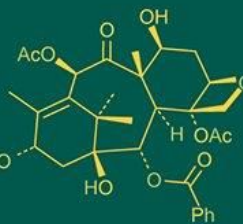
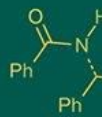


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; SP-9(8): 1121-1125
www.biochemjournal.com
Received: 08-06-2025
Accepted: 13-07-2025

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Identification of resistance source of forage sorghum genotypes against the spotted stem borer (*Chilo partellus*)

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DOI: <https://www.doi.org/10.33545/26174693.2025.v9.i8Sp.5327>

Abstract

A field experiment was conducted during the kharif season of 2024-25 at ICAR-IIMR, Hyderabad, to evaluate forage sorghum genotypes for resistance to the spotted stem borer, *Chilo partellus*. Twenty genotypes, including resistant (IS 2205) and susceptible (Swarna) checks, were screened under artificial infestation for seven damage parameters. All traits showed highly significant differences ($p < 0.001$). IS 2205 and Rampur Local consistently recorded the lowest damage, indicating strong antibiosis and/or antixenosis, whereas Swarna and DJ 6514 were the most susceptible. Principal component analysis revealed that PC1 and PC2 explained 72.23% of the total variation, with leaf damage, deadhearts, tunnelling, and exit holes identified as the most reliable resistance indicators. PCA-based grouping classified genotypes into resistant, moderately resistant, susceptible, and highly susceptible categories, providing valuable information for incorporating resistant sources into forage sorghum breeding programs aimed at durable stem borer management.

Keywords: Stem borer, sorghum, *Chilo partellus*, genotypes, susceptible, resistance

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench], known as the “global grain,” is a crop of worldwide significance due to its multipurpose use as food, feed, fodder and fuel (Pahuja *et al.*, 2014) [4]. In India, the livestock sector plays a vital role in the agricultural economy, driving the need for large-scale fodder production. The estimated forage requirement stands at 1,325.7 million tons, while the actual production is only 978.7 million tons, resulting in a 35.6% deficit in green fodder and notable shortages in dry fodder and concentrate feeds (IGFRI Vision, 2050). Among *kharif* fodder crops, sorghum occupies 2.6 million hectares and is valued for its drought tolerance, high biomass yield, efficient water and nitrogen use and good nutritive quality. However, challenges such as prussic acid and nitrate accumulation require careful management. Its productivity is also hampered by various biotic and abiotic stresses.

Among the biotic constraints, insect pests are a major cause of yield loss, affecting sorghum from seedling to maturity. The crop is attacked by over 150 insect species with key pests including the spotted stem borer (*Chilo partellus* Swinhoe), shoot fly (*Atherigona soccata* Rondani), ear head bug (*Calocoris angustatus* Leth.), and ear head worm (*Cryptoblabes gnidiella* Mab.) (Patidar *et al.*, 2019) [5]. From these, *Chilo partellus* is the most destructive, causing up to 40% avoidable losses in forage sorghum. Native to Asia and later introduced to Africa, this pest is a serious problem in several Indian states. The moth lays clusters of eggs on leaf undersides, which hatch in 4-5 days, and larvae bore into the stem, disrupting nutrient translocation and causing dead hearts, peduncle breakage, and chaffy panicles (Prasad *et al.*, 2021) [8].

For sustainable management of *Chilo partellus* in forage sorghum, host plant resistance (HPR) is a crucial component of integrated pest management (IPM). As the use of insecticides is undesirable for fodder crops due to residue hazards to livestock, resistant varieties offer an eco-friendly and cost-effective alternative. Over the last five decades, extensive screening of global sorghum germplasm has identified lines resistant to major pests (Sharma *et al.*, 2003) [11]. Deploying such genotypes reduces dependence on chemical control, lowers production costs and supports environmental safety.

A clear understanding of the mechanisms underlying resistance will aid in breeding durable pest-resistant varieties and form the backbone of effective sorghum pest management strategies. The present study aimed to identify the new sources of forage sorghum genotypes resistant to *Chilo partellus* under artificial infestation.

Materials and Methods

Planting material

The present study was conducted during the *kharif* season of 2024-25 at the ICAR-Indian Institute of Millets Research, Rajendranagar, Hyderabad, Telangana. Research farm located at an altitude of 523 m above mean sea level with geo-coordinates 17.32° N latitude and 78.39° E longitude, which records an annual rainfall of 854.6 mm. A total of 20 forage sorghum genotypes including one resistant check (IS 2205) and one susceptible check (Swarna) were selected for screening against the spotted stem borer. The trial was laid in randomized block design with three replications.

Artificial infestation

Each plant of the selected genotype was artificially inoculated with 5-7 neonates of spotted stem borer per plant by using bazooka applicator with poppy seeds as carrier material (Sharma *et al.*, 1992)^[10] at 20 days old seedlings into the whorls to inflict an optimum level of leaf damage and dead-heart formation during morning hour.

Observations

Leaf damage

The leaf damage by stem borer larvae was assessed by observing damaged leaves on five randomly selected plants per genotype at 35 days after emergence (DAE) and rating (1-9) was ascribed to them as per the scale given by Sharma *et al.*, 1992^[10].

Deadheart (%)

Observations on deadheart incidence were recorded at 45 days after emergence (DAE) in the experimental plot. The percentage was calculated using the following formula:

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

Stem and peduncle tunneling

At the time of harvesting five plants in each row were split apart from base to tip and the length of the stem and peduncle tunnels made by the stem borer were measured in centimetres and convert the length into percentage of tunneling by using formula,

$$\text{Tunnelling (\%)} = \frac{\text{Length of stem or peduncle tunnel (cm)}}{\text{Total length of stem or peduncle (cm)}} \times 100$$

Exit holes per stalk

Five plants per genotype were randomly selected and split from base to tip and count the number of exit holes were made by stem borer at harvesting.

Larva and pupae/ stalk

The number of larvae and pupae of the stem borer remaining in the stalks was recorded at harvest from five randomly

selected plants.

Statistical analysis

The data on leaf damage, dead-hearts, stem and peduncle tunneling, exit holes, larvae and pupa per stalk were subjected to principle component analysis and genotypes classified, by using OPSTAT software.

Results and Discussion

Observations recorded on different forage sorghum genotypes in response to damage caused by sorghum stem borer, *Chilo partellus*. (Table 1).

- A. Leaf damage:** The data on leaf damage score revealed highly significant differences among the genotypes tested ($p < 0.001$), with scores ranging from 3.43 to 8.03 and a mean of 6.53. IS 2205 (RC) and Rampur Local recorded the lowest scores (3.43 and 3.57, respectively), indicating reduced larval establishment in the whorl leaves and suggesting a higher degree of resistance to *Chilo partellus*, (Van den Berg and Westhuizen, 1998). while HC 308 (5.23) was also statistically comparable to these resistant entries. In contrast, Swarna (SC) (8.03), DJ 6514 (7.93), HJ 541 (7.70), and HJ 513 (7.50) recorded the highest damage scores, reflecting greater susceptibility. Most other genotypes showed scores above 6.0, placing them in the susceptible range. Although leaf feeding is not always a precise predictor of yield loss due to the plant's capacity to compensate through new leaf production (Starks and Doggett, 1970).
- B. Stem borer dead-heart:** Incidence ranged from 11.17% in IS 2205 (resistant check) to 53.67% in Swarna (susceptible check), with an overall mean of 29.66%. IS 2205 (RC) and Rampur Local (15.50%) showed the lowest infestation levels, reflecting strong resistance to *Chilo partellus*, while HC 308 (21.33%) was statistically comparable to these resistant entries. In contrast, Swarna (SC) and DJ 6514 (51.33%) recorded the highest dead-heart percentages, with HC 136 (36.33%) also showing elevated levels, positioning them closer to the susceptible checks. Dead-heart formation remains a consistent and reliable parameter for evaluating stem borer resistance, with antibiosis reported as the predominant resistance mechanism (Singh & Rana, 1984)^[13].
- C. Stem tunnelling:** Showed significant variation across genotypes, ranging from 2.83% in HJ 1514 to 26.82% in Swarna (susceptible check), with resistant entries generally exhibiting lower tunnelling. Minimal damage was observed in IS 2205 (RC) (4.32%), Rampur Local (4.91%), CSV 38F (2.94%), and HJ 1514 (2.83%), indicating strong resistance. Conversely, Swarna (SC) and Pantchari 5 (14.37%), along with DJ 6514 (14.10%), recorded the highest tunnelling percentages, reflecting high susceptibility. Several genotypes, including CSV 30F, CSV 44F, HC 260, and HJ 513, maintained low to moderate tunnelling (<5%), suggesting partial resistance. The extent of stem tunnelling, influenced largely by antibiosis, serves as a key indicator for assessing genotypic susceptibility to *Chilo partellus* (Alghali, 1987)^[1].
- D. Peduncle tunnelling:** Among the tested genotypes ranged from 9.84% in IS 2205 (RC) to 27.67% in SH 1955, with a mean incidence indicating considerable

variation in susceptibility. The resistant check IS 2205 (RC) along with HC 260 (12.76%), CSV 32F (13.22%), CSV 38F (13.93%), Pantchari 5 (13.81%), and Rampur Local (15.32%) recorded the lowest tunnelling, reflecting strong resistance to *Chilo partellus*. In contrast, SH 1955 (27.67%), HJ 1514 (26.39%), CSV 30F (22.58%), and CSV 47F (22.11%) exhibited the highest tunnelling, suggesting higher susceptibility. Swarna (SC), the susceptible check, showed 18.52%

tunnelling, placing it among the moderately affected entries. These results indicate that certain genotypes possess effective resistance mechanisms, possibly linked to antibiosis, reducing larval penetration and damage. peduncle tunneling had the correlation and direct effects in the same direction for stem borer deadhearts, and hence, these can be used to select for resistance to stem borer. (Sharma *et al.*, 2007) ^[9]

Table 1: Reaction of forage sorghum genotypes against stem borer, *Chilo partellus* incidence during *kharif*, 2024.

Sl. No	Genotypes	Deadhearts Percentage	Leaf damage	Stem tunnelling (%)	Peduncle tunnelling (%)	No. of exit holes/stalk	No. of larvae/stalk	No. of pupa/stalk
1	CSV21F	24.5 (29.625)	6.267	6.29 (14.504)	21.72 (27.755)	0.933	1.067	0.593
2	CSV30F	27.167 (31.391)	6.433	3.06 (10.032)	22.582 (28.357)	1.533	1.2	0.693
3	CSV32F	28 (31.918)	6.733	5.013 (12.923)	13.22 (21.29)	2	1.067	0.74
4	CSV38F	32 (34.425)	7.4	2.943 (9.857)	13.93 (21.89)	1.8	1.067	0.72
5	CSV44F	32.5 (34.728)	6.8	3.777 (11.19)	15.573 (23.204)	2.4	1.067	0.713
6	CSV47F	32.833 (34.937)	7.233	4.337 (12.013)	22.107 (27.818)	2.133	1.6	0.873
7	CSV53F	35 (36.245)	7.133	3.31 (10.474)	17.517 (24.703)	2.533	1.133	0.973
8	HC136	36.333 (37.034)	6.967	8.3 (16.719)	17.297 (24.541)	2.8	1.467	0.66
9	HC260	28.667 (32.331)	6.233	3.847 (11.3)	12.76 (20.895)	1.533	1.133	0.77
10	HC308	21.333 (27.458)	5.233	5.257 (13.245)	19.2 (25.962)	1.667	1.333	0.9
11	HC1171	30.833 (33.706)	6.733	4.093 (11.657)	21.603 (27.669)	1.933	1.067	0.8
12	HJ513	27.833 (31.821)	7.5	3.037 (10.03)	17.377 (24.6)	1.867	1.067	0.673
13	HJ541	28.833 (32.456)	7.7	4.74 (12.569)	21.697 (27.692)	2.067	1	0.657
14	HJ1514	26 (30.611)	6.833	2.83 (9.645)	26.393 (30.899)	1.933	1.2	0.707
15	SH1955	27.917 (31.866)	6.067	5.3 (13.298)	27.673 (31.696)	1.333	1.067	0.98
16	Pantchari5	27.667 (31.707)	6.8	14.373 (22.256)	13.813 (21.764)	1.8	1.2	0.567
17	Rampur local	15.5 (23.123)	3.567	4.907 (12.755)	15.323 (23.021)	1.067	1.133	0.6
18	IS2205 (RC)	11.167 (19.309)	3.433	4.317 (11.976)	9.837 (18.236)	0.733	1.133	0.567
19	Swarna (SC)	53.667 (47.087)	8.033	26.82 (31.177)	18.517 (25.468)	2.867	1.533	1.153
20	DJ6514	51.333 (45.746)	7.933	14.1 (22.037)	20.12 (26.543)	2.933	1.4	1.007
	C.D.	4.872	1.158	0.979	4.502	0.413	0.268	0.177
	SE(m)	1.695	0.403	0.341	1.566	0.144	0.093	0.062
	C.V.	9.802	10.655	9.035	14.735	13.159	13.502	13.934
	P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

E. Number of exit holes per stalk: Among the evaluated genotypes varied from 0.733 in the resistant check IS 2205 to 2.933 in DJ 6514, with an overall mean of 2.03. IS 2205 and Rampur Local exhibited the fewest exit holes, reflecting strong resistance to stem borer emergence, whereas Swarna (2.867) and DJ 6514 (2.933) were the most susceptible. Genotypes such as CSV21F, CSV 30F, and SH 1955 demonstrated moderate resistance, with values closer to that of the

resistant check. The coefficient of variation (13.16%) indicated a moderate level of variability for this trait, suggesting that genetic factors substantially contributed to differences in resistance among genotypes (Prasad *et al.*, 2011) ^[7].

F. The number of larvae per stalk: Among the evaluated genotypes ranged from 1.000 in HJ 541 to 1.600 in CSV 47F, with an overall mean of 1.21. Genotypes such as HJ 541, CSV 21F, CSV 32F, HC 260, HC

1171, and Pantchari 5 exhibited lower larval counts, reflecting stronger resistance to stem borer infestation, whereas CSV 47F (1.600) and HC 136 (1.467) were identified as the most susceptible. Several entries, including the resistant check IS 2205 and Rampur Local, recorded larval numbers comparable to the resistant

G. The number of pupae per stalk: among the forage sorghum genotypes ranged from 0.567 in Pantchari 5 and IS 2205 (resistant check) to 1.153 in Swarna (susceptible check), with an overall mean of 0.77. Genotypes such as Pantchari 5, IS 2205, CSV 21F, CSV 30F, and Rampur Local recorded lower pupal counts, indicating better resistance to stem borer development, whereas Swarna (1.153) and DJ 6514 (1.007) were the most susceptible. Several genotypes, including CSV 38F and HC 136, showed intermediate pupal densities. Low pupation has also been suggested as a selection criterion for resistance to *Chilo partellus*. (Singh *et al.* 1983) [12].

In view of complexity of interactions in stem borer infestation, principal component analysis (PCA) was applied

for assessing the reliable traits by taking into consideration seven parameters *viz.*, leaf damage, deadhearts percentage, stem tunnelling (%), peduncle tunnelling (%), no. of exit holes/stalk, no. of larvae /stalk, no. of pupa/stalk.

The principal component analysis (PCA) reduced the seven measured traits (A-G) into a smaller set of components that explain most of the variation in the data. PC1 alone accounted for 55.80% of the total variance, and together PC1 and PC2 explained 72.23% of the variability. The first three components cumulatively explained 84.90%, which is sufficient to capture most of the data. (Table 2)

Table 2: Proportion of variance explained by principal components for genotypes.

Principal components	Percentage of variance	Cumulative percentage of variance
PC1	55.804	55.804
PC2	16.429	72.233
PC3	12.671	84.904
PC4	6.754	91.658
PC5	5.898	97.556
PC6	1.788	99.344
PC7	0.656	100

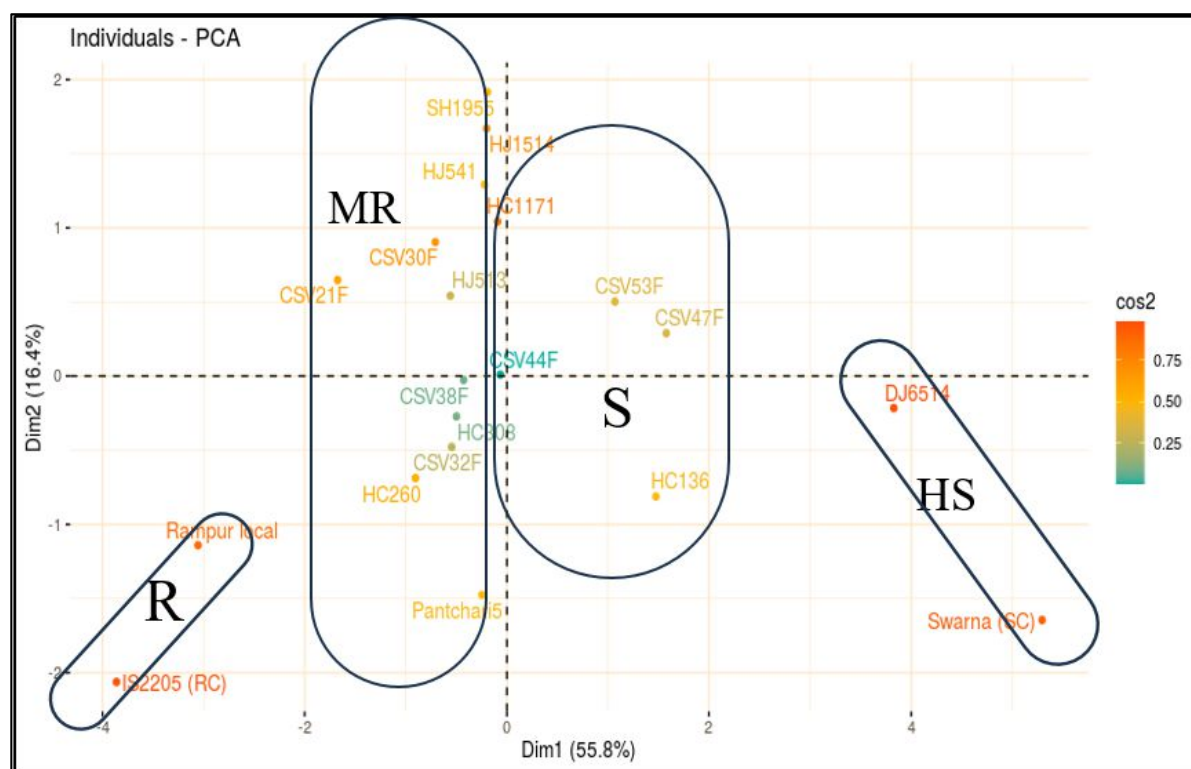


Fig 1: PCA score plot showing grouping of forage sorghum genotypes based on measured traits

The PC₁ and PC₂ were plotted for separating the genotypes based upon the seven characters considered. The plot showed four clusters of genotypes grouped into resistant (R) moderately resistant (MR) and susceptible (S), highly susceptible (HS) (Table 3) (Fig.1).

The present study suggests that leaf damage, deadhearts percentage, stem tunnelling (%), peduncle tunnelling (%), no. of exit holes/stalk, are the most reliable parameters for characterization of resistance/ susceptibility to *Chilo partellus* among the damage parameters in forage sorghum. PCA-based grouping of sorghum genotypes effectively distinguished their resistance or susceptibility to *Chilo partellus* (sorghum stem borer). The resistant genotypes IS

2205 (RC) and Rampur Local exhibited consistently low values for key damage parameters—leaf damage score, deadhearts, stem and peduncle tunnelling, exit holes, larvae, and pupae per stalk—indicating strong antibiosis and/or antixenosis. Moderately resistant genotypes, including CSV 21F, CSV 30F, CSV 32F, CSV 38F, HC 260, HC 308, HJ 513, HJ 541, HJ 1514, SH 1955, and Pantchari 5, showed intermediate damage levels, suggesting partial resistance that limits pest development and damage. In contrast, susceptible genotypes such as HC 171, CSV 44F, CSV 47F, CSV 53F, and HC 136 recorded higher damage, particularly in tunnelling and exit hole counts, while the highly susceptible Swarna (SC) and DJ 6514 consistently displayed

maximum damage across all traits, highlighting their vulnerability. This classification provides valuable guidance for breeding programs to incorporate resistant sources and avoid highly susceptible lines. Prasad *et al.*, (2015) [6] also reported the multiple-resistance to sorghum shoot fly and spotted stem borer in forage sorghum.

Table 3: Categorisation of forage sorghum genotypes based on principal component analysis (PCA).

Response	Genotypes
Resistant	IS2205(RC), Rampur local
Moderately resistant	CSV21F, CSV30F, CSV32F, CSV38F, HC260, HC308, HJ513, HJ541, HJ1514, SH1955, Pantchari5.
Susceptible	HC171, CSV44F, CSV47F, CSV53F, HC136,
Highly susceptible	Swarna (SC), DJ6514.

Conclusion

The present study revealed that the genotypes IS 2205 (RC) and Rampur Local exhibited high levels of resistance to *Chilo partellus*, while CSV 21F, CSV 30F, CSV 32F, CSV 38F, HC 260, HC 308, HJ 513, HJ 541, HJ 1514, SH 1955, and Pantchari 5 showed moderate resistance. These genotypes hold strong potential for inclusion in forage sorghum improvement programs aimed at enhancing stem borer resistance in agronomically superior lines. Conversely, the highly susceptible genotypes Swarna (SC) and DJ 6514 should be avoided in breeding for resistance.

Disclaimer (Artificial Intelligence)

Author(s) hereby declares that no generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc) and text-to-image generators have been used by them during writing or editing manuscripts.

Acknowledgements

The Author(s) expresses their sincere gratitude to Head of the Department, College of Agriculture, Rajendranagar, PJTAU, Hyderabad and to Indian Institute of Millet Research, Hyderabad as well as to the Scientists and Professors for their constant support and guidance in conducting the experiment.

Competing Interests

None

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