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Research Article

Screening of Sorghum Genotypes Resistance to Sorghum Shoot Fly (*Atherigona Soccata*) In West Hararghe, Oromia

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Abstract

Shoot fly (Atherigona soccata) is one of the major insect pests limiting sorghum production by causing severe seedling damage and significant yield losses. Although management options such as timely planting, seed treatment with systemic insecticides, and foliar insecticide applications are available, their effectiveness is often constrained by rainfall variability and the high cost of insecticides for resource-poor farmers. Therefore, host plant resistance offers an economically viable and environmentally sustainable approach for managing shoot fly infestations. This study aimed to identify sorghum genotypes with stable resistance to shoot fly under field conditions. The experiment was conducted at the Mechara Agricultural Research Center (McARC), Ethiopia, where eighty sorghum genotypes were evaluated for their response to shoot fly infestation. The results revealed substantial variation among genotypes in their level of resistance. Out of the eighty genotypes tested, fifty-nine exhibited resistant or tolerant reactions to shoot fly damage. These resistant/tolerant genotypes represent valuable genetic resources for sorghum improvement programs and can be utilized in future breeding efforts aimed at developing shoot fly-resistant varieties. The identified genotypes provide a sustainable option for enhancing sorghum productivity and reducing yield losses caused by shoot fly infestations.

Keywords

Atherigona Soccata, Sorghum, Host Plant Resistance, Genotype Evaluation, Shoot Fly, Breeding, Sustainable Crop Production

1. Introduction

Sorghum (Sorghum bicolor L. Moench) is among the most important cereal crops cultivated in the semi-arid and arid regions of the world. It serves as a staple food for millions of people and plays a critical role in ensuring food security in drought-prone environments. Historical evidence indicates that sorghum originated in the northeastern part of Africa, particularly Ethiopia and neighboring regions, where its domestication began approximately 4,000–3,000 BC [3, 21]. Owing to its remarkable adaptability to moisture-limited conditions and low-input production systems, sorghum is widely cultivated across Africa, Asia, and the Americas [5]. In many African countries, the crop is primarily grown for human consumption, especially in areas characterized by erratic rainfall and poor soil fertility [5]. Beyond its importance as a food crop, sorghum grain is utilized for livestock feed, traditional beverages, and industrial purposes, including bioethanol production through fermentation technologies [12]. Despite its resilience, sorghum productivity is constrained by numerous biotic and abiotic stresses.

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Among the biotic factors limiting sorghum production, insect pests represent a major challenge throughout the crop growth cycle, from seedling emergence to grain maturity. Economic losses attributed to insect damage in sorghum-producing regions of the semi-arid tropics exceed US$1 billion annually. More than 150 insect species have been reported on sorghum, although only a limited number are considered economically significant. Among these, the sorghum shoot fly (Atherigona soccata) is one of the most destructive pests, particularly under delayed planting conditions during the rainy season [2]. Infestation by shoot fly causes the characteristic "dead-heart" symptom, resulting in reduced plant population and substantial losses in both grain and fodder yield. Previous studies have shown that each one-percent increase in dead-heart incidence may reduce grain yield by approximately 143 kg ha^{-1}, while severe infestations can result in yield losses approaching 90–100% under favorable conditions for pest development [2].

The severity of shoot fly infestation is generally greater in late-planted crops, although outbreaks may also occur in early plantings when intermittent rainfall follows a prolonged dry period [9]. Several management practices have been recommended to reduce shoot fly damage, including timely sowing, seed treatment with systemic insecticides, and targeted foliar insecticide applications during the seedling stage [15]. However, the effectiveness of these measures is often limited by unpredictable rainfall patterns and the high cost of chemical inputs, which may be unaffordable for smallholder farmers in semi-arid regions [14]. Consequently, host plant resistance has emerged as one of the most economical, environmentally sound, and sustainable approaches for suppressing shoot fly populations below economically damaging levels [13, 15].

In the western Hararghe area of eastern Ethiopia, information on sorghum genotypes possessing reliable resistance or tolerance to shoot fly is limited. The identification of resistant germplasm is essential for developing improved varieties and strengthening integrated pest management strategies. Therefore, the present study was conducted to evaluate sorghum genotypes and identify stable sources of resistance or tolerance to shoot fly infestation under field conditions.

2. Materials and Methods

2.1. Description of Experimental Sites

The field experiment was conducted during the 2023 main cropping season at the Mechara Agricultural Research Center (McARC), located in western Hararghe, eastern Ethiopia. The research site is situated at approximately 8°35′ N latitude and 40°19′ E longitude, at an elevation of about 1,700 m above sea level, and lies nearly 434 km east of Addis Ababa. The area receives an average annual rainfall of approximately 1,120 mm. Climatic conditions are characterized by a mean annual temperature of 21°C, with average maximum and minimum temperatures of 28°C and 15°C, respectively.

Experimental Materials: Treatments, Experimental procedures, design and field management

The sorghum genotypes used in this study were obtained from the Fadis Agricultural Research Center. A total of eighty genotypes were evaluated under field conditions using an augmented experimental design without replication. Each genotype was planted in two rows, and all recommended agronomic management practices were applied uniformly throughout the experimental period, except for insecticide treatments, which were intentionally omitted to allow natural shoot fly infestation. Rows were spaced 0.75 m apart, while plants within a row were maintained at a spacing of 0.20 m.

2.2. Data Collection

Shoot fly damage and morphological parameters:

Percent dead heart: The incidence of dead hearts was assessed 21 days after seedling emergence. The number of plants exhibiting dead-heart symptoms was recorded and expressed as a percentage of the total number of plants evaluated in each genotype, following the procedure described by [9].

$$\text{Dead Heart\%} = \frac{\textit{Number of plants with dead heart}}{\textit{Total Number of plants}} \text{X100}$$

Oviposition: Oviposition was assessed at 14 days after seedling emergence (DAE) by recording the number of plants bearing shoot fly eggs in each plot. The level of oviposition was expressed as a percentage of the total plants examined, following the method described by [7].

$$\text{Oviposition\%} = \frac{\textit{Number of plants with eggs}}{\textit{Total Number of plants}} \text{X100}$$

Seedling vigour: Seedling vigour was evaluated 16 days after emergence (DAE) based on plant height, leaf development, and overall plant robustness. Genotypes were rated using a 1–5 scoring scale, where a score of 1 indicated highly vigorous seedlings characterized by greater plant height, extensive leaf expansion, and robust growth, while a score of 5 represented poor seedling vigour, characterized by reduced growth, limited leaf development, and weak plant establishment. The assessment was conducted following the procedure described by [7].

Overall resistance score: The overall resistance of each genotype to shoot fly infestation was assessed before harvest using a 1–9 rating scale, as described by [17]. The scoring was based on the extent of dead-heart formation, tiller development, and the production of harvestable panicles. A score of 1 indicated a highly resistant genotype, characterized by less than 10% dead hearts, uniform tiller development, and the presence of productive harvestable panicles. In contrast, a score of 9 represented a highly susceptible genotype, exhibiting more than 80% dead hearts and few or no productive tillers. Intermediate scores reflected varying levels of resistance or susceptibility.

2.3. Data Analysis

Data were subjected to descriptive statistics.

3. Results and Discussion

Oviposition Response of Sorghum Genotypes

Substantial variation was observed among the eighty sorghum genotypes for shoot fly oviposition. At 14 days after emergence (DAE), oviposition levels ranged from 25.00% to 81.25%, indicating marked differences in host preference by shoot fly females. The lowest oviposition percentage (25.00%) was recorded in genotype EBI-69076, whereas genotypes EBI-244230, EBI-244707, and EBI-235448 exhibited the highest oviposition level (81.25%). These results suggest that certain genotypes possess traits that reduce attractiveness for egg laying and may contribute to resistance against shoot fly infestation.

Based on oviposition percentage, four genotypes were grouped within the 20.1–30.0% category, twenty-five within 30.1–40.0%, twenty-six within 40.1–50.0%, and twenty-four within 50.1–81.25%. Using a resistance threshold of less than 40% oviposition, thirty genotypes were identified as resistant or tolerant. Reduced oviposition is an important component of host plant resistance because it minimizes egg deposition and subsequently limits larval establishment. Similar findings have been reported by several researchers who identified non-preference for oviposition (antixenosis) as a major mechanism of shoot fly resistance in sorghum [11, 16, 18-20]. Therefore, the genotypes exhibiting low oviposition percentages may serve as valuable sources of resistance in sorghum improvement programs.

Dead-Heart Incidence

Dead-heart incidence, a direct measure of shoot fly damage, varied considerably among the evaluated genotypes. The percentage of dead hearts ranged from 12.50% to 46.67%, demonstrating substantial genetic variability in response to infestation. The lowest dead-heart incidence (12.50%) was recorded in three genotypes, while the highest incidence (46.67%) was observed in one genotype.

Of the eighty genotypes evaluated, twenty-nine exhibited dead-heart incidence between 10.1 and 20.0%, thirty genotypes ranged from 20.1 to 30.0%, twelve genotypes recorded values between 30.1 and 40.0%, and nine genotypes showed dead-heart incidence ranging from 40.1 to 46.67% (Figure 1). Based on the resistance criterion of less than 35% dead-heart incidence, sixty genotypes were classified as resistant or tolerant. Lower dead-heart formation indicates reduced larval survival and feeding activity, thereby enhancing plant establishment and productivity. Sharma et al. [16] similarly reported that sorghum genotypes with less than 35% dead-heart incidence possess resistance levels comparable to established resistant breeding lines. The large number of resistant genotypes identified in the present study highlights the availability of useful genetic resources for breeding sorghum cultivars with improved resistance to shoot fly.

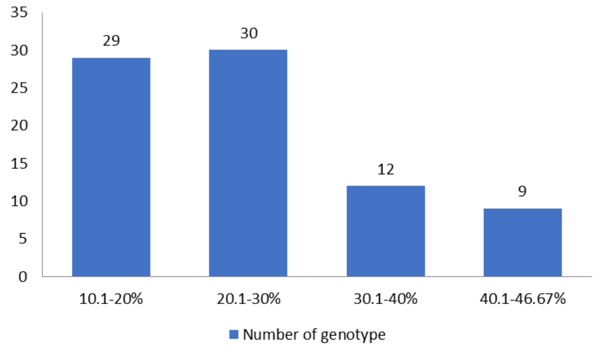

Figure 1. *Number of genotypes based on dead heart percentage.*

Seedling Vigour

Significant variation was also observed among the genotypes for seedling vigour. Of the eighty genotypes evaluated, twenty-nine received a vigour score of 1, thirty genotypes received a score of 2, twelve genotypes scored 3, and nine genotypes scored 4 (Figure 2). Since lower scores indicate greater vigour, the majority of the evaluated genotypes exhibited good seedling establishment and growth performance.

Most genotypes recorded vigour scores below 2.5, indicating high seedling vigour and a greater degree of resistance to shoot fly damage. Vigorous seedlings are characterized by enhanced growth, increased leaf expansion, and greater plant robustness, enabling them to better withstand insect attack and recover from damage. These findings agree with those of Navinkumar [8], who reported that genotypes with poor seedling vigour were more susceptible to shoot fly infestation. Likewise, Prasad [10] and Sharma and Nwanze [16] identified seedling vigour as an important morphological trait associated with shoot fly resistance. The predominance of highly vigorous genotypes in the present study suggests the existence of favorable resistance-related characteristics that could be exploited in breeding programs.

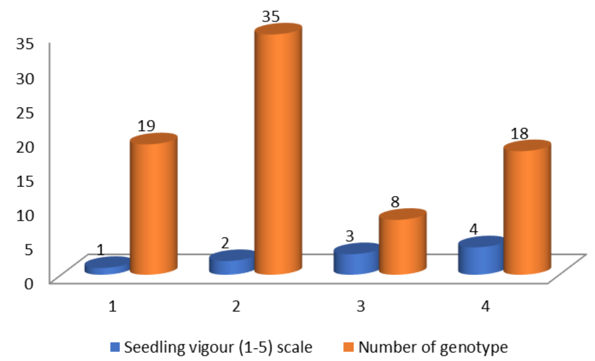

Figure 2. *Number of genotypes based on Seedling vigour.*

Overall Resistance Score

The overall resistance ratings of the evaluated genotypes ranged from 2 to 8 on the standard 1–9 resistance scale. Among the eighty genotypes screened, twenty-five recorded a resistance score of 2, indicating a high level of resistance, whereas eight genotypes received a score of 8, reflecting a high degree of susceptibility to shoot fly infestation (Figure 3).

Genotypes with lower resistance scores consistently exhibited reduced oviposition, lower dead-heart incidence, and superior seedling vigour. Based on the established classification criteria, genotypes with overall resistance scores below 4.5 were considered resistant. These genotypes demonstrated an enhanced capacity to recover from shoot fly attack through the production of productive tillers and harvestable panicles. Recovery resistance is an important mechanism that reduces the impact of early-season infestation and contributes to yield stability.

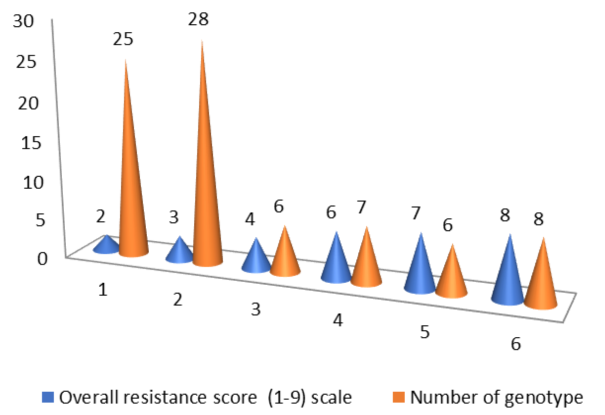

Figure 3. *Number of genotypes based on overall resistance score.*

The present findings are consistent with the observations of Riyazaddin [13], who reported that genotypes with overall resistance scores below 4.5 exhibit effective recovery resistance and improved tolerance to shoot fly damage. Previous studies have further demonstrated that recovery resistance is closely associated with primary resistance mechanisms and the intensity of shoot fly infestation [1, 4, 6, 11, 16]. Therefore, the resistant genotypes identified in this study represent promising genetic resources for the development of sorghum varieties with durable resistance to shoot fly.

Table 1. *Mean percentage of oviposition, dead heart, seedling vigour and overall resistance score.*

Genotypes	% Ovi	% DH	SV	ORS
EBI-21457	50.00	13.33	1.00	2.00
EBI-69077	33.33	13.33	1.00	2.00
EBI-69078	38.46	23.08	2.00	3.00
EBI-69208	53.33	26.67	2.00	3.00
EBI-212873	50.00	23.08	2.00	3.00
EBI-239125	54.55	45.45	4.00	6.00
EBI-239122	62.50	25.00	2.00	3.00
EBI-240807	42.86	14.29	1.00	2.00
EBI-241726	33.33	13.33	1.00	2.00
EBI-243680	56.25	25.00	2.00	3.00
EBI-243681	33.33	13.33	1.00	2.00
EBI-243682	75.00	25.00	2.00	3.00
EBI-243685	37.50	37.50	3.00	7.00
EBI-243686	46.67	33.33	3.00	6.00
EBI-244707	81.25	37.50	3.00	7.00
EBI-244728	35.71	21.43	2.00	3.00
EBI-69079	40.00	13.33	1.00	2.00
EBI-69271	50.00	35.71	4.00	6.00
EBI-204611	37.50	25.00	2.00	3.00
EBI-213348	43.75	37.50	4.00	7.00
EBI-213349	57.14	28.57	2.00	3.00
EBI-223518	33.33	16.67	1.00	2.00
EBI-230244	42.86	14.29	2.00	2.00
EBI-235447	38.46	15.38	2.00	2.00
EBI-235449	35.71	14.29	2.00	2.00
EBI-239251	78.57	42.86	4.00	8.00
EBI-241197	57.14	42.86	4.00	8.00
EBI-242009	30.77	15.38	1.00	2.00
EBI-243684	37.50	25.00	2.00	3.00
EBI-244702	68.75	43.75	4.00	7.00
EBI-244704	43.75	37.50	4.00	6.00
EBI-244709	57.14	35.71	4.00	6.00
EBI-24405	50.00	37.50	4.00	6.00
EBI-69065	43.75	20.00	2.00	2.00
EBI-69156	37.50	25.00	2.00	3.00
EBI-69229	37.50	25.00	2.00	3.00
EBI-210901	50.00	25.00	2.00	3.00
EBI-214258	56.25	26.67	2.00	3.00
EBI-227103	38.46	15.38	1.00	2.00
EBI-231179	28.57	14.29	1.00	2.00
EBI-235448	81.25	43.75	4.00	8.00
EBI-235450	46.67	20.00	2.00	2.00
EBI-235452	56.25	28.57	2.00	3.00

Genotypes	% Ovi	% DH	SV	ORS
EBI-235453	68.75	25.00	2.00	3.00
EBI-235458	76.92	15.38	2.00	2.00
EBI-241210	42.86	14.29	2.00	2.00
EBI-244230	81.25	37.50	4.00	6.00
EBI-244710	62.50	46.67	4.00	8.00
EBI-24184	43.75	25.00	3.00	3.00
EBI-61235	50.00	14.29	1.00	2.00
EBI-69230	43.75	26.67	2.00	3.00
EBI-204624	50.00	43.75	4.00	8.00
EBI-210968	53.85	15.38	1.00	2.00
EBI-211193	38.46	23.08	2.00	4.00
EBI-228821	61.54	15.38	1.00	2.00
EBI-228822	62.50	37.50	4.00	8.00
EBI-229229	25.00	18.75	2.00	3.00
EBI-230065	56.25	43.75	4.00	8.00
EBI-235460	43.75	26.67	2.00	4.00
EBI-235470	37.50	25.00	3.00	3.00
EBI-241265	31.25	18.75	1.00	2.00
EBI-241724	25.00	12.50	2.00	2.00
EBI-242046	43.75	25.00	3.00	3.00
EBI-244727	50.00	37.50	4.00	7.00
EBI-24183	31.25	25.00	2.00	3.00
EBI-69076	25.00	12.50	1.00	2.00
EBI-69209	31.25	18.75	1.00	3.00
EBI-69210	50.00	43.75	4.00	8.00
EBI-69211	43.75	28.57	2.00	4.00
EBI-69212	37.50	21.43	2.00	3.00
EBI-69246	50.00	25.00	2.00	3.00
EBI-69566	43.75	20.00	2.00	3.00
EBI-69568	31.25	12.50	1.00	2.00
EBI-204612	50.00	25.00	2.00	3.00
EBI-204628	31.25	18.75	1.00	2.00
EBI-226842	56.25	28.57	2.00	4.00
EBI-241286	50.00	25.00	2.00	4.00
EBI-244698	37.50	25.00	2.00	4.00
EBI-244706	31.25	18.75	1.00	3.00
EBI-244708	56.25	38.46	4.00	7.00
Mean	47.09	25.63	2.29	3.83

Note: %Ovi=Oviposition percentage,%DH=dead heart percentage, SV=seedling vigour, ORS=over all resistance score

4. Conclusion and Recommendations

The present study revealed substantial variation among the evaluated sorghum genotypes in their response to shoot fly (Atherigona soccata) infestation. Assessment of key resistance parameters, including oviposition percentage, dead-heart incidence, seedling vigour, and overall resistance score, identified fifty-nine genotypes as resistant or tolerant to shoot fly damage. These genotypes consistently exhibited desirable resistance characteristics, such as reduced oviposition, lower dead-heart incidence, superior seedling vigour, and favorable overall resistance ratings.

The identification of a large number of resistant or tolerant genotypes demonstrates the availability of valuable genetic resources for improving shoot fly resistance in sorghum. The resistant genotypes identified in this study have the potential to serve as parental materials in breeding programs aimed at developing high-yielding and shoot fly-resistant cultivars. Their utilization could contribute significantly to reducing yield losses, minimizing reliance on insecticides, and enhancing the sustainability of sorghum production systems.

It is recommended that the selected genotypes be further evaluated across multiple locations and seasons to verify the stability of their resistance under varying environmental conditions. In addition, these genotypes should be incorporated into breeding programs to facilitate the development of improved sorghum varieties with durable resistance to shoot fly. The deployment of such varieties will provide an environmentally sound, economically feasible and sustainable strategy for managing shoot fly infestations and improving sorghum productivity in affected regions.

Abbreviations

IQQO	Oromia Agricultural Research Institute
McARC	Mechara Agricultural Research Center
DAE	Days After Emergence

Author Contributions

Daba Etafa: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing

Conflicts of Interest

The author declares no conflict of interest.

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