SH 1934, GP 2049, S13 x K20, SH 2026, SH 1514, 467 x SSG, GP 2047, SH 1519, CSV 33 MF, SH 1936, SH 2018, SP 2077, GP 2015, GP 2055, SH 1908, IS 2312, IS 2205
2.	3.29 (≥2.37)	25.81	16	HBM 3, SH 2017, SH 2009, SH 1919, GP 2008, GP 2040, SH 1955, 593 x SSG, SH 2019, SP 2033, SH 2012, GP 2101, SH 1917, 104 x 541, DJ 6514, Swarna

plant at 14 DAE. Kumar (2024a) and Kumar (2024b) also pointed out role of morphological characters associated with some sort of resistance in different sorghum genotypes. A number of authors; Arora *et al.* (2021), Shid *et al.* (2021) and Anandan *et al.* (2009) also supported present results with their outcome of this studies that presence of higher number of eggs in susceptible set side by side lower egg laid in resistant checks.

Plant vigour

Plant vigour is considered an important factor in determining susceptibility and or resistance to sorghum shoot fly infestation in different sorghum genotypes. Infestations of sorghum shoot fly observed to be less in plants that have more plant vigour in the early stages of crop growth. During *Kharif*, 2021, a considerable variation in plant vigour in different sorghum genotypes do existed. Two sorghum genotypes that lied in a range of 0.0–1.0, nine in a range of 1.1–2.0, 12 in a range of 2.1- 3.0, 14 in a range of 3.1–4.0 and three genotypes positioned in a range of 4.1–5.0. Resistant checks, IS 2312 and IS 2205 recorded plant vigour with a score of 1.0 each, indicating that these are to be more vigorous entries. Test entries, SH 1917, SH 1919, GP 2043, GP 2008, GP 2099 (1.3) and 465x308 (1.7) were statistically similar to resistant checks. Highest seedling vigour score of 4.7, exhibited by the susceptible check Swarna was at par with DJ 6514 (4.3), SP 2033 (4.3), SH 1908 (4.0), GP 2047 (4.0) and 593xSSG (4.0) indicating least vigorous seedlings. 40 sorghum genotypes categorized into five categories on the basis of plant vigor (Table 3 and Fig. 2). Two genotypes lied in a range of 0.0–1.0 and their average deadheart per cent was 9.77; nine genotypes fallen in a range of

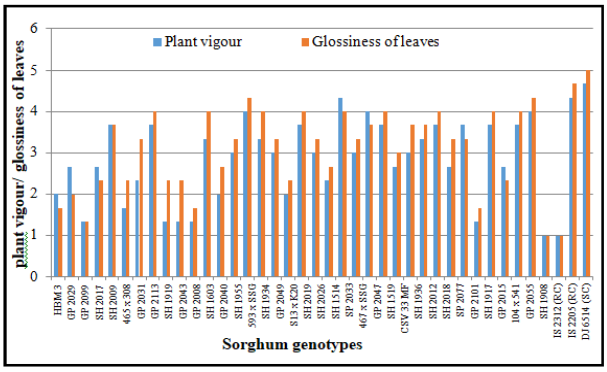

Fig. 2. Plant vigour and glossiness of leaves score in various sorghum genotypes.

1.1–2.0 and deadheart (%) was 19.84; 12 genotypes classed in a range of 2.1-3.0 with deadheart per cent 20.47; 14 genotypes stand in a range of 3.1–4.0 having deadheart per cent 24.14; and three genotypes positioned in a range of 4.1–5.0 carried deadheart 29.41 per cent infestation. Thus, as the plant vigour declined, per cent deadheart infestation decreased and vice versa in screened sorghum genotypes. Bhan and co-workers (2018) also reported maximum plant vigour rating in sorghum varieties, CSV23 (4.67) and CSV 20 (4.67) and minimum in CSV 10 (3.33) at 12 days after germination. Jayanthi *et al.* (2002) inferred that seedling vigour plays a significant impact in imparting resistance in sorghum against *Atherigona soccata* and high seedling vigour was observed in resistant group compared to susceptible groups as higher seedling vigour prevents establishment of larvae of shoot fly.

Glossiness of leaves

Glossiness of leaves in the 40 sorghum genotypes accessed visually (on the scale1 to 5) at 12 days after germination during *Kharif*, 2021. A substantial variation among the sorghum genotypes in

TABLE 2
Categorisation of sorghum genotypes on the basis of ovipositional preference at 14 DAE against sorghum shoot fly, *Atherigona soccata Kharif*, 2021

S. No.	Ovipositional preference (no. of eggs/plant) (Mean)	Deadheart (%)	No of genotypes	Sorghum genotypes
1.	3.06 (≤4.32)	17.83	18	GP 2029, GP 2099, SH 2017, 465 x 308, GP 2031, GP 2113, GP 2043, SH 1603, SH 1934, GP 2049, S13 x K20, SH 2026, 467 x SSG, GP 2047, CSV 33 MF, GP 2055, IS 2312, IS 2205
2.	5.35 (≥4.32)	24.97	22	HBM 3, SH 2009, SH 1919, GP 2008, GP 2040, SH 1955, 593 x SSG, SH 2019, SH 1514, SP 2033, SH 1519, SH 1936, SH 2012, SH 2018, SP 2077, GP 2101, SH 1917, GP 2015, 104 x 541, SH 1908, DJ 514, Swarna

TABLE 3
Categorisation of sorghum genotypes on the basis of plant vigour against sorghum shoot fly, *Atherigona soccata* during *Kharif*, 2021

S. No.	Plant vigor rating	Deadheart (%)	Number of genotypes	Sorghum genotypes
1.	0.0-1.0	9.77	2	IS 2312, IS 2205
2.	1.1-2.0	19.84	9	GP 2099, SH 1917, 465 x 308, SH 1919, GP 2043, GP 2008, HBM 3, GP 2040, S13 x K20,
3.	2.1-3.0	20.47	12	GP 2029, SH 2017, GP 2031, SH 1955, GP 2049, SH 2026, SH 1514, 467 x SSG, CSV 33 MF, SH 1936, SP 2077, 104 x 541
4.	3.1-4.0	24.14	14	SH 2009, GP 2113, SH 1603, 593 x SSG, SH 1934, SH 2019, SH 1519, SH 2012, SH 2018, GP 2101, GP 2015, GP 2055, GP 2047, SH 1908,
5.	4.1-5.0	29.41	3	SP 2033, DJ 6514, Swarna

Plant vigour = Scale 1-5.

terms of glossiness of leaves was apparent (Table 4 and Fig. 2), lower the score higher of the glossiness of leaves and vice versa. Resistant checks, IS 2312 and IS 2205 recorded minimum glossiness of leaves score of 1.00, test lines *viz.*, GP 2099 (1.33), SH 1917, HBM 3, GP 2008 each with a score of 1.67 and GP 2029 (2.00) were statistically similar to resistant checks. A higher score of 5.00 in glossiness of leaves was observed in susceptible check Swarna followed by DJ 6514 (4.67) and two test lines *viz.*, SH 1908, 593xSSG recorded a score of 4.33 and nine sorghum genotypes *viz.*, GP 2055, GP 2015, GP 2113, SH 2018, SH 1519, SH 1603, SH 2019, SH 1934 and SP 2033 recorded rating of glossiness as 4.00 found statistically at par with each other. Furthermore, 40 sorghum genotypes classed into five categories on the basis of glossiness of leaves. Two sorghum genotypes fell in the range of 0.0–1.0 with average deadheart per cent 9.77; five genotypes fallen in a range of 1.1–2.0 with deadheart per cent 14.75; nine genotypes positioned in a range of 2.1-3.0 with deadheart per cent 22.82; 20 genotypes lied in a range of 3.1–4.0 and deadheart per cent was 23.93; and four genotypes fallen in a range of 4.1–5.0 got deadheart per cent 28.70. It is to be note worthy that as the glossiness of leaves declined, per cent deadheart infestation increased and vice versa in different sorghum genotypes. Results of this study get conformed during the screening of fifteen sorghum genotypes on the basis of glossiness of leaves that varied from 1.02 to 4.48 by Raut *et al.* (2015) as found lowest value recorded in IS 18551 (resistant check) and highest value found in DJ 6514 (susceptible check). Similarly, Bhan *et al.* (2018), Madavi and Sonalkar (2019) and Shid *et al.* (2021) also reported that higher glossiness of leaves in resistant genotypes and susceptible checks had lower glossiness of leaves.

Shape of canopy

Crop canopy can be determined by observing variations in leaf angle across the plant. Sorghum plants

TABLE 4
Categorisation of sorghum genotypes on the basis of glossiness of leaves against sorghum shoot fly *Atherigona soccata* during *Kharif*, 2021

S. No.	Glossiness of leaves scale	Deadheart (%)	Number of genotypes	Sorghum genotypes
1.	0.0-1.0	9.77	2	IS 2312, IS 2205
2.	1.1-2.0	14.75	5	HBM 3, GP 2008, SH 1917, GP 2029, GP 2099
3.	2.1-3.0	22.82	9	SH 2017, 465 x 308, SH 1919, GP 2043,GP 2040, S13 x K20, SH 1514, CSV 33 MF, 104 x 541
4.	3.1-4.0	23.93	20	SH 2009, GP 2031, SH 1955, GP 2049, 467 x SSG, GP 2047, SH 1936, SH 2012, SP 2077, GP 2101, GP 2113, SH 1934, SH 2019, SH 2026, SP 2033, SH 1519, SH 2018, GP 2055 SH 1603, GP 2015
5.	4.1-5.0	28.70	4	593 x SSG, SH 1908, DJ 6514, Swarna

Glossiness of leaves = Scale1-5.

TABLE 5
Categorisation of sorghum genotypes on the basis of shape of canopy against sorghum shoot fly, *Atherigona soccata* during *Kharif*, 2021

S. No.	Shape of canopy	Deadheart (%)	Number of genotypes	Sorghum Genotypes
1.	Closed	23.18	11	HBM 3, SH 2017, 465 x 308, GP 2113, GP 2008, SH 1934, SH 1514, SH 2012, GP 2015, 104 x 541, GP 2036
2.	Open	21.21	29	GP 2029, GP 2099, SH 2009, GP 2031, SH 1919, GP 2043, SH 1603, GP 2040, SH 1955, 593 x SSG, GP 2049, S13 x K 20, SH 2019, SH 2026, SP 2033, 467 x SSG, GP 2047, SH 1519, CSV 33 MF, SH 1936, SH 2018, SP 2077, GP 2101, SH 1917, GP 2055, SH 1908, SH 1918, DJ 6514, Swarna

with a lesser angle of leaf inclination are supposed to have a closer canopy, while those with a greater angle of leaf inclination said to have an open canopy. Out of 40 sorghum genotypes screened, eleven genotypes had a closed canopy and 29 had an open canopy as depicted in Table 5. Percentage of deadheart caused by sorghum shoot fly was higher in closed canopy genotypes (23.18%) compared to lower in open canopy genotypes (21.21%) indicated a preference for close canopy. Kumar *et al.* (2018) contradicted the results as authors reported early shoot borer preferred to bore accessions/cultivars of sugarcane with light green and drooping foliage. As early as 1962, reports of Rao Shiva (1962) on preference of shoot borer, *Chilo infuscatellus* for Co clones with droopy foliage available. Similarly, light green and droopy foliage has been observed (Chaudhary and Yadav, 1995) in case sugarcane top borer, *Scirpophaga excerptalis* and aphid in wheat (Niraz *et al.* 1987).

CONCLUSION

Deadheart (%) caused by shoot fly varied from 6.23 to 23.94 per cent (mean of 15.80%) and from 11.42 to 43.48% (mean 27.43%) at 21, 28 days after crop emergence, respectively in 40 sorghum genotypes. During *Kharif*, 2021, a considerable variation in plant vigour in different sorghum genotypes do existed and less Infestations of shoot fly observed in plants that have more plant vigour in the early stages of crop growth. 24 sorghum genotypes exhibited ovipositional preference mean of 1.76 eggs laid/plant (deadheart infestation 18.95%) while, 16 genotypes aggregated ovipositional preference *i.e.*, 2.37eggs laid/ plant having deadheart 25.81 per cent. Same trend was evident at 14 days after seedling emergence, thus indicating higher the ovipositional preference behaviour, higher of deadheart (%) in sorghum lines. On the basis of glossiness of leaves (scale 1-5), it is to be note worthy that as the glossiness of leaves declined, per cent deadheart infestation increased and vice versa in screened sorghum genotypes. Sorghum genotypes (11) with closed canopy preferred more (deadheart 23.18%) over genotypes (29) having open canopy (deadheart 21.21%). Sorghum genotypes with improved plant vigour, glossy leaves, and open canopies showed reduced shoot fly infestation. These traits can be used as markers for developing shoot fly-resistant sorghum varieties.

ACKNOWLEDGEMENTS

All sort of assistance rendered by Director of Research and Forage section, Department of Genetics and Plant Breeding, CSS Haryana Agricultural University, Hisar, India for the above study is gratefully acknowledged.

REFERENCES

Abreha, K.B., M. Enyew, A.S. Carlsson, R.R. Vetukuri, T. Feyissa, T. Motlhaodi, D. Nguni, and M. Geleta, 2022: Sorghum in dryland: morphological, physiological, and molecular responses of sorghum under drought stress. *Plantae*. **255**(1): 99-107.

Anonymous, 2023. Accessed from agricoop.nic.in. Department of Agriculture Cooperation and Farmer Welfare. (accessed on 22th June, 2024).

Badigannavar A, N. Teme, A.C. de Oliveira, G Li, M Vaksmann, V.E. Viana, T. Ganapathi and F. Sarsu, 2018: Physiological, genetic and molecular basis of drought resilience in sorghum [*Sorghum bicolor* (L.) Moench]. *Indian Journal of Plant Physiology*, **23**(4): 670-688.

Bhan, C., H. Swami, Lekha, A. Mordia, S. S. Lakhawat and M. K. Mahla, 2018: Screening of different sorghum varities for resistance against sorghum shoot fly. *Indian Journal of Applied Entomology*, **32**(1): 42-47.

Chaudhary, J. P. and S. R. Yadav, 1995: Studies on correlation between some morphological characteristics of sugarcane genotypes and plant susceptibility to top borer, *Scirpophaga excerptalis* walker (Lepidoptera: Pyralidae)-III. Cooperative Sugar. **26**: 919-930.

Dehinwal, A.K., S. K. Pahuja and M. Shafiqurrahaman, 2016: Environmental effect on sorghum fodder yield and its related traits. *Forage Res.*, **42**(3): 189-194.

FAO, 2024: http//www.fao.org/faostat/en/#data (accessed on 20th October, 2024).

Jaanthi, P. D. K., B. V. Reddy, T. B. Gour and D. D. R. Reddy, 2002: Early seedling vigour in sorghum and its relationship with resistance to shoot fly, *Atherigona soccata* Rondani. *Journal of Entomological Research*, **26**(2): 93-100.

Kahate, N.S., S.M. Raut, P.H. Ulemale and A.F. Bhogave, 2014: Management of sorghum shoot fly. *Popular Kheti*, **2**(1):72-74.

Kumar, D., D. S. Ahlawat, S. S. Yadav, D. Kalkal, V. K. Saini and D. Singh, 2018: Phenetic resistance in sugarcane, tentative conclusions and new research directions. *Journal of Entomology and Zoology Studies*, E-ISSN: 2320-7078 P-ISSN: 2349-6800; 6(4): 999-1003.

Kumar R., D. Kumar, B. L. Sharma, T. Verma, P. Kumari, V. K. Saini, S. Mehla and P. Yadav, 2024a: Assessment of sorghum genotypes against sorghum shoot fly, *Atherigona soccata* with respect to morphological characters. *Forage Res.*, **50**(1): pp.82-86.

Kumar R., D. Kumar, B. L. Sharma, T. Verma, P. Kumari, V. K. Saini, S. Mehla and Subham., 2024b: Impact of date of sowing on the incidence of sorghum stem borer, *Chilo partellus* and sorghum shoot fly, *Atherigona soccata* in dual purpose sorghum. *Forage Res.*, **49**(4): pp. 486-492.

Madavi, M. G. and V. U. Sonalkar, 2019. Evaluation of sorghum genotypes for their resistance to shoot fly *Atherigona soccata*. *Indian Journal of Entomology*, **81**(3): 558-563.

Niraz, S, B. Leszczynski, A. Ciepiela, A. Urabanska, 1987: The importance of various plant chemical compounds to constitutive aphid resistance in winter wheats. Rozczniki Nauk Rolniczuch, E (Ochrona Roslin), **17**: 61-75.

Patidar, R., S. B. Singh, N. Kamde and R. Patidar, 2019: Reaction of different sorghum hybrids against sorghum insect pest population. *Journal f Entomology and Zoology studies.* **7**(5): 13-21.

Patil, S.P. and A.S. Bagde, 2017: Effect of new molecules of insecticides on shoot fly (*Atherigona soccata*) (Rondani) incidence and grain yield of sorghum. *International Journal of Current Microbiology and Applied Sciences*, **6**(1): 2751-2754.

Rao, Siva DV., 1962 Studies on the resistance of sugarcane to early shoot borer, *Chilo infuscatellus* Snell. MSc Thesis, Andhra University, waltair, 1962.

Raut, A. H., Pawar D.B. & Damre, A. S., 2015: Resistance mechanism of sorghum genotypes against shoot fly, *Atherigona soccata* Rondani in *Rabi* season. Doctoral dissertation, Mahatma Phule Krishi Vidyapeeth, Rahuri.

Sharma, H.C. and K. F. Nwanze, 1997: Mechanism of resistance to insects and their usefulness in sorghum improvement. Information Bulletin no. 55. International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, 51pp.

Sheoran, O.P., D.S. Tonk, L.S. Kaushik, R.C. Hasija, and R.S. Pannu, 1998: *Statistical software package for agricultural research workers*. Recent advances in information theory, statistics and computer application by Hooda, D.S. and Hasija, R.C., Department of Mathematics and Statistics, CCS HAU, Hisar. 139-14.

Shid, D. C., U. K. Kadam and U. S. Dalvi, 2021: Screening and biochemical evaluation of different sorghum genotypes for shoot fly resistance. *The Pharma Innovation*, **10**(12): 134-138.

Verma, T., and S. P. Singh, 2000: Multiple resistance in forage sorghum hybrids to the sorghum shootfly, *Atherigona soccata* (Rondani) and the spotted stem borer, *Chilo partellus* (Swinhoe). *International Journal of Tropical Insect Science*, **20**: 203-206.