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Assessment of genetic resistance in sorghum germplasm against charcoal rot under field conditions

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Abstract

Charcoal rot caused by *Macrophomina phaseolina* is a major biotic constraint for rabi sorghum production. Total seventy-four genotypes were screened under field conditions to assess diseases resistance. Among the 74 genotypes, E 36-1 was the most resistant genotype with the lowest disease incidence (11.53%), least stalk colonization (1.50 Mean Nodes Crossed, 7.70 cm Mean Length of Spread, and the lowest Charcoal Rot Index (CRI) (9.23). Conversely, SPV 86 was found to be a highly susceptible (CRI 43.00) genotype. Further, based on CRI, one resistant genotype (E 36-1) and 16 moderately resistant genotypes (including DSV 4 and Dagadi Solapur) were identified, while the remaining 56 genotypes were susceptible. These resistant and moderately resistant genotypes can be used as genetic resources for sorghum breeding programs aimed at improving charcoal rot tolerance.

Keywords: *Sorghum bicolor*, *Macrophomina phaseolina*, charcoal rot index, disease resistance

Introduction

Sorghum [*Sorghum bicolor* (L.) Moench], commonly known as "Jowar," has an important role in food security. It is a member of the Poaceae family. In the context of India, sorghum is one of the main cereals included under the umbrella of millets, commonly referred to as "Shree Anna". In India, area under sorghum cultivation is 39.84 lakh hectares with a production of 48.80 lakh tonnes, with productivity of 1,225 kg/ha (DES, DAFW, 2025) [5]. In Karnataka, sorghum is primarily grown under the rabi (post-rainy) season using residual soil moisture. Over the years, the sorghum growing area and productivity have declined from their peak 28.86 lakh hectares to 8.0 lakh hectares. Crop's production is severely affected by many biotic and abiotic factors; among biotic stress, charcoal rot, caused by the soil-borne fungus *Macrophomina phaseolina* (Tassi) Goid is the major constraint to sorghum production, particularly during the post-rainy season, where moisture stress and high temperatures trigger rapid stalk colonization and lodging (Arora and Dhurwe 2014) [2]. With nearly all currently cultivated hybrids and varieties showing some degree of susceptibility (Jahagirdar, 2007) [7], particularly up to 70% in rabi crops (Ghosh *et al.*, 2018) [6]. Hence, this study was done to assess the level of genetic resistance to charcoal rot in 74 sorghum genotypes under field conditions, in order to identify the better resistance sources as sorghum is an excellent food crop which supports the food security of semi-arid regions.

Materials and Methods

Experimental Site and Design

A total of seventy-four sorghum genotypes were screened against charcoal rot during rabi 2021-22 in charcoal rot sick plot at Main Agriculture Research Station, Dharwad to ensure high and uniform natural primary inoculum of *M. phaseolina*. The experiment was laid out in a Randomized Block Design (RBD) with two replications. Test genotypes were sown during first fortnight of November with a spacing of 45 cm × 15 cm with two replications. To ensure disease pressure, the susceptible check CSV 8R was sown after every two test entries in single row.

Disease Assessment and Data Collection

At physiological maturity, all plants within each plot were harvested with intact root systems to evaluate disease progression. The following parameters were recorded for each genotype, the charcoal rot percentage (CRP) was calculated based on the proportion of plants exhibiting characteristic symptoms to the total plant population per plot, Mean Nodes crossed (MNC) taken based on the vertical progression of the pathogen by splitting the stalks longitudinally and was scored using a standard 1-5 scale, where 1 represents infection restricted to the point of inoculation and 5 represents infection extending beyond four nodes or total plant wilting. Mean length of spread of lesion (MLS) was measured as lesion spread within the stalk.

Disease Indexing and Categorization

To provide a composite evaluation of resistance, Charcoal Rot Index (CRI) was calculated by using the $CRI = CRP \times 0.4 + MLS \times 0.6$ (Das *et al.*, 2018) [4]. Based on the calculated CRI values, genotypes were categorized into five reaction groups: Highly Resistant ($CRI < 5.0$), Resistant (5.1-10.0), Moderately Resistant (10.1-25.0), Susceptible (25.1-40.0), and Highly Susceptible (> 40.1).

Results

Evaluation of Sorghum Genotypes for Charcoal Rot Resistance

A total of 74 sorghum genotypes were screened under sick plot conditions during the 2021-22 *rabi* season. The genotypes exhibited significant variation in their response to *M. phaseolina* across all measured parameters, including disease incidence, Mean Nodes Crossed (MNC), Mean Length of Spread (MLS), and the calculated Charcoal Rot Index (CRI).

Charcoal rot Incidence and Stalk Colonization Parameters

The charcoal rot incidence across the screened germplasm varied from 11.53% to 54.34% (Table 11). The lowest incidence was recorded in genotype E 36-1 (11.53%), followed by DSV 4 (12.24%) and Dagadi Solapur (13.40%). Conversely, the maximum disease incidence was observed in SPV 86 (54.34%). With respect to stalk colonization, which is measured by Mean number of Nodes crossed (MNC) and MLS (Mean Length of spread), The minimum MNC of 1.50 was recorded in E 36-1 and DMS 652, followed by DSV 4 and Solapur Dagadi (1.60). The highest MNC was recorded in SPV 86 (3.00). While least spread

of pathogen (MLS) was recorded in E 36-1 (7.70 cm) and DSV 4 (12.33 cm), whereas SPV 86 exhibited the highest lesion spread (35.40 cm).

Charcoal Rot Index (CRI) and Resistance Categorization

The Charcoal Rot Index (CRI), a composite measure of incidence and pathogen colonization, ranged from 9.23 (E 36-1) to 43.00 (SPV 86). Based on the CRI scales, the 74 genotypes were categorized into five disease reaction groups (Table 12). None of the genotypes screened were found to be Highly Resistant. E 36-1 was the only genotype that showed a resistant disease reaction. Total 16 genotypes, including DSV 4 and Dagadi Solapur, exhibited a moderately resistant disease reaction. The majority of the genotypes (56) were classified as susceptible, while SPV 86 (43%) was identified as highly susceptible.

Discussion

The screening of 78 sorghum genotypes revealed significant genetic variability in resistance to charcoal rot, the identification of genotype E 36-1 as a resistant source (CRI 9.23) and DSV 4 as moderately resistant aligns with the findings of Virupaksha Prabhu *et al.* (2012) [10], who reported similar low disease incidence in Dagadi Solapur (12.35%) and related germplasm. The high incidence of charcoal rot was observed in SPV 86 (54.34% incidence).

The differential disease reactions observed are likely governed by the host's physiological and biochemical profile. Charcoal rot is a senescence-driven disease in which susceptible genotypes typically possess lower soluble sugar content in the stalk compared to resistant ones. (Anahosur and Naik, 1985; Chattannavar, & Bannur, 2020) [1, 3], suggesting that higher carbohydrate levels in the stalk after flowering help the plant to maintain its vigor and thereby it delays fungal colonization.

Furthermore, lower number of mean nodes crossed and mean length of lesion spread in resistant genotypes may be contributed due to the accumulation of defense-related metabolites. Resistant lines maintain higher concentrations of total phenols, which act as defense barriers against fungal enzymes (Nalawade *et al.*, 2008; Pandey, *et al.*, 2022) [8, 9]. In the present study, the superior performance of E 36-1 and the 16 moderately resistant genotypes suggests that a series of biochemical defense mechanisms may operate, and making them valuable resistant sources for breeding charcoal rot-tolerant sorghum hybrids.

Table 1: Screening of sorghum genotypes against charcoal rot

Sl. No.	Genotype name	Charcoal rot incidence (%)	Mean nodes crossed (No.)	Mean length of spread (cm)	Charcoal rot index
1	Karada Maldandi	38.88	2.25	26.60	31.80
2	Kekri Local	24.24	2.00	28.00	26.50
3	Yermal Dakuri	29.72	2.00	26.00	27.50
4	E 36-1	11.53	1.50	7.70	9.23
5	Pop Sorghum	38.23	2.40	25.00	30.30
6	Tandalw	35.29	1.66	25.33	29.31
7	IS 14338	46.42	2.00	27.50	35.07
8	M 35-1	35.13	2.40	28.00	30.85
9	Bulk Y	20.50	2.20	21.00	20.80
10	IS 8283	37.83	2.00	28.75	32.38
11	IS 3546	37.50	2.25	28.00	31.93
12	SPV 1829	33.33	2.00	25.66	28.75
13	Solapur M 35-1	32.50	2.50	28.25	29.95
14	Phule Anuradha	28.12	2.00	28.50	28.34
15	DSV 4	12.24	1.60	12.33	12.30
16	SPV 86	54.34	3.00	35.40	43.00
17	CSV 22	35.89	2.00	27.50	30.85

18	Parbhani Moti	36.36	2.00	25.33	29.74
19	SPV 2217	22.22	2.00	23.50	23.00
20	Phule Panchami	39.53	2.00	28.00	32.61
21	IS 8607	33.33	2.20	29.00	29.35
22	PVK Kranti	29.54	2.40	26.70	27.83
23	Dagadi Solapur	13.04	1.60	19.00	16.61
24	M 35-1 Akola	34.61	2.40	28.76	31.10
25	Phule Vasudha	34.14	2.40	27.25	30.00
26	Jalna Dagdi	26.19	2.25	24.00	24.87
27	SGMRN1-3-2	23.72	2.00	28.00	26.28
28	Phule Maubee	27.27	2.40	26.25	26.65
29	Annigeri	25.53	2.00	22.33	23.61
30	Muguti Dharwad	24.39	2.00	23.70	23.97
31	Barsi Jowar	34.09	2.00	27.70	30.25
32	BJV 44	19.56	1.67	20.70	20.24
33	M 35-1-1	33.53	2.00	26.50	29.23
34	M 35-1-2	36.53	2.00	27.80	31.30
35	Barsi Joot	30.30	2.00	25.33	27.31
36	Tandur Local	26.08	2.20	21.70	23.45
37	Harini Jagadi	32.60	2.20	23.25	27.00
38	E 24 Kdagdi	38.46	2.00	22.00	28.58
39	Kddgn Local	25.58	2.00	27.20	26.55
40	Biligunda	28.84	2.60	23.50	25.63
41	Karjat Local	26.67	2.00	27.50	27.16
42	Tassal	24.39	2.20	22.33	23.15
43	Kadbina Jola	20.51	2.40	27.00	24.40
44	Yarnal Local	39.47	2.20	22.70	29.40
45	Maldandi Local	34.21	2.00	28.70	30.90
46	Yermalal Local	38.89	2.20	27.80	32.23
47	Tangrinigan Maldandi 3	31.81	2.25	27.33	29.12
48	Sikkandar Lakkadi	26.47	2.30	27.00	26.78
49	DSV 5	25.58	2.40	21.75	23.28
50	Phule Revati	24.39	2.40	27.00	25.95
51	Chappalgaon Local	35.89	2.00	28.00	31.15
52	Mssbr Local	32.65	2.00	26.33	28.85
53	B 58586	27.27	2.00	21.00	23.50
54	Hardakan Local	33.33	2.50	28.00	30.13
55	IS 14332	28.57	2.33	28.25	28.37
56	IS 27042	22.50	2.25	28.00	25.80
57	H 112	33.33	2.00	23.70	27.55
58	IS 8757-2-3	20.83	2.25	28.00	25.13
59	IS 8185	25.53	2.75	29.00	27.61
60	IS 3547	40.00	2.40	25.70	31.42
61	CSV 216R	25.00	2.60	27.50	26.50
62	Maldandi Local	29.54	2.40	28.00	28.61
63	SPV 1231	25.00	2.20	30.00	28.00
64	SPV 475	32.00	2.20	27.33	29.19
65	DSFR 5	28.94	2.00	26.33	27.37
66	AKFS 3	29.03	2.00	28.70	28.83
67	DMR 1	26.31	2.00	22.33	23.92
68	DBR 1	32.50	2.00	26.70	29.02
69	IS 2205	23.68	2.25	28.00	26.27
70	IS 2312	29.41	2.00	28.25	28.71
71	DMR 2	27.50	1.75	22.70	24.62
72	IS 18551	36.80	2.25	28.25	31.67
73	DSV 3	21.42	2.00	21.75	21.61
74	DSFR 1	34.21	2.00	24.25	28.23

Table 12: Reaction of sorghum genotypes to charcoal rot

Disease reaction	CRI value	No. of Genotypes	Genotype Name
Highly resistant	< 5	0	Nil
Resistant	5-10	1	E 36-1
Moderately resistant	11-25	16	Bulk Y, DSV 4, SPV2217, Dagadi Solapur, Jalna Dagdi, Annigeri, Muguti Dharwad, BJV44, Tandur Local, Tassal, Kadbina Jola, DSV 5, B 58586, DMR 1, DMR 2 & DSV 3
Susceptible	26-40	56	Karada Maldandi, Kekri Local, Yermal Dakuri, Pop <i>Sorghum</i> , Tandalw, IS 14338, M 35-1, IS 8283, IS 3546, SPV

			1829, Solapur M 35-1, Phule Anuradha, CSV 22, Parbhani Moti, Phule Panchami, IS 8607, PVK Kranti, M 35-1 Akola, Phule Vasudha, SGMRN1-3-2, Phule Maubee, Barsi jowar, M 35-1-1, M 35-1-2, Barsi joot, Harini Jagadi, E 24 Kdagdi, Kddgn Local, Kajarat Local, Yarnal Local, Maldandi Local, Yerimala Local, Tengrinigan Maldnadi 3, Phule Revati, Chappalgaon Local, Mssbr Local, Hardakan Local, IS 14332, IS 27042, H 112, IS 8185, IS 3547, CSV 216R, Maldandi Lakkadi, SPV 1231, SPV 475, DSFR 5, AKFS 3, DMR 1, DBR 1, IS 2205, IS 2312, IS 18551, DSFR 1
Highly susceptible	> 40	1	SPV 86

Conclusion

The study identified genotype E 36-1 emerged as the most resistant genotype, SPV 86 as highly susceptible. The identification of resistant (E 36-1) and 16 moderately resistant lines (e.g., DSV 4 and Dagadi Solapur) provides a critical genetic pool and are recommended as donors in hybridization programs to enhance yield stability under post-flowering moisture stress.

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