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Varietal Screening of Sorghum against *Gloeocercospora sorghi, Colletotrichum graminicola* and *Cercospora sorghi*

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ABSTRACT: The sorghum crop is believed to have first been cultivated in Africa, it is grown primarily as a food, feed source, and also as staple food source in many countries, particularly in arid regions of the world. The three main foliar pathogens *viz.,* Zonate leaf spot, Anthracnose, and Gray leaf spot, it infects foliage, stalk, panicle, grain and cause severe yield losses in quantity as well as the quality of both grain and straw (fodder). The most effective and environmentally responsible strategy to control these pathogens by incorporation of resistance genes. The best method of control is the use of resistant varieties which is economically feasible and has no residual effect. Fifty-four varieties were evaluated against these three foliar pathogens, to characterize the host responses. PC-4 and Rampur local varieties are highly susceptible to these three pathogens, UTFS-109 is resistant to Anthracnose and Gray leaf spot but susceptible to Zonate leaf spot, CSV-21F is moderately susceptible to Anthracnose and Gray leaf spot, and UTMC-543×PC-7, moderately susceptible to Zonate leaf spot but susceptible to Anthracnose and Gray leaf spot diseases. Out of fifty-four varieties, none of the varieties are resistant to Zonate leaf spot but few varieties are resistant to Anthracnose and Gray leaf spot diseases. Since, Tarai region of Uttarakhand is a hot spot for foliar diseases *viz.,* zonate leaf spot, anthracnose and Gray leaf spot, this study was conducted to screen the varieties/lines showing multiple resistance.

Keywords: Zonate, Anthracnose, Gray leaf spot, screening, sorghum.

INTRADUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is the world's fifth leading cereal crop and is an important staple cereal in many countries. In India sorghum is mainly used as fodder and occasionally used as food. Sorghum is a strong grass and usually grows to a height of 3 to 8.5 feet, sometimes reaching as high as 15.5 feet. Stalks and leaves are coated with white wax, and a central portion of the stalks is juicy and sweet. The leaves are about 2 inches broad and up to 3.5 feet long. The tiny flowers produced in panicles are loose to dense each flower cluster bears 850–3,050 kernels. The seeds vary different shape, colour, and size. It is a staple food source, particularly in arid regions of the world taking advantage of its hardiness, because of its high tolerance for water shortages, making it is possible to grow on soils with relatively low fertility compared to other cereal crops. It has a nutritional profile similar to corn, rice, and wheat to be a potential staple food and its grain has a very good source of vitamins which are B6, B1, copper iron, potassium selenium, phosphorus, magnesium, and zinc.

Abiotic and Biotic challenges are the major production constraints of the crop. Sorghum is susceptible to many foliar diseases, among them, fungal origins prevalent in India are zonate leaf spot, rust, anthracnose, downy mildew, leaf blight, sooty stripe, tar spot, gray leaf spot, target leaf spot, and rough leaf spot. Among these foliar pathogens, anthracnose, zonate leaf spots, and gray leaf spots reduce the productivity and profitability of sorghum. Leaf weight decreased and leaf dry matter content increased with increasing severity of infection. This type of damage affects forage and grain production. The most effective and environmentally responsible strategy to control these pathogens by incorporation of resistance genes. The best method of control is the use of resistant varieties which is economically feasible and has no residual effect. Till date, no variety is available that shows multiple resistance against these devastating foliar diseases. The present investigation was done to find out the sources of multiple resistance.

Zonate Leaf Spot. Zonate leaf spot of sorghum cause disease all over the moist sorghum growing part of the world, it was first found as a pathogen of sweet sorghum in Louisiana. Zonate leaf spots on sorghum damaged up to 85% of the photosynthetic leaf area under humid and cloudy weather conditions in India (Anahosur, 1986).

Gloeocercospora sorghi (Bain & Edgerton) causes a zonate leaf spot on sorghum, corn, pearl millet, and other grasses (Frederiksen and Odvody 2000). The symptoms occurred in seedlings, leaf, leaf sheath, grains of sorghum, and Johnson grass. The first visible symptoms are the appearance of small non-diagnostic lesions on the lower leaves. These lesions may occur anywhere on the leaf and as the lesions mature, they become circular or target-shaped on the interior of the leaf and semi-circular on the leaf margins with alternating bands of dark red, purple, tan, or straw colour, giving them the characteristic concentric zonate appearance depending on the variety (Purohit *et al*., 2013). Seedling infection can result in defoliation and death of the plant (Franklin, 2000). When favourable environmental conditions occur, the disease progresses covering the whole plant and lesions may occur on all leaves with slimy pink spores on leaves that may be blighted, in older lesions, microsclerotia are formed. Microsclerotia is also present in the seed and soil. The conidia are rain-splash disseminated, and sclerotia are the survival propagules and germinate via sporodochial formation or germ tube. The sexual stage is not yet known. Sclerotia are formed sub-epidermally in infected leaf tissue and are released into the soil during leaf decomposition and continue the life cycle for the next season. Zonate leaf spot is more prevalent in warm, humid around the years and overwinters on crop residue. Disease severity depends on high rainfall, cloudy weather, and high relative humidity. Disease development is favourable at 28-32^{o}C and 90 percent relative humidity. Seed, root exudates, and leaf guttation stimulate sclerotial germination.

Anthracnose. Anthracnose caused by *Colletotrichum graminicola* (Ces.) G. W. Wilson (syn. *Colletotrichum sublineolum* (Henn.) is a devastating disease, particularly under warm and humid environmental conditions (Costa *et al*., 2015). The pathogen is highly variable, conidia are non-septate, uninucleate, hyaline, sickle, and spindle-shaped. They are produced singly and terminally on conidiophores among the setae and occur as masses immersed in the mucilaginous substrate. Acervuli produced on the infected host tissue are pink or dark brown in colour and oval to cylindrical in shape may be with or without setae. Setae in acervuli are dark black and prominent long (up to 100 µm), and are intermixed with conidia and conidiophores (Thakur, 2007). Anthracnose is a polycyclic disease and infection is enhanced by rain and contact of leaves with infested soil (Thakur and Mathur 2000). The favourable conditions for disease development are an average temperature >25^{o}C with frequent rain or humidity greater than 90% (Acharya *et al.,* 2019). Under favourable conditions, the disease developed more rapidly during the flowering to the grain-filling stage than in the early developmental stages of sorghum (Ngugi *et al.,* 2000). The pathogen is internally seed-borne in sorghum and can survive up to 20 months of storage (Gwary *et al.,* 2006). It can overwinter as microsclerotia and mycelia, in crop debris, in infected seeds, and on weed hosts such as johnsongrass (Thakur and Mathur 2000).

The pathogen causes leaf spots (anthracnose) and stalk rot. The disease symptoms first appear as 5-6 mm circular, elliptical and reddish spots with gray to straw-coloured centres on leaves. Later these spots subsequently enlarge or coalesce with visible setae from acervuli containing conidial spores in the gray centre of the lesions. The lesion can cover the entire leaf at advanced stages and in severe cases, defoliation and premature senescence occur (Thakur and Mathur 2000). When infected stems are spilled open, it appears dark red or purplish red discoloration. The infection of foliar tissue blocks photosynthate accumulation while infection of the stalk leads to stalk rot eventually leading to lodging.

Gray Leaf Spot. Gray leaf spot caused by *Cercospora sorghi* (Ellis & Everh) (Marley *et al*., 2001). *G. Sorghi* is a late-season disease of grain and fodder sorghum that occurs from the first week of September to mid-November. Small red spots on both sides of the leaves and leaf sheath lesions enlarge into dark red to purple rectangular areas bordered by leaf veins which may merge to form elongated stripes. The spots produce a gray cast as the causal fungus sporulates during moist, humid weather conditions.

A small lesion surrounded by a yellow halo is visible when the leaf is held up to the light. Within fifteen days, these lesions will begin to elongate. Mature lesions are brown or gray to tan, long (0.2 to 1.0 inches), narrow and rectangular, being characteristically restricted by the veins. In about two weeks, these lesions generate a new crop of spores, which then infect the middle and upper leaves. As plants mature, susceptibility to gray leaf spots increases. When the weather was favourable, the lesions rapidly merge, killing entire leaves. Extensive blighting of leaves may continue until a plant has died. Prolonged periods of leaf wetness (10 to 13 hours) and high relative humidity of 90 per cent with heavy dews or fogs and cloudy days are more important to disease development than actual rainfall. Temperature 22^{o}C to 26^{o}C, morning dew or fog favours the disease development. Due to gray leaf spots yield loss has been recorded of up to 67%. Epidemics have occurred sporadically and, in some favourable conditions, have been widespread.

Zonate, Anthracnose, and Gray leaf spot cause yield losses in quantity, as well as the quality of both grain and straw (fodder) as the pathogen, infects the foliage, stalk, panicle, and grain.

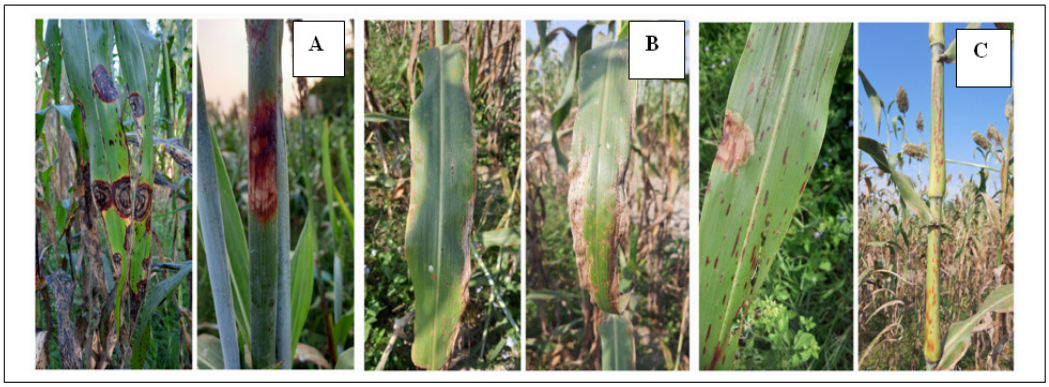

Fig. 1. Symptoms of A. Zonate leaf spot B. Anthracnose and C. Gray leaf spot.

MATERIAL AND METHODS

Fifty-four Sorghum cultivars/varieties were collected and screened at the AICRP Sorghum Centre, G.B. Pant University of Agriculture and Technology, Pant Nagar, Uttarakhand; during Kharif, 2021 (29.0222^{O}N, 79.4908^{o}E). This study was conducted to identify the resistant and susceptible varieties against zonate leaf spot, anthracnose and gray leaf spot of sorghum. Varieties were sown in three replications (50 × 15 cm). Sorghum plants were artificially inoculated with spore suspensions of 1.2 × 10^{6} of *Gloeocercospora sorghi, Colletotrichum graminicola* and *Cercospora sorghi* respectively. The disease intensity and disease severity of Zonate leaf spot, Anthracnose and Gray leaf spot were recorded at 75th days after germination (DAG) based on a disease severity 1 to 9 scale (Sharma, 1983). The reaction of varieties was categorized as below described by Kumari and Singh (2014). Sorghum variety Pant Chari-10 was taken as a control (Check variety) for screening.

RESULT AND DISCUSSION

For Zonate disease, among the fifty-four sorghum varieties, two varieties (PC-3, and CSV-33MF) showed moderate resistant reactions and four varieties (UTFS-120, UTMC-543 × PC-7, HC-171, and UP- Chari-3) were moderately susceptible. Among them, seventeen varieties were susceptible *viz.,* PC-5, UTFS-109, (PC-5×PSSV-16)×(UPMC-8×SDSL-92111), SSG-222×GD-68717, IS-23586-2×IS-3226, CSV-21F, CSV-14, PC-5 × EC-582508, IS-3359×IS-22996, SPV-422×EC-582508, EC-582506×PC-5, UP-CHARI-2, Ramkel, Pant-CMS and HC-136 and remaining thirty-one varieties are highly susceptible *viz.* PC-6, Pc-4, PC-8, PC-9, PC-11, PC-13, PC-14, UTFS-108, UTFS-110, UTFS-111, UTFS-121, UTFS-122, UTFS-123, CSV-35F, CSV-15, Rampur Local, UTMC-580, UTMC-581, UTMC-582, UTMC-583, IS-40961×IS-14357, GD-68717 × IS-3555, IS-3555×SSG-59-3, HJ-541×PC-6, GMS-1417×GD68724, EC-582506×PC-3, PC-5×EC-582508, UP-Chari-2×EC-582506, EC-582506×PC-4, SSG-59-3×UTFS-41, RS-673, EC-582506×PC-4. No varieties are neither immune nor resistant to *G. sorghi*.

In case of anthracnose disease, out of fifty-four sorghum varieties, UTFS-109 showed resistant reactions, varieties PC-5, PC-6, PC-9, PC-11, PC-14, UTFS-108, CSV-35F, UTMC-580, UTMC-581, UTMC-582, Pant Chari-5 × EC-582508, IS-3359×IS-22996, and SSG-222×GD-68717 showed moderate resistant and nineteen varieties were moderately susceptible *viz.,* PC-8, PC-13, UTFS-111, UTFS-121, UTFS-122, CSV-21F, CSV-15, UTMC-583, IS-40961×IS-14357, GD-68717 × IS-3555, (PC-5×PSSV-16) ×(UPMC-8×SDSL-92111), IS-3555×SSG-59-3, IS-23586-2×IS-3226, HJ-541×PC-6, UP-Chei-2×EC-502506, EC-582506×PC-4, EC-582506×PC-3, SSG-59-3×UTFS-41, Ramkel, and RS-673, fourteen varieties were susceptible *viz.* PC-3, UTFS-110, UTFS-120, CSV-14, CSV-33MF, UTMC-543 × PC-7, EC-582506×PC-5, UP-Chari-2, Pant-CMS, and HC-136 and remaining seven varieties were highly susceptible. None of the varieties were immune to *C. graminicola.*

Table 1: Disease Rating of Foliar Pathogens.

Diseasese verity rating scale	
Score	**Description**
1	No symptoms or presence of chlorotic flasks
2	1-5% leaf area covered with lesion
3	6-10% leaf area covered with lesion
4	11-20% leaf area covered with lesion
5	21-30%leaf area covered with lesion
6	31-40% leaf area covered with lesion
7	31-50% leaf area covered with lesion
8	51-75% leaf area covered with lesion
9	>75 % leaf area covered with lesion

Reaction of varieties		
Sr. No.	**Per centintensity**	**Reaction**
1	0to <1.0	Immune
2	1.1-5.0	Highly Resistant
3	5.1-10.0	Resistant
4	10.1-20.0	Moderately Resistant
5	20.1-30.0	Moderate Susceptible
6	30.1-40.0	Susceptible
7	40.1-50.0	Susceptible
8	50.1-75.0	Highly Susceptible
9	75.1andabove	Highly Susceptible

Table 2: Screening of multiple resistant varieties against Zonate Leaf Spot, Anthracnose, and Gray leaf spot in field conditions.

Sr. No.	Variety name	Disease rating		
		Zonate	Anthracnose	Gray leaf spot
1	PC-3	2	4	8
2	PC-4	8	8	9
3	PC-5	4	2	6
4	PC-6	6	2	5
5	PC-8	7	3	8
6	PC-9	8	2	7
7	PC-11	6	2	6
8	PC-13	8	3	7
9	PC-14	8	2	7
10	UTFS-108	7	2	1
11	UTFS-109	5	1	1
12	UTFS-110	9	5	7
13	UTFS-111	6	3	2
14	UTFS-120	3	4	1
15	UTFS-121	6	3	3
16	UTFS-122	6	3	9
17	UTFS-123	7	9	1
18	CSV-35F	6	2	3
19	CSV-21F	5	3	3
20	CSV-15	7	3	4
21	CSV-14	5	4	2
22	CSV-33MF	2	4	5
23	Rampur Local	8	8	9
24	UTMC-580	9	2	6
25	UTMC-581	9	2	5
26	UTMC—582	8	2	7
27	UTMC-583	7	3	4
28	PC-5 × EC-582508	5	2	3
29	IS-40961×IS-14357	6	3	3
30	GD-68717 × IS-3555	6	3	3
31	UTMC-543 × PC-7	3	4	4
32	(PC-5×PSSV-16) ×(UPMC-8×SDSL-92111)	4	3	3
33	IS-3359×IS-22996	5	2	2
34	IS-3555×SSG-59-3	6	3	5
35	SSG-222×GD-68717	4	2	4
36	IS-23586-2×IS-3226	4	3	2
37	HJ-541×PC-6	6	3	8
38	SPV-422×EC-582508	5	1	1
39	UP-Cheri-2×EC-502506	8	3	6
40	GMS-1417×GD68724	9	2	5
41	EC-582506×PC-3	6	9	2
42	SSG-59-3×ICSV-702	5	8	2
43	PC-5×EC-582508	7	2	3
44	UP-Cheri-2×EC-582506	8	1	3
45	EC-582506×PC-4	9	3	5
46	EC-582506×PC-5	5	4	3
47	SSG-59-3×UTFS-41	7	3	3
48	UP-Cheri-2	5	5	9
49	UP- Chari-3	3	6	4
50	Ramkel	5	3	6
51	Pant-CMS	5	4	5
52	HC-171	3	6	4
53	HC-136	5	4	6
54	RS-673	6	3	5
Check	**Pant cheri-10**	**9**	**2**	**8**

Table 3: The per cent disease incidence (PDI) of Zonate leaf spot.

Disease grade	Disease intensity	Variety name
Immune	No infection	---
Resistance	1-10	---
Moderate resistance	10.1-20	PC-3, and CSV-33MF
Moderate susceptible	20.1-30	UTFS-120, UTMC-543 × PC-7, HC-171, and UP- Cheri-3
Susceptible	30.1-50	PC-5, UTFS-109, (PC-5×PSSV-16) ×(UPMC-8×SDSL-92111), SSG-222×GD-68717, IS-23586-2×IS-3226, CSV-21F, CSV-14, Pant Cheri-5 × EC-582508, IS-3359×IS-22996, SPV-422×EC-582508, EC-582506×PC-5, UP-CHARI-2, Ramkel, Pant-CMS and HC-136.
Highly susceptible	>50	PC-6, Pc-4, PC-8, PC-9, PC-11, PC-13, PC-14, UTFS-108, UTFS-110, UTFS-111, UTFS-121, UTFS-122, UTFS-123, CSV-35F, CSV-15, Rampur Local, UTMC-580, UTMC-581, UTMC-582, UTMC-583, IS-40961×IS-14357, GD-68717 × IS-3555, IS-3555×SSG-59-3, HJ-541×PC-6, GMS-1417×GD68724, EC-582506×PC-3, PC-5×EC-582508, UP-Cheri-2×EC-582506, EC-582506×PC-4, SSG-59-3×UTFS-41, RS-673, EC-582506×PC-4

Table 4: The per cent disease incidence (PDI), Anthracnose of sorghum.

Disease grade	Disease intensity	Variety name
Immune	No infection	---
Resistance	1-10	UTFS-109
Moderate resistance	10.1-20	PC-5, PC-6, PC-9, PC-11, PC-14, UTFS-108, CSV-35F, UTMC-580, UTMC-581, UTMC-582, Pant Cheri-5 × EC-582508, IS-3359×IS-22996, and SSG-222×GD-68717
Moderate susceptible	20.1-30	PC-8, PC-13, UTFS-111, UTFS-121, UTFS-122, CSV-21F, CSV-15, UTMC-583, IS-40961×IS-14357, GD-68717 × IS-3555, (PC-5×PSSV-16) ×(UPMC-8×SDSL-92111), IS-3555×SSG-59-3, IS-23586-2×IS-3226, HJ-541×PC-6, UP-Chei-2×EC-502506, EC-582506×PC-4, EC-582506×PC-3, SSG-59-3×UTFS-41, Ramkel, and RS-673.
Susceptible	30.1-50	PC-3, UTFS-110, UTFS-120, CSV-14, CSV-33MF, UTMC-543 × PC-7, EC-582506×PC-5, UP-CHARI-2, Pant-CMS, and HC-136.
Highly susceptible	>50	Pc-4, UTFS-123, Rampur Local, EC-582506×PC-3, SSG-59-3×ICSV-702, UP- Cheri-3, HC-171

Table 5: The per cent disease incidence (PDI), Gray leaf spot of sorghum.

Disease grade	Disease intensity	Variety name
Immune	No infection	–
Resistance	1-10	UTFS-109, UTFS-108, UTFS-120, UTFS-123, and SPV-422×EC-582508.
Moderate resistance	10.1-20	UTFS-111, CSV-14, IS-3359×IS-22996, IS-23586-2×IS-3226, EC-582506×PC-3, SSG-59-3×ICSV-702
Moderate susceptible	20.1-30	UTFS-121, CSV-35F, CSV-21F, Pant Chari-5 × EC-582508, IS-40961×IS-14357, GD-68717 × IS-3555, (PC-5×PSSV-16) ×(UPMC-8×SDSL-92111), PC-5×EC-582508, UP-Cheri-2×EC-582506, EC-582506×PC-5, SSG-59-3×UTFS-41.
Susceptible	30.1-50	PC-6, CSV-15, CSV-33MF, UTMC-581, UTMC-583, UTMC-543 × PC-7, IS-3555×SSG-59-3, SSG-222×GD-68717, GMS-1417×GD68724, EC-582506×PC-4, UP-Chari-3, Pant-CMS, HC-171, and RS-673.
Highly susceptible	>50	PC-3, PC-4, PC-5, PC-8, PC-9, PC-11, PC-13, PC-14, UTFS-110, UTFS-122, Rampur Local, UTMC-580, UTMC-582, HJ-541×PC-6, UP-CHARI-2, Ramkel, HC-136

Screening of Gray leaf spots disease, among fifty-four sorghum varieties five varieties showed resistant reactions (UTFS-109, UTFS-108, UTFS-120, UTFS-123, and SPV-422×EC-582508), six moderate resistant varieties *viz.,* UTFS-111, CSV-14, IS-3359×IS-22996, IS-23586-2×IS-3226, EC-582506×PC-3, SSG-59-3×ICSV-702, and eleven varieties were moderately susceptible *viz.,* UTFS-121, CSV-35F, CSV-21F, Pant Chari-5 × EC-582508, IS-40961×IS-14357, GD-68717 × IS-3555, (PC-5×PSSV-16) ×(UPMC-8×SDSL-92111), PC-5×EC-582508, UP-Chari-2×EC-582506, EC-582506×PC-5, SSG-59-3×UTFS-41. Among them, fourteen varieties were susceptible *viz.* PC-6, CSV-15, CSV-33MF, UTMC-581, UTMC-583, UTMC-543 × PC-7, IS-3555×SSG-59-3, SSG-222×GD-68717, GMS-1417×GD68724, EC-582506×PC-4, UP- Chari-3, Pant-CMS, HC-171, and RS-673. There were no immune varieties against *C. Sorghi.*

CONCLUSION

The present study shows, among fifty-four varieties PC-4 and Rampur local are highly susceptible to all three pathogens, UTFS-109 showed resistance to Anthracnose and Gray leaf spot but susceptible to Zonate leaf spot, CSV-21F is moderately susceptible to Anthracnose and Gray leaf spot and UTMC-543×PC-7 was moderately susceptible to Zonate leaf spot but susceptible to Anthracnose and Gray leaf spot diseases. Out of fifty-four varieties, none of the varieties show resistance against Zonate leaf spot but some varieties showed resistance against Anthracnose and Gray leaf spot diseases.

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Conflict of Interest. None.

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