Original Research Article

Survey and Disease Prevalence of Sorghum Zonate Leaf Spot in the Terai Region of Uttarakhand

ABSTRACT

Aims: The objective of the study was to conduct a disease survey to understand the regional dynamics of sorghum zonate leaf spot disease in the Uttarakhand Terai region.

Study design: The investigation was carried out usinga stratified random sampling technique.

Place and Duration of Study:GBPUA&T, Pantnagar and Terai Region of Uttarakhandduring Kharif 2024

Methodology: The survey was conducted from July to September 2024, covering several stages of sorghum crop development. A stratified random sampling technique was used to select fields, and observations were recorded on plants making five stops in a W-pattern to cover the whole field on foot. The disease incidence and severity were scored and recorded.

Results: The survey covered 25 fields and disease incidence& severitywere recorded using a standard scale.The study found that the prevalence and severity of zonate leaf spot disease (*G. sorghi*) varied significantly between locations, with the highest disease incidence in Chikaghat (71.11%) and lowest in Kanthgri(43.56%) from Sitarganj block.Environmental parameters such as temperature, humidity, and rainfall were directly linked to the occurrence and severity of zonate leaf spots.

Conclusion: The study concluded that zonate leaf spot disease is a significant problem in the Uttarakhand Terai Region. Developing efficient management techniques to reduce zonate leaf spot negative effects on crop productivity might be facilitated by knowledge of the distribution and contributing elements. To control zonate leaf spot in these areas, more study is required to investigate resistant cultivars and better agronomic methods.

Keywords: Zonate leaf spot, Gloeocercospora sorghi, Disease incidence, Sorghum, Uttarakhand, Terai region, Survey.

1. INTRODUCTION

A major grain crop, sorghum (*Sorghum bicolor* L.) ranks fifth in the world's production and is essential to food security, especially in arid and semi-arid areas. It is the perfect grain to grow in areas where other cereals are difficult to grow because of its resistance to drought and high temperatures (Khalifa and Eltahir, 2023). Sorghum has become a staple crop for millions of people, particularly in developing nations, and is widely farmed in Africa, Asia, the United States, and Australia. An estimated 58.38 million metric tons of sorghum will be produced worldwide in 2023–2024. The US, Nigeria, and India are major sorghum producers, with respective yields of approximately 8.07 million, 6.4 million, and 4.74 million metric tons (USDA, 2024).Sorghum is one of the major fodder crops in India, taking up 2.6 million hectares of land and being cultivated in the country's central, southern, hilly, and northwest areas (Atri*et al.,* 2022).The composition of sorghum, which includes protein, fat, carbohydrates, and non-starch polysaccharides, as well as bioactive elements like vitamin B and fat-soluble vitamins (D, E, and K), micronutrients, macronutrients, and non-nutrients like carotenoids and polyphenols, suggests that it has comparable nutritional value to other cereals (Tanwar*et al.,* 2023).The sugary kind of sorghum is very effective at creating biofuel; its stalk is used to make ethanol, and its grain is used to make biodiesel. Sorghum production has far-reaching and enormous socioeconomic effects, making it a vital resource for many small-scale farmers and businesses with an agricultural focus, supporting rural economies. Therefore, the importance of sorghum is not limited to guaranteeing food security; it also has a strong influence on encouraging sustainable farming methods and promoting rural development (Arouna, 2020).Its economic significance in animal feed, biofuel generation, and other industrial applications expands beyond its function in ensuring food security (Habyarimana *et al.,* 2020).Numerous serious diseases affect sorghum, a vital cereal crop, and reduce its productivity globally. Of these, *Gloeocercospora sorghi* zonate leaf spot of sorghum is still a major foliar disease that is on the rise, especially in tropical and subtropical areas. Worldwide, reports of the disease have come from the US, Brazil, Mexico, and some regions of Africa. In extreme circumstances, the disease has been known to cause significant yield losses. Pathogens produce symptoms on lower leaves starting with little lesions that grow into huge, purple-red, or dark brown lesions with two to eight rings. These lesions eventually take on a circular or target shape (Nagaraja*et al.,* 2021). Semi-oval lesions can be found close to the midrib or along the leaf border. The entire area becomes blighted in the latter stages, when dark-red to blackish-purple or brown lesions on leaves and leaf sheaths combine. The size and target appearance of certain zonate lesions vary. The slimy, salmon-coloured lumps on the upper surface of the blotch can occasionally be identified as *G. sorghi* sporodochia. In a linear pattern, black dots of spherical sclerotia appear on dead, greyish-tan tissue. The surface of severely diseased seeds has black oval dots and is either dark brown, crimson, or red-brown (Heo*et al.,* 1999).China reported sorghum yield losses of up to 30% (Jiang et al. 2018). In India, under ideal circumstances, the pathogen harmed up to 85% of the photosynthetic leaf area. As infection severity grew, leaf weight dropped and leaf dry matter content rose, which had an impact on fodder production (Anitha*et al.,* 2020).Food security is seriously threatened by the spread of sorghum zonate leaf spot disease in Uttarakhand's Terai area, which affects sorghum harvests, a vital crop for local income and nutrition. Since sorghum is an essential staple in this region that experiences frequent drought, the disease poses a risk of lowering productivity and jeopardizing the dietary intake of susceptible groups. A thorough study of this disease is necessary to evaluate its spread, find resistant cultivars, and create efficient management plans to protect sorghum output. Resolving this problem is essential to guaranteeing a consistent food supply and enhancing the robustness of regional agricultural systems.

2. MATERIALS AND METHODS

2.1 Survey and Sampling of Sorghum Zonate Leaf Spot Disease

The survey was carried out in Uttarakhand's Terai region during the sorghum growing season of 2024. The area consists of various blocks that are well-known for growing sorghum. The survey covered several stages of the development of the sorghum crop and was conducted from July to September. The fields used for illness assessment were chosen using a stratified random sampling technique. At regular intervals of 5 to 8 km, two sample fields were routinely taken at each point along the accessible roads. Zonate leaf spot occurrence and severity in the area, plant growth phases, GPS locations, and various cropping systems were used to classify sorghum farms. 25 fields in all, spread among the main sorghum-growing regions, were surveyed. In each field, the observations were recorded on plants making five stops by following a W-pattern to cover the whole field on foot (Ngugi *et al.,* 2002).

2.2 Disease Scoring

Each location's zonate leaf spot severity and disease incidence were recorded. One square meter quadrants were marked in each field to assess ten randomly chosen plants. Out of all the plants observed, the proportion of infected plants was used to compute the incidence. To calculate disease incidence, Cooke *et al.* (2006) presented the following formula,

$$\text{Disease incidence} = \frac{Number\ of\ plants\ showing\ disease\ symptoms}{Total\ number\ of\ plant\ observed} \times 100$$

Disease severity was assessed by using the standard scale (1 to 9) as described by Thakur *et al*. (2007) in the **Table.1** and the Percentage Disease Index (PDI) was calculated using the following formula suggested by Wheeler (1969):

$$\text{Percent disease index (PDI)} = \frac{Sum\ of\ individual\ ratings}{Total\ unit\ assessed\ \times Maximum\ grade} \times 100$$

Disease severity was recorded using a 1-9 scale based on lesion size, necrotic area, and defoliation

Table 1. Disease Scale for Zonate Leaf Spot in Sorghum

Rating	Description
1	No symptoms on the leaf and perfectly healthy
2	1-5% of the total leaf area is affected by spot

3	6-10% of the total leaf area is affected by spot
4	11-20% of the total leaf area is affected by spot
5	21-30% of the total leaf area is affected by spot
6	31-40% of the total leaf area is affected by spot
7	41-50% of the total leaf area is affected by spot
8	51-75% of the total leaf area is affected by spot
9	>75% of the total leaf area is affected by spot

2.3 Statistical Analysis

Analysis of Variance (ANOVA) was performed on the gathered data using SPSS version 16.0 in order to find significant effects at $P<0.05$. At a 5% probability level, Duncan's Multiple Range Test (DMRT) was used to identify significant mean differences of Sorghum Zonate Leaf Spot disease severity.

3. RESULTS AND DISCUSSION

3.1 Survey of Sorghum Zonate Leaf Spot Disease in the Terai Region of Uttarakhand

The prevalence and incidence of zonate leaf spot disease (*G. sorghi*) were evaluated by a thorough study of sorghum fields in the Terai region of Uttarakhand. Characteristics symptoms of Zonate leaf spot of Sorghumrepresented in Fig 1.Shows concentric rings of light brown to dark red lesions on the leaf surface were the typical symptoms seen in all regions in badly afflicted plants, these lesions merged to produce enormous necrotic patches. Premature defoliation was prevalent in strongly infested regions, which could result in crop losses and decreased plant vigor.Stewart *et al.,* 2019, recorded the leaf lesions were semicircular or round, with brown to cinnamon bands alternating with purple to red bands, creating a zonate or concentric lesion. The majority of the leaf surface was impacted by a number of coalescing lesions.Zonate leaf spot is more prevalent in warm, humid years and overwinters on crop residue. Disease severity depends on high rainfall, cloudy weather, and high relative humidity. Disease development is favorable at 28 to 32^{o}C and 90 % RH(Chandrashekar*et al.,* 2022).

Fig 1. Characteristics symptoms of Zonate leaf spot of Sorghum recorded during the Kharif 2024 survey in the Terai region of Uttarakhand

3.2 Disease Incidence and Environmental Factors Influencing Sorghum Zonate Leaf Spot

A thorough investigation was carried out to determine the prevalence and seriousness of sorghum zonate leaf spot disease at 10 sites in Uttarakhand's Terai area during 2024 Kharif season, which ranged in elevation from 208 to 372 meters.Bhardwaj*et al.,* 2021, recorded during their monitoring experiment at a humid, subtropical location (Ludhiana, India) from 2010 to 2020, the severity of zonate leaf spot on susceptible cultivar SL-44 was recorded during the rainy season (last week of June to third week of October). The resultsinTable 2. and Fig 2. highlighted the impact of zonate leaf spot disease varies depending on the area by revealing significant variance in disease incidence (DI) and percent disease index (PDI).There was a significant disease pressure at Chikaghat (234 m altitude), as evidenced by the highest DI of 96%, which was followed by Hathmana and Pantnagar (both at 92%). Kanthgri, Champawat, and Sitarganj, on the other side, had the lowest DI, 76%. Chikaghat once again shown the highest severity of PDI (71.11%), constituting a separate group (a) according to Duncan's Multiple Range Test (DMRT). Pantnagar (68.89%, group ab) and Banusi (66.26%, group b) came next. Along with Banusi, Hathmana had a high PDI (66.22%) and was assigned to category "b." With the lowest PDI (43.56%), Kanthgri was designated as "g," indicating that it was the least impacted area. Intermediate PDI levels were noted in Champawat (57.33%, group f), Baghroga (60.44%, group cd), Khatima (60.00%, group ef), Bari (63.11%, group c), and Sitarganj (59.11%, group ef).During the 2022 growing season in Senegal, West Africa, there was a 76% frequency of anthracnose and zonate leaf spot, respectively, in 93 of the 122 fields studied by Prom *et al.,* 2023. The relationship between altitude and disease severity did not follow a clear linear pattern, suggesting that other factors, such as environmental conditions, cultural practices, and pathogen dynamics, might influence disease prevalence. Notably, locations like Chikaghat, Pantnagar, and Banusi, which recorded high DI and PDI, are likely hotspots for the disease, requiring focused management strategies.In order to develop sustainable and effective disease management solutions, future research should examine the influence of microclimatic factors, pathogen virulence, and host-pathogen interactions. The substantial differences in DI and PDI among locations, as identified by DMRT, highlight the need for site-specific disease management strategies, including the use of resistant sorghum varieties and improved agronomic practices. The mean DI across the locations was 84.4%, and the mean PDI was 61.6%, with standard deviations of 7.41% and 7.77%, respectively, indicating moderate variability in disease impact.Window pane analysis revealed that weekly average minimum temperature (Tmin), average temperature (Tav), and afternoon relative humidity (RHa) were identified as potential predictors of zonate leaf spot, and regression models based on Tmin, Tmin + RHa, and Tav + RHa were able to explain 56, 56, and 54% variation in disease severityat various tested location (Bhardwaj*et al.,* 2021).Environmental parameters, including temperature, humidity, and rainfall, were directly linked to the occurrence and severity of zonate leaf spots. Zonate leaf spot is regarded as a minor disease that causes insignificant output losses in drier sorghum-producing countries. Nonetheless, the disease can result in notable yield and quality losses in humid and rainy environments, particularly on sweet sorghum and fodder (Prom and Isakeit, 2022).

Table 2. Disease Incidence of Sorghum Zonate Leaf Spot in the Terai Region of Uttarakhand during Kharif 2024

S. No	Block	Location	Latitude/ Longitude	Altitude (m)	Disease Incidence (%)	Per Cent Disease Index (%)
1	Baheri	Hathmana	28.881038°N 79.574629°E	228	92	66.22^{b}
2	Champawat	Champawat	28.98366°N 79.062477°E	372	76	57.33^{f}
3	Khatima	Khatima	28.936564°N 79.912259°E	219	84	60.00^{ef}
4	Khatima	Banusi	28.935654°N 79.915555°E	212	88	66.26^{b}
5	Rudrapur	Bari	28.863337°N 79.616342°E	208	84	63.11^{c}
6	Rudrapur	Pantnagar	29.0080960°N 79.5125136°E	244	92	68.89^{ab}
7	Sitarganj	Kanthgri	28.871373°N 79.629631°E	234	76	43.56^{g}
8	Sitarganj	Chikaghat	28.931449°N 79.737094°E	234	96	71.11^{a}
9	Sitarganj	Baghroga	28.931736°N 79.729997°E	234	80	60.44^{cd}
10	Sitarganj	Sitarganj	28.903346°N 79.700507°E	234	76	59.11^{ef}
				Mean DI & PDI	**84.4**	**61.60**
				SD	**7.41**	**7.77**

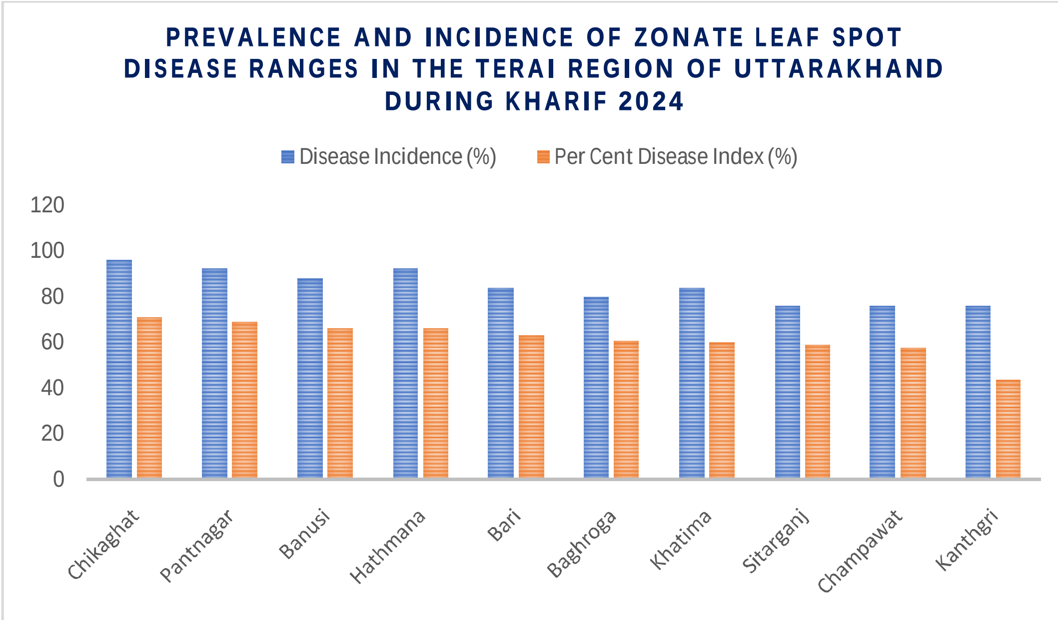

Fig 2. Prevalence and Incidence of Zonate Leaf Spot Disease Ranges in the Terai Region of Uttarakhand during Kharif 2024

CONCLUSION

The study focuses on the considerable impact of zonate leaf spot (*Gloeocercospora sorghi*) on sorghum in the Terai region of Uttarakhand during the 2024 kharif season. The study finds that disease incidence varies between assessed areas, with incidence rates ranging from 40% to 75%, with Chikaghat (71.11%) and Pantnagar (68.89%) showing very high levels. Disease progression, characterized by concentric lesions and premature defoliation, highlights the susceptibility of sorghum crops to favorable weather circumstances such as high humidity and rainfall. The findings underscore the importance of regional disease surveillance and adaptive management measures in reducing yield losses. Furthermore, knowing the interaction of environmental factors and pathogen dynamics is critical for creating resilient sorghum cultivars.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) now declare that generative AI technologies such as Large Language Models, etc. have been used during the editing of manuscripts.This explanation will include the name, version, model, and source of the generative AI technology as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1. ChatGpT

2.Grammarly

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