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Spatial distribution and survey of soybean anthracnose in the Kumaon region of Uttarakhand, India

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ABSTRACT: Among oilseed crops, soybean is widely cultivated because of its high protein and oil content, making it an important component of agricultural and food production systems. However, its productivity is often affected by anthracnose, a serious disease caused by hemi-biotrophic fungus *Colletotrichum truncatum*. A GIS based field survey was conducted across 55 locations in six districts of Uttarakhand during the *kharif* seasons of three consecutive years (2022–2024) to study the spatial distribution of soybean anthracnose. The investigation revealed considerable variation in disease occurrence among the surveyed regions. Lower DI and PDI were generally observed in the hill regions of *Kumaon*, while the *Tarai* plains exhibited the highest disease levels, followed by the *Bhabar* region. Among the surveyed districts, Udham Singh Nagar recorded the highest Disease Incidence (53.13%) and Percent Disease Index (34.18%), while Bageshwar showed the lowest Disease Incidence (5.13%), whereas Almora showed the lowest Percent Disease Index (2.63%). The GIS based disease maps generated in this study can support location specific disease surveillance, timely intervention, and efficient resource allocation for soybean disease management.

Key words: Anthracnose, Disease incidence, Geographic information system, Percent disease index, Survey

Soybean (*Glycine max* L. Merrill) is an important oilseed crop cultivated across many parts of the world. It plays a vital role in the world's agricultural landscape as a key source of vegetable oil and protein for both human and animal consumption, accounting for approximately 3.3% of global caloric intake (FAOSTAT, 2018). Despite its importance, soybean cultivation is affected by several abiotic and biotic factors that limit productivity and seed quality. Biotic factors, including insects, pathogens, and weeds, pose significant challenges to soybean production, leading to yield reductions. Plant diseases remain one of the major constraints to sustainable soybean production (Sinclair and Backman, 1989; Hartman *et al.*, 1999). Among the important fungal diseases of soybean, anthracnose is recognized as a major cause of yield and quality losses (Bouffleur *et al.*, 2020). The disease is primarily caused by the fungal pathogen *Colletotrichum truncatum*. It is one of the most devastating soybean diseases, affecting nearly all aboveground parts of the plant, including seedlings, stems, petioles, leaves, and pods, leading to significant yield losses worldwide (Nene and Srivastava, 1971; Sharma *et al.*, 2011). The most characteristic symptoms include dark, depressed,

irregular lesions on cotyledons, pods, stems, and petioles, often accompanied by acervuli and dark setae. Grain yield losses due to anthracnose are significant, ranging from 16% to 26% in the United States, 30%–50% in Thailand, and up to 100% in India (Hartman *et al.*, 1999; Sharma *et al.*, 2011). Accurate assessment of disease occurrence is essential for minimizing crop losses and to plan effective management strategies. Traditional approaches based on visual observation are widely used, but they can be subjective and may not always give consistent results, which can delay proper disease control. Geospatial technologies, particularly Geographic Information Systems (GIS), have emerged as valuable tools for monitoring and managing plant diseases (Taliei *et al.*, 2013; Surbhi *et al.*, 2023). A detailed survey helps in understanding the exact distribution of diseases, which is important for developing region specific management strategies. The present investigation utilized GIS techniques to characterize the spatial distribution and severity of soybean anthracnose in the *Kumaon* region of Uttarakhand. The resulting spatial insights aim to facilitate the development of region specific and targeted management strategies,

thereby contributing to the more effective mitigation of this economically important disease.

MATERIALS AND METHODS

Field surveys were conducted during three successive *kharif* seasons (2022–2024) to determine the occurrence of soybean anthracnose in six districts of Uttarakhand: Nainital, Bageshwar, Pithoragarh, Almora, Champawat, and Udham Singh Nagar. Observations were recorded from the flowering stage until crop maturity at 55 soybean growing locations across the *Kumaon* region. Disease assessment in each field was performed following a standard sampling procedure. Five sampling quadrats of 1 m² each were examined, with one located at each corner of the field and one at the centre. Geographic coordinates (latitude and longitude) together with Disease incidence and Percent disease index were documented for each survey location. The disease was assessed using the rating scale of Mayee and Datar (1986), and the observations were converted into Percent disease index (PDI) following the procedure outlined by Wheeler (1969). The recorded observations were compiled and analysed to generate GIS based disease distribution maps at the Department of Plant Pathology, GBPUA&T, Pantnagar. The Disease incidence (DI) and Percent disease index (PDI) were calculated according to the formula given by Wheeler (1969) as follows:

$$\text{PDI (\%)} = \frac{\text{Sum of all ratings}}{\text{Number of ratings} \times \text{Maximum grade}} \times 100$$

$$\text{Disease incidence} = \frac{\text{Number of diseased}}{\text{Total number of plants observed}} \times 100$$

RESULTS AND DISCUSSION

Symptomatology of Anthracnose

Field observations made during the cropping seasons revealed characteristic anthracnose symptoms on soybean plants infected by *Colletotrichum truncatum* (Figure 1). Initial symptoms were observed as small irregular necrotic lesions, dark brown to black in colour, on the leaf surface. With disease development, the lesions expanded and coalesced, resulting in large blighted patches (Figure 1a). Pods exhibited blight symptoms characterized

by shrivelling and premature drying (Figure 1b). In several cases, dark, scattered acervuli were visible on the pod surface as minute black fruiting bodies (Figure 1c). Microscopic examination of diseased tissues showed acervuli containing characteristic dark, needle shaped setae (Figure 1d). The occurrence of these symptoms was quantified through DI and PDI assessments across locations, as presented in Table 1.

A systematic field survey was undertaken to determine the occurrence and distribution of soybean anthracnose in major soybean growing areas (Figure 2). The survey focused on key parameters such as geographic location, disease incidence, and percent disease index. The primary objective of this study was to evaluate the spatial variability in the occurrence of soybean anthracnose and to identify regions that may be more susceptible to the disease. By analysing these spatial patterns, the study also aimed to gain insights into environmental or regional factors that may influence the development and spread of the disease. Comparison of DI and PDI among locations provides useful information for recognizing high risk areas and developing location specific management practices. The geographic coordinates of all surveyed sites, along with the recorded DI and PDI, are presented in Table 1. The spatial distribution of soybean anthracnose across the surveyed regions is also shown in Figure 3, which provides a clear visual representation of how the disease varies among different soybean growing areas.

Status of soybean anthracnose in Kumaon region

Hills of Kumaon

Out of the six districts surveyed, five are characterized by hilly terrain, while only one has a plain geographical landscape. In several hilly areas such as Matela and Hualbhag (Almora), Choni and Palen (Bageshwar), and Dhapa (Pithoragarh), both DI and PDI were found to be zero, during all the three years indicating no signs of disease presence. In contrast, certain other areas within these districts showed noticeable disease presence. In Bageshwar district, the highest DI and PDI were observed in

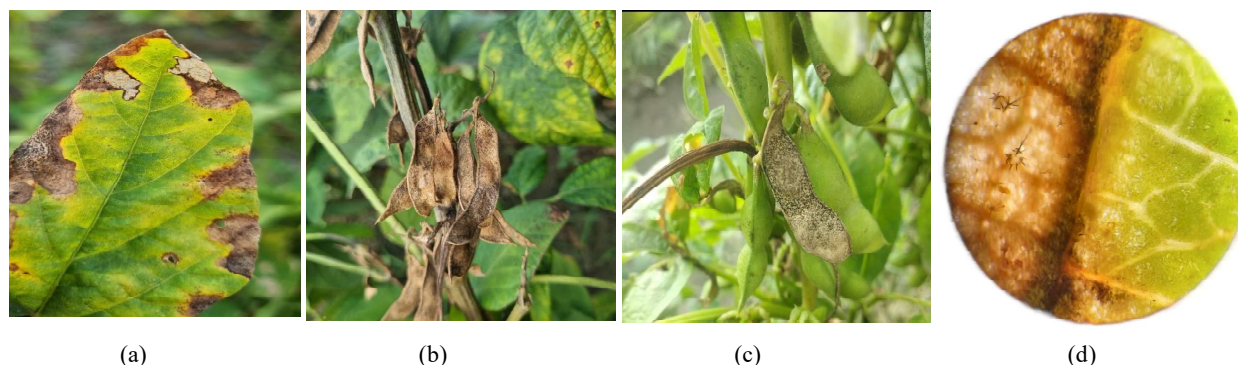


Fig. 1: Characteristic symptoms of soybean anthracnose caused by *Colletotrichum truncatum*: (a) irregular necrotic lesions on leaves, (b) pod blight with shrivelled pods, (c) infected pods showing dark acervuli, and (d) microscopic view of acervuli with setae on infected leaf tissue

Someshwar, with 12.00% and 6.27% respectively. Similarly, in Pithoragarh, the Panda region showed the highest DI at 11.00%, while Bajeti recorded the peak PDI at 6.73%. In Champawat district, the Swala region recorded the highest disease impact, with a DI of 15.73% and a PDI of 6.00%. In the hilly areas of Nainital district, Majehra exhibited the most severe disease occurrence, showing a DI of 45.73% and a PDI of 20.87%. In Almora district, Dhyari

reported the highest DI at 13.10%, while Bamsyun recorded the peak PDI at 5.07%.

Bhabar region of Kumaon

The *Bhabar* region is a narrow strip, ranging from 8 to 16 kilometers in width, located along the foothills of the Shiwalik range in Uttarakhand, India. This zone includes the lower parts of the Nainital district. Among the surveyed areas, Haripur showed the

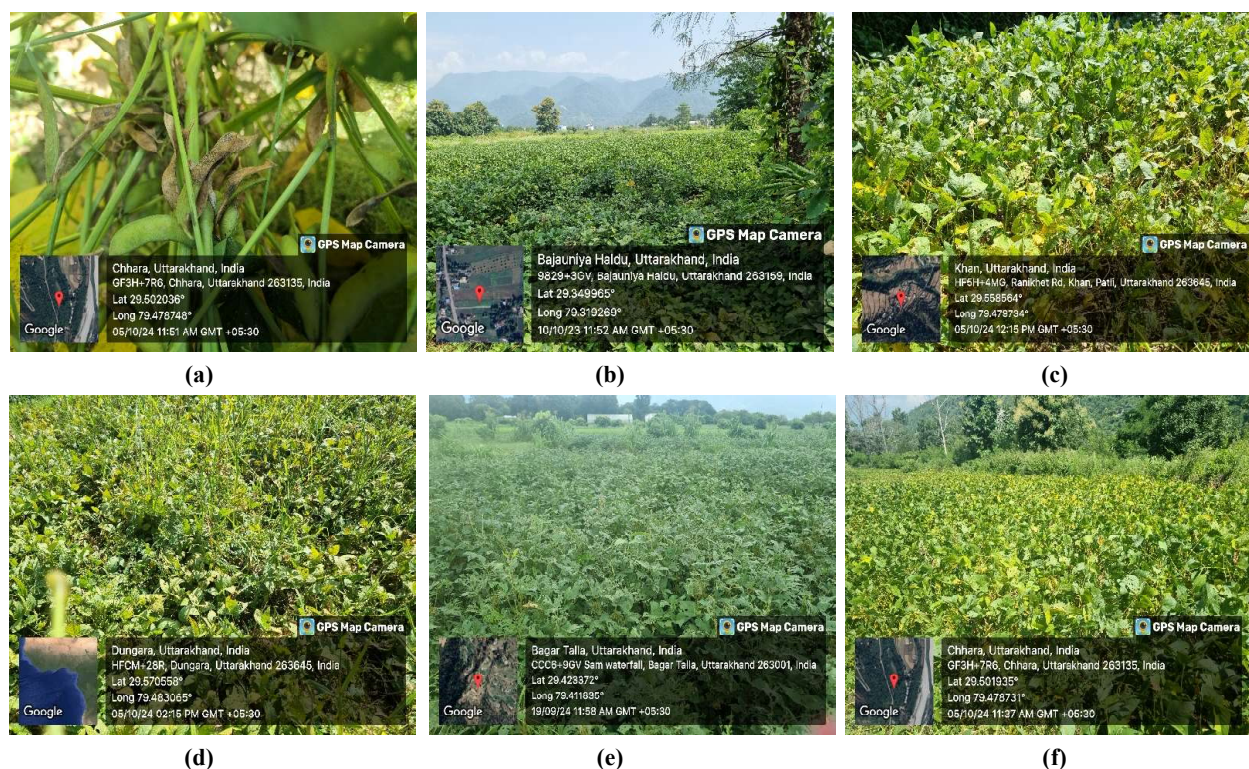


Fig. 2: Field survey of soybean anthracnose in soybean fields across different locations of Uttarakhand

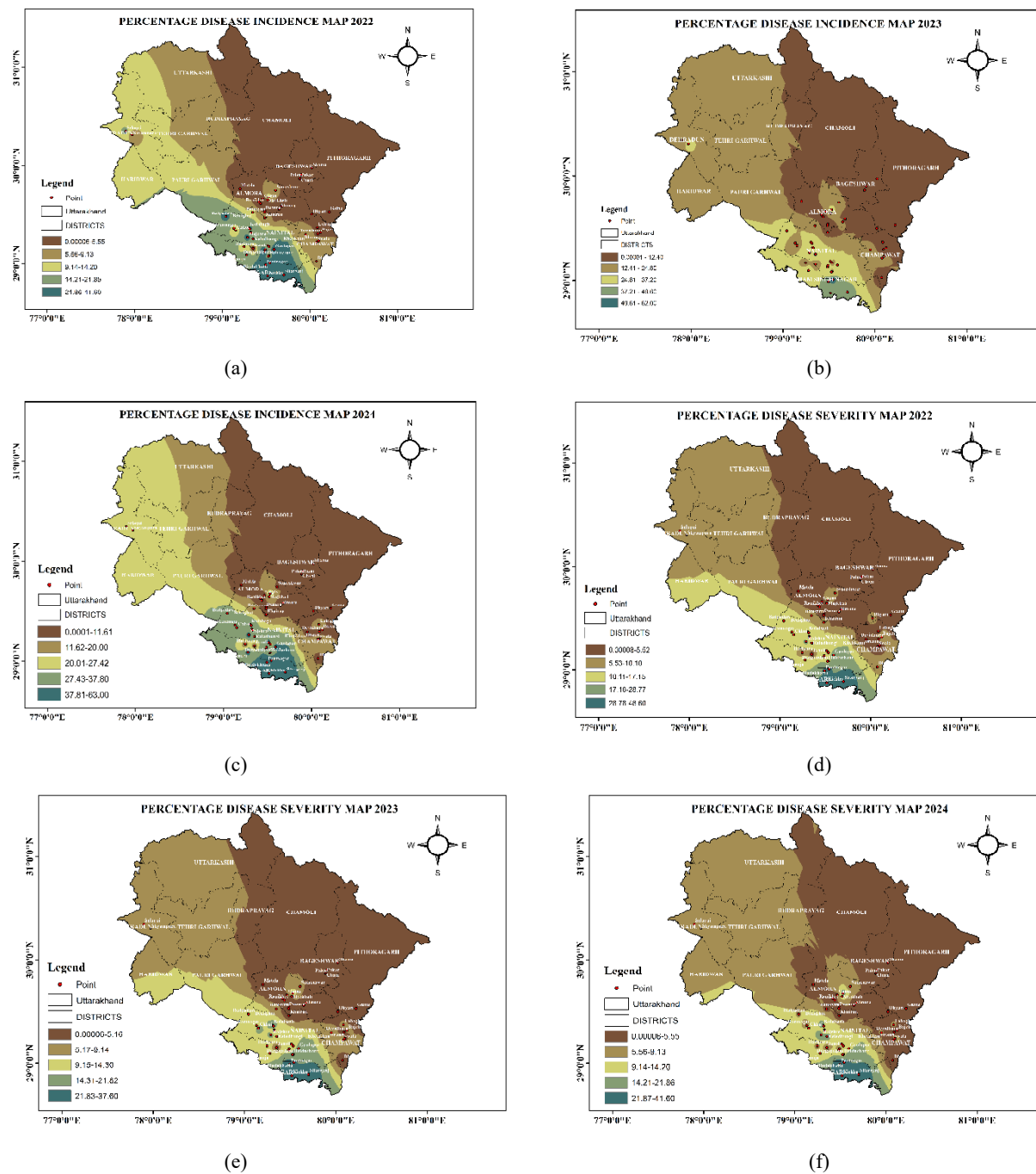


Fig. 3: Year wise spatial variation of anthracnose disease in soybean across the study area, illustrating percentage disease incidence for 2022 (a), 2023 (b), and 2024 (c) and percentage disease index for 2022 (d), 2023 (e), and 2024 (f)

lowest levels of Disease incidence (16.53%) and Percent disease index (7.13%). In contrast, Ganna Centre recorded the highest DI at 40.47%, while the highest PDI, 19.13%, was reported in Gaulapar.

Plains of Kumaon

The plains of Kumaon, commonly referred to as the *Tarai* region, are low lying areas located south of the

Table 1: Disease Incidence and Percent Disease Index of soybean anthracnose at different locations of Uttarakhand during *Kharif* season 2022, 2023, and 2024

S. No.	District	Area	Location	Altitude	Longitude and Latitude	Soybean Anthracnose							
						Disease Incidence (%)				Percent Disease Index (%)			
						2022	2023	2024	Mean	2022	2023	2024	Mean
1	Udham Singh Nagar	Plains (04)	Pantnagar	244.06	29.0222° N, 79.4908° E	57.00	51.00	63.00	57.00	31.60	37.60	41.60	36.93
2			Kiehha	293.16	28.9115° N, 79.5154° E	48.00	43.00	50.60	47.20	43.60	31.60	23.00	32.73
3			Bindukhatta	241.04	29.0406° N, 79.5407° E	65.00	62.00	57.00	61.33	33.60	22.40	30.60	28.87
4			Sitarganj	293.00	28.9235° N, 79.7007° E	51.00	41.00	49.00	47.00	48.60	31.20	34.80	38.20
	Mean					55.25	49.25	54.90	53.13	39.35	30.70	32.50	34.18
5	Almora	Hills (11)	Dungra	1834.00	29.5707° N, 79.4821° E	5.00	6.00	4.80	5.27	3.00	1.40	1.60	2.00
6			Bamsyun	1175.10	29.5578° N, 79.4792° E	14.60	12.20	10.00	12.27	5.40	2.40	7.40	5.07
7			Janoli	1832.00	29.1863° N, 79.3482° E	4.40	9.60	13.20	9.07	1.40	2.80	4.40	2.87
8			Chilliyaula	1805.00	29.6622° N, 79.4121° E	4.80	0.00	4.20	3.00	1.80	0.00	2.00	1.27
9			Ranikhet	1869.00	29.6434° N, 79.4322° E	9.40	4.60	8.40	7.47	1.60	1.60	4.80	2.67
10			Majkhali	1829.00	29.6792° N, 79.5133° E	4.60	14.60	17.20	12.13	1.40	2.20	9.80	4.47
11			Gagas	1107.12	29.6933° N, 79.4590° E	4.80	15.00	8.20	9.33	2.40	5.20	3.80	3.80
12			Almora	1642.00	29.5892° N, 79.6467° E	6.41	9.80	0.00	5.40	6.54	1.56	0.00	2.70
13			Matela	1214.75	29.7960° N, 79.1933° E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14			Haualbhadg	1204.67	29.6181° N, 79.6741° E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15			Dhyari	1523.38	29.5330° N, 80.0214° E	9.10	18.60	11.60	13.10	2.20	4.80	5.20	4.07
	Mean					5.74	8.22	7.05	7.00	2.34	2.00	3.55	2.63
16	Nainital	Hills (03)	Khairna	1830.00	29.4961° N, 79.4811° E	12.80	7.40	11.00	10.40	8.00	3.40	3.40	4.93
17			Majehra	2620.00	29.3011° N, 79.2844° E	51.00	39.60	46.60	45.73	21.80	16.80	24.00	20.87
18			Betalghat	2057.00	29.5555° N, 79.3423° E	21.00	16.40	14.75	17.38	7.80	6.80	4.80	6.47
19		Bhabar (22)	Haldwani	424.00	29.2183° N, 79.5130° E	35.00	31.00	47.00	37.67	10.20	13.60	12.40	12.07
20			Ganna Centre	432.00	29.1590° N, 79.4812° E	53.40	31.00	37.00	40.47	14.60	13.00	11.20	12.93
21			Gaulapar	443.00	29.1764° N, 79.5903° E	47.60	30.80	42.00	40.13	25.00	18.20	14.20	19.13
22			Ramnagar	345.00	29.3948° N, 79.1265° E	25.60	14.40	27.60	22.53	12.20	8.60	5.40	8.73
23			Durgapalpur	443.00	29.1161° N, 79.5308° E	30.60	20.00	23.80	24.80	16.40	21.80	14.00	17.40
24			Pipalchok	210.00	29.7103° N, 79.5231° E	30.20	41.00	33.00	34.73	13.20	17.60	21.00	17.27
25			Halduchaur	424.00	29.1121° N, 79.5237° E	32.20	25.00	36.25	31.15	15.00	10.40	11.40	12.27
26			Indira Nagar	450.00	29.2023° N, 79.5308° E	25.00	14.40	16.80	18.73	10.40	8.00	9.00	9.13
27			Panchayat Ghar	443.00	29.1729° N, 79.4859° E	35.00	28.40	35.00	32.80	12.60	11.00	1.75	8.45
28			Kamalwaganja	441.00	29.1242° N, 79.2741° E	30.20	37.00	42.50	36.57	16.40	12.60	13.00	14.00
29			Lalkuan	260.00	29.0311° N, 79.3139° E	35.00	29.00	36.25	33.42	9.60	9.20	12.40	10.40
30			Himmatpur	508.00	29.1327° N, 79.2911° E	21.00	18.40	15.00	18.13	14.40	7.60	8.20	10.07
31			Tanda Range	290.00	29.0438° N, 79.2553° E	53.00	37.80	29.50	40.10	20.40	18.40	11.20	16.67
32			Kotabagh	656.00	29.3992° N, 79.3001° E	32.60	31.80	39.00	34.47	13.80	15.00	22.00	16.93
33			Chhoi	346.00	29.3709° N, 79.1464° E	17.60	22.00	31.00	23.53	14.40	18.00	13.00	15.13
34			Ginti Gaon	345.00	29.3915° N, 79.3113° E	48.00	37.00	31.20	38.73	18.80	20.20	8.20	15.73
35			Kaladhungi	393.00	29.2854° N, 79.3480° E	26.00	41.00	28.40	31.80	18.00	13.80	18.40	16.73

outer Himalayan foothills (Shiwalik Hills) and north of the Indo-Gangetic plains. In Uttarakhand, a major portion of Udham Singh Nagar district lies within this *Tarai* belt, which is characterized by fertile soils and favourable conditions for soybean cultivation. Among the surveyed locations within this region, Bindukhatta recorded the highest DI (61.33%) however, it exhibited the lowest PDI at 28.87%. In contrast, Sitarganj showed the lowest DI (47.00%) but recorded the highest PDI (38.20%). These variations indicate differences in disease intensity and severity across locations, suggesting that local environmental conditions and agronomic practices may influence the development and spread of soybean anthracnose in the *Tarai* region.

According to district averages, the highest disease incidence was observed in U.S. Nagar (53.13%), followed by Nainital (30.17%) and Champawat (12.95%). In contrast, Bageshwar had the lowest incidence, with only 5.13%. The Percent Disease Index (PDI) was also highest in U.S. Nagar (34.18%), followed by Nainital (12.76%). The disease exhibited widespread prevalence across all major soybean growing regions, with incidence levels ranging from moderate to severe. Notably, a higher intensity of the disease was recorded in the *Tarai* and *Bhabhar* zones compared to the hill regions. This spatial variation is likely driven by differences in prevailing agroclimatic conditions associated with altitude, particularly variations in temperature, humidity, and rainfall. Additional contributing factors include cropping patterns, sowing dates, varietal susceptibility, phenological stage of the crop, regional cultural practices, and microclimatic fluctuations. In the *Tarai* and *Bhabhar* region of Uttarakhand, the temperature from July to October ranges from 25 to 30°C, with relative humidity exceeding 90%. These climatic conditions are highly favourable for the development of anthracnose, as reported by several researchers (Fitzell and Peak,

1984; Aggarwal *et al.*, 2017).

Similar survey studies have been conducted by various investigators in different regions. Kulkarni and Benagi (2013) studied anthracnose of greengram in Northern Karnataka, while Mathpal and Singh (2017) investigated *Rhizoctonia* aerial blight of soybean in Uttarakhand. Chavan and Dhutraj (2017) reported on anthracnose and pod blight of soybean in the Marathwada region of Maharashtra. A roving survey in Rajasthan also reported variation in mungbean anthracnose intensity across districts, with a mean disease intensity of 22.60% (Choudhary *et al.*, 2024). The application of geospatial techniques has expanded considerably in plant disease epidemiology, enabling researchers to characterize disease distribution and identify spatial patterns under diverse agro-climatic conditions. In India, GIS has been employed to study the spatio temporal distribution of bacterial leaf blight of rice caused by *Xanthomonas oryzae* pv. *oryzae* (Rajesh, 2017). Similar observations have been reported for bacterial blight of soybean in Uttarakhand, where GIS based disease mapping revealed marked spatial variation in disease incidence, with higher disease prevalence in the Kumaon region (12.57%) than in the Garhwal region (9.0%). The study further identified Udham Singh Nagar, Champawat, and Pithoragarh as major disease hotspots, highlighting the usefulness of GIS for identifying high risk areas and strengthening disease surveillance (Surbhi *et al.*, 2023). Similar applications have also been reported from other countries. In Malaysia and Thailand, GIS has been used to analyse the spatial distribution and density of plant species (Sanyong and Amarakul, 2001; Azahar *et al.*, 2011), while Taliei *et al.* (2013) employed GIS to map the spatial distribution of soybean charcoal rot. Likewise, GIS based mapping has been used to investigate bacterial wilt of banana in East Africa (Bouwmeester *et al.*, 2016) and to assess the epidemiology of wetwood disease of elm in Iran (Alizadeh *et al.*, 2017). Collectively, these studies demonstrate the broad applicability of GIS as a valuable tool for disease surveillance, spatial analysis, and epidemiological investigations.

CONCLUSION

The present study revealed that soybean anthracnose

is widely distributed across the major soybean growing regions of Uttarakhand, although its severity varied considerably among districts. Among the surveyed districts, U.S. Nagar recorded the highest disease incidence and percent disease index, followed by Nainital, whereas Bageshwar remained the least affected district. The GIS based disease maps clearly delineated areas with low, moderate, and high disease intensity, providing a comprehensive understanding of the spatial distribution of soybean anthracnose in the state. These findings highlight the usefulness of GIS for disease surveillance, hotspot identification, and epidemiological studies, and can facilitate location specific disease management, timely monitoring, and efficient allocation of resources for the sustainable management.

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