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RESEARCH ARTICLE

Occurrence of soil borne diseases of garlic in Himachal Pradesh

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Abstract

Basal rot, white rot and blue mould rot were identified as the major soil-borne diseases affecting garlic fields in Solan, Sirmour and Kullu districts of Himachal Pradesh during the 2019-21 cropping seasons. Diseased samples were collected from the fields and analyzed at the Plant Pathology Laboratory of the university. Data were calculated based on disease incidence. The results of the study revealed that among all the districts namely, Solan, Sirmour and Kullu, the maximum disease incidence was recorded at Lanacheta village of Sirmour district (29.96 %) and minimum was observed in Nauni village of Solan district (2.11 %). Moreover, the highest overall disease incidence (14.71 %) was recorded in 2019 and the lowest (3.38 %) in 2020. Among the three soil-borne diseases, basal rot exhibited the highest incidence, followed by white rot and blue mould rot. Furthermore, it was observed that Sirmour district was significantly more affected by these diseases, in terms of incidence, than the other two districts. These soil-borne diseases pose a serious threat to garlic production and farmer income, underscoring the need for effective management strategies.

Keywords: disease incidence; garlic; Kullu; losses; Sirmour; soil borne diseases; Solan

Introduction

Garlic (*Allium sativum* L.), a species in the family Amaryllidaceae, belongs to the same genus as onion (1). It originated in Central Asia, while the Mediterranean region is considered its secondary center of origin. It's close *Allium* relatives include onion, shallot, leek, chive and Chinese onion. Garlic is successfully grown worldwide, from temperate to subtropical climates (2).

The area garlic cultivation and its production have been increasing globally year after year. At the global level, the total area and production are 1634 thousand hectares and 307.08 million metric tonnes, respectively, with productivity of 18 tonnes per hectare (3). China is the world leader in both area and production of garlic, followed by India. In India, garlic is cultivated on 391 thousand hectares with a production of 3185 thousand metric tonnes a productivity of 8.14 metric tonnes per hectare (4). It is grown across India, mainly in the states of Gujarat, Orissa, Madhya Pradesh, Rajasthan, Uttar Pradesh and Maharashtra. Among these, Madhya Pradesh is the leading producer, ranking first in both area and production, followed by Rajasthan, Gujarat and Uttar Pradesh.

In Himachal Pradesh, garlic is cultivated at 7.19 thousand hectares, with a production of 11.60 thousand metric tonnes and a productivity of 1.61 tonnes per hectare (4). The lower productivity in Himachal Pradesh compared to other regions is attributed to several factors, including climatic conditions, disease susceptibility and less adoption of improved technologies. Furthermore, although long-day garlic varieties are better suited for the temperate climate of Himachal Pradesh, they are not widely cultivated.

In addition to its reputation as a health-promoting food, garlic has demonstrated antiviral, antibacterial, antifungal and antioxidant properties. Garlic has higher nutritive value containing approximately 65 % water, 28 % carbon, hydrogen and oxygen, 2.3 % organosulfur, 2 % protein, 1.2 % free amino acids and 1.5 % fiber. The ascorbic acid content is very high in garlic greens than in dried cloves. Raw garlic contains water, carbohydrates and proteins briefly in the amounts of 58.58, 33.06 and 6.36 g/100 g, respectively (5).

In addition to its nutritional value, garlic is widely used as a traditional remedy for various ailments, including the cold, flu, joint pain, digestive issues, heart diseases and even cancer prevention. It is also valued for its physiological benefits and is commonly used as a culinary spice (6). Due to its extensive antimicrobial use, it is often referred to as "Russian penicillin" (7). In modern medicine, garlic has demonstrated effectiveness in improving several cardiovascular health markers, including blood pressure, cholesterol levels, blood sugar and immune function (8). Its extracts have shown antibacterial, antifungal, antiviral and antiprotozoal properties.

However, garlic is susceptible to several plant pathogens, particularly soil-borne fungi (9, 10). Among these, basal rot (*Fusarium oxysporum* f. sp. *cepae, F. moniliforme* var. *subglutnous, F. bulbigenum, F. solani* and *F. equiseti*), white rot (*Sclerotium cepivorum*) and blue mold (*Penicillium allii, P. hirsutum* and *P. viridicatum*) are the most destructive, causing substantial losses.

The primary disease affecting garlic is basal rot, caused by *F. oxysporum*. This disease is also known as rotten base, Fusarium rot, Fusarium wilt or basal plate rot and is a major limitation to *Allium* production worldwide (11-13). Some species of *Fusarium* can also damage bulbs leading to losses of up to 50 % in the field and 30-40 % in storage (14).

White rot disease is another major soil-borne disease affecting garlic globally, including in India (15-17). The causal organism, *S. cepivorum*, produces sclerotia in the soil, which facilitates its persistence and spread (18). The disease results in substantial economic losses in garlic production worldwide, with losses ranging from 1 % to 100 % (19).

In addition to being a post-harvest pathogen of *Allium* species, the blue mold rot pathogen, *P. allii*, has also been identified as a field pathogen of garlic in Argentina. Although *P. hirsutum* and *P. viridicatum* were previously considered potential pathogens, *P. allii* has been confirmed as the species responsible for blue mold rot in garlic crops in Argentina (20).

Considering the crop's importance and the significant damage caused by these pathogens, the present study was undertaken to assess the status of soil-borne diseases affecting garlic in Himachal Pradesh.

Material and Methods

The present studies were conducted in the Plant Pathology Laboratory of Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh, located at 1250 m above mean sea level, at 30°51′N latitude and 77°11′E longitude. During these investigations, surveillance studies were carried out over a period of three years, 2018-2019, 2019 -2020 and 2020-2021 in various garlic growing localities of the Solan, Sirmour and Kullu districts of Himachal Pradesh.

The different locations were surveyed in Solan district included Nauni, Rangah, Kalod, Oachghat, Anu, Deothi, Bania Devi, Anji, Jauna Ji and Kandaghat. In Sirmour district, the surveyed areas were Lana Cheta, Lana Palar, Kathali Bharan, Daberghat, Naura Dhar, Chokar, Kaintha, Narag, Shoti, Thanni, Ghaloot and Mohar. In Kullu district, the locations included Bajaura, Ropa, Naul, Kalheli, Saujain, Badah, Jhiri, Jarar, Hurla and Bhunter. In total, thirty-two locations were surveyed to record the incidence of soil-borne diseases of garlic.

The per cent disease incidence was calculated as follows:

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants}} \times 100 \quad \text{(Eqn. 1)}$$

During surveys, the diseased plants were collected in paper bags and brought to the laboratory and the test fungi were isolated and preserved in PDA slants at 4 °C.

Results and Discussion

To study the incidence of soil-borne diseases of garlic, surveys were conducted in various garlic-growing areas of the Solan, Sirmour and Kullu districts of Himachal Pradesh from January to April during the years 2019, 2020 and 2021, at different stages of crop growth. Table 1 indicates that the soil-borne diseases of garlic were prevalent in nearly all surveyed locations across the three districts.

Table 1 shows that three soil-borne diseases, namely, basal rot, white rot and blue mould rot were identified at all the surveyed locations within the three districts. Among these, basal rot exhibited the highest incidence in 2019, 2020 and 2021, with overall mean incidence of 14.71 %, 14.68 % and 13.76 %, respectively. Conversely, blue mould rot showed the lowest incidence in all three years, with mean values of 3.96 %, 3.38 % and 3.87 %, respectively.

Among the districts, Sirmour recorded the highest mean incidence of basal rot (25.36 %, 25.14 % and 23.36 %), followed by Solan (9.30 %, 8.10 % and 7.83 %), while Kullu had the lowest incidence (7.56 %, 8.93 % and 8.37 %) during the years 2019, 2020 and 2021, respectively (Fig. 1).

For white rot, the mean disease incidence was also highest in Sirmour (27.11 %, 20.89 % and 18.39 %) and lowest in Kullu district (2.73 %, 2.47 % and 2.67 %) across the three consecutive years (Fig. 2). Similarly, for blue mould rot, the highest disease incidence was again recorded in Sirmour (7.85 %, 6.00 % and 6.83 %), while Kullu showed incidence (1.64 %, 1.56 % and 1.83 %) (Fig. 3).

In the Solan district, the maximum mean incidence of basal rot was observed at Kandaghat (14.33 %, 12.00 % and 15.33 %), while the minimum was recorded at Nauni (5.00 %, 4.33 % and 3.00 %). In Sirmour, the highest incidence was reported at Lana Cheta (40.00 %, 45.00 % and 47.00 %) for all three seasons, whereas the lowest was recorded at Mohar (9.00 %, 7.00 % and 2.00 %). In Kullu district, Ropa had the highest incidence (12.33 %, 11.33 % and 10.00 %), while Bhunter showed the lowest (4.33 %, 6.00 % and 5.33 %) throughout the study period.

Regarding the incidence of white rot in the Solan district, the highest incidence was recorded at Kalod (10.00 % and 7.33 %) in 2019 and 2020, respectively. In the season 2021, the maximum incidence (8.00 %) was observed at location Jauna Ji. The minimum incidence was recorded at Nauni and Bania Devi (2.00 %) in 2019, at Nauni (1.33 %) in 2020 and again Nauni and Bania Devi (2.00 %) in 2021. In Sirmour, the highest incidence was observed at Lana Cheta, with values of 42.00 %, 40.00 % and 35.00 % in 2019, 2020 and 2021, respectively, while the minimum incidence was recorded at Mohar (10.00 %, 1.33 % and 1.00 %) during the same years. In Kullu, the highest incidence was recorded at Bajaura (5.33 %, 4.00 % and 3.33 %) in 2019, 2020 and 2021, respectively. The lowest incidence was observed at Bhunter during 2019 and 2020 (1.00 % and 1.33 %), while, in 2021 it was recorded at Hurla and Naul (2.00 % each).

Regarding the incidence of blue mould rot in Solan district, the highest incident was recorded at Kandaghat (4.75 %, 4.17 % and 4.53 %) in 2019, 2020 and 2021, respectively.

Table 1. Incidence of major soil-borne diseases in garlic growing areas of Solan, Sirmaur and Kullu districts of Himachal Pradesh

District	Locations	Incidence of major soil borne diseases (%)									
		Year									
		2019			2020			2021			Overall mean
		Basal rot	White rot	Blue mould rot	Basal rot	White rot	Blue mould rot	Basal rot	White rot	Blue mould rot	
	Nauni	5.00	2.00	0.66	4.33	1.33	0.20	3.00	2.00	0.50	2.11
	Rangah	7.33	8.33	0.40	6.00	6.00	0.37	4.33	5.00	0.85	4.30
	Kalod	11.00	10.00	2.00	10.33	7.33	3.75	8.00	6.33	4.00	6.97
	Oachghat	8.00	5.33	1.33	6.33	5.00	2.00	5.00	4.33	1.25	4.28
	Anu	6.00	4.00	2.25	5.00	3.33	1.67	6.33	3.00	2.62	3.80
Solan	Deothi	9.00	6.00	1.97	7.33	4.00	3.75	8.00	2.33	3.67	5.12
	Bania Devi	12.00	2.00	0.96	10.33	3.00	1.20	9.33	2.00	1.42	4.69
	Anji	8.33	3.33	1.61	9.00	2.00	1.25	7.00	4.00	2.11	4.29
	Jauna Ji	12.00	2.33	1.00	10.33	4.00	2.62	12.00	8.00	3.33	6.18
	Kandaghat	14.33	6.33	4.75	12.00	5.00	4.17	15.33	7.00	4.53	8.16
	Mean	9.30	4.97	1.69	8.10	4.10	2.09	7.83	4.40	2.43	4.99
	Lana Cheta	40.00	42.00	8.33	45.00	40.00	5.00	47.00	35.00	7.31	29.96
	Lana Palar	34.00	35.33	6.67	36.00	34.00	5.43	41.00	30.00	7.69	25.57
	Kathali Bharan	33.67	35.67	7.36	32.33	37.00	9.50	38.00	32.00	11.25	26.31
	Daberghat	31.33	32.67	8.75	29.00	30.00	9.17	35.00	28.00	10.71	23.85
	Naura Dhar	36.00	38.00	12.00	38.00	32.00	11.42	33.00	26.00	13.33	26.64
	Chokar	35.33	36.67	10.34	37.00	29.00	9.85	31.00	22.00	10.40	24.62
Sirmour	Kaintha	33.00	35.00	6.67	30.00	26.00	5.93	23.00	25.00	4.81	21.04
	Narag	16.00	18.67	12.31	14.00	8.00	4.12	9.00	7.00	3.69	10.31
	Shoti	13.67	15.99	5.88	12.00	6.00	3.16	11.00	6.33	3.60	8.62
	Thanni	12.00	13.33	4.24	10.00	4.33	3.87	6.33	5.00	3.56	6.96
	Ghaloot	10.33	12.00	7.69	11.33	3.00	1.15	4.00	3.33	2.62	6.16
	Mohar	9.00	10.00	4.00	7.00	1.33	3.33	2.00	1.00	3.00	4.52
	Mean	25.36	27.11	7.85	25.14	20.89	6.00	23.36	18.39	6.83	17.88
	Bajaura	10.00	5.33	3.00	12.00	4.00	2.81	14.00	3.33	2.24	6.30
	Ropa	12.33	4.00	2.75	11.33	3.33	2.34	10.00	3.00	2.58	5.74
	Naul	8.00	3.00	2.36	9.33	2.33	1.39	8.00	2.00	1.49	4.21
	Kalheli	6.33	2.00	1.58	8.00	2.00	1.15	7.33	3.00	2.11	3.72
	Saujain	5.00	2.33	1.67	7.33	3.00	2.62	6.00	2.50	1.33	3.53
Kullu	Badah	9.33	3.33	2.18	11.00	2.33	1.97	11.33	3.00	2.35	5.20
	Jhiri	7.00	2.00	0.66	8.33	2.00	0.37	7.00	2.33	1.61	3.48
	Jarar	8.33	2.33	1.00	9.00	2.00	1.25	8.33	3.00	2.33	4.17
	Hurla	5.00	2.00	0.96	7.00	2.33	1.20	6.33	2.00	0.85	3.07
	Bhunter	4.33	1.00	0.20	6.00	1.33	0.50	5.33	2.50	1.42	2.51
	Mean	7.56	2.73	1.64	8.93	2.47	1.56	8.37	2.67	1.83	4.19
Overall mean		14.71	12.48	3.96	14.68	9.82	3.38	13.76	9.05	3.87	9.52

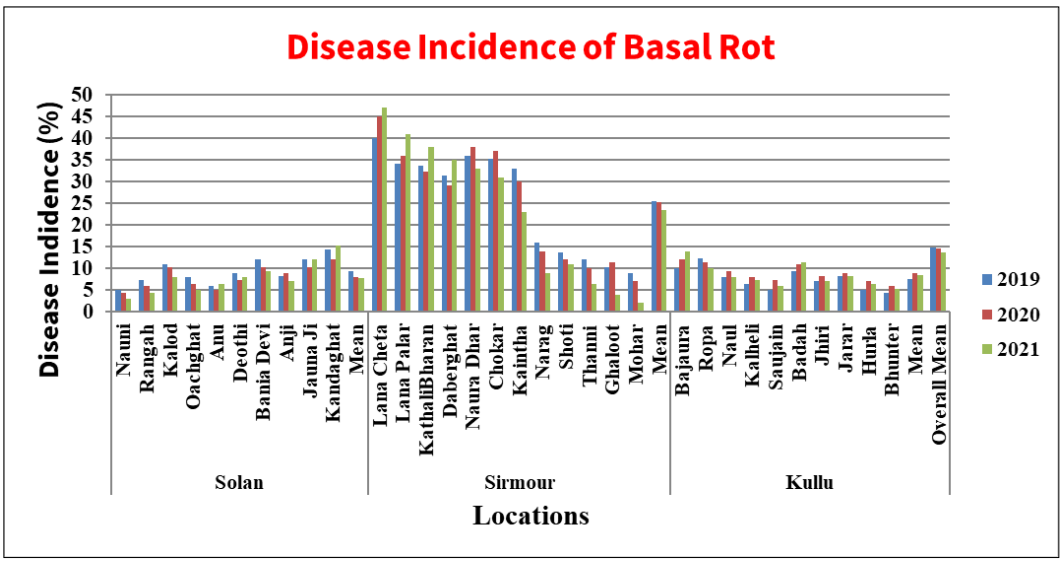

Fig. 1. Disease incidence of basal rot.

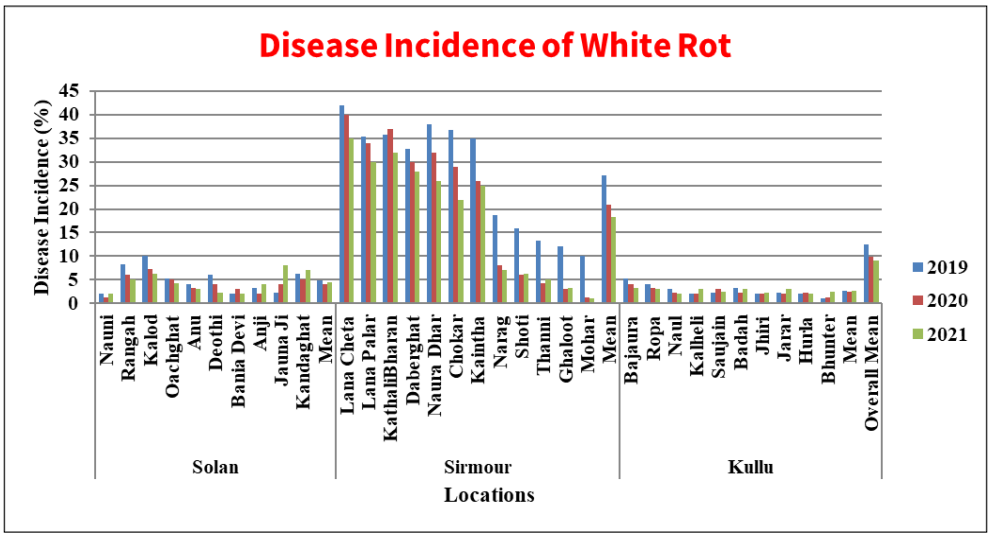

Fig. 2. Disease incidence of white rot.

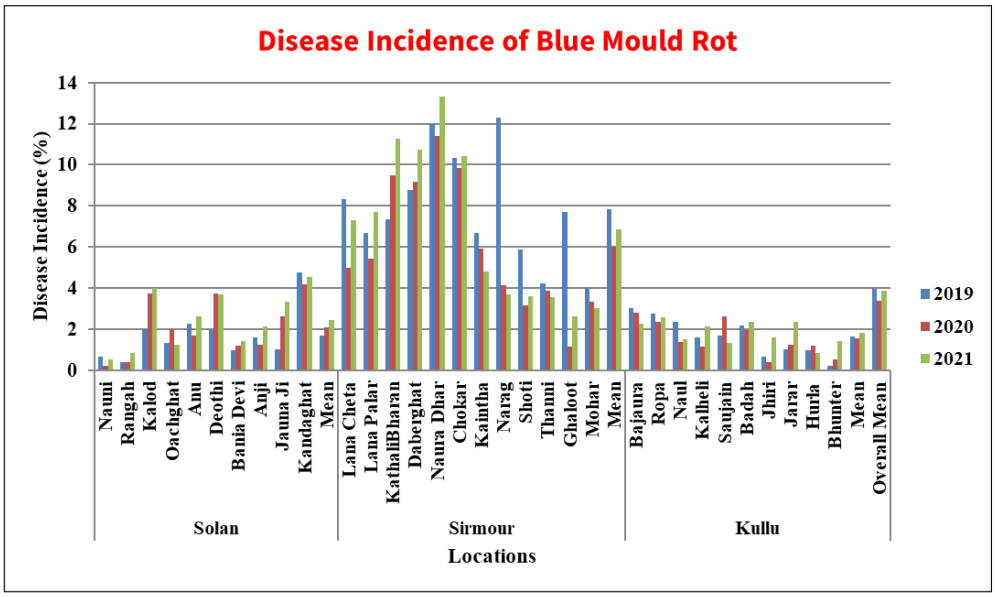

Fig. 3. Disease incidence of blue mould rot**.**

The lowest incidence was found at Rangah (0.40 %) in 2019 and at Nauni (0.20 % and 0.50 %) in 2020 and 2021, respectively. In Sirmour, the highest incidence was found at Narag (12.31 %) in 2019 and at Naura Dhar (11.42 % and 13.33 %) in 2020 and 2021, respectively. The lowest incidence was found at Mohar (4.00 %) in 2019 and at Ghaloot (1.15 % and 2.62 %) in 2020 and 2021, respectively. In Kullu district, the highest incidence was observed at Bajaura (3.00 % and 2.81 %) in 2019 and 2020 and at Ropa (2.58 %) in 2021. The lowest incidence was found at Bhunter (0.20 %) during 2019, at Jhiri (0.37 %) in 2020 and in at Hurla (0.85 %) 2021.

Irrespective of all the districts namely, Solan, Sirmour and Kullu, the maximum disease incidence was recorded at Lanacheta village in Sirmour district (29.96 %), while the minimum was observed at Nauni village in Solan district (2.11 %). Similarly, across all three years (2019, 2020 and 2021), the highest overall disease incidence was reported in 2019 (14.71 %) and the lowest in 2020 (3.38 %) (Fig. 4).

These results are consistent with the findings, where white rot as a serious pathogen of garlic with maximum disease incidence of 27 % at Nauhradhar of district Sirmour, Himachal Pradesh (21). Basal rot is the most devastating disease of garlic, resulting in yield losses globally. Yield reductions of up to 50 % have been documented in susceptible cultivars (22-24). Field losses typically range from negligible to 40 % of garlic bulbs, with additional storage losses reaching up to 60 % in some cases. Using a bulb infection method, the incidence of basal rot has been shown to range from 20 % to 80 %, with the most severe damage occurring during storage (25-27).

Garlic and onion crops grown in fields infested with white rot may experience plant losses ranging from 20 % to 40 % (28). White rot is a major economic threat to garlic production worldwide, with reported yield losses from 1 % to 100 % (29). The disease usually begins in small, isolated patches with minimal impact in previously uninfested fields; however, plant losses typically increase significantly upon replanting. It is presumed that numerous sclerotia produced on decomposing plants in these localized areas gradually disseminate throughout the field and soil profile over subsequent years. Although *S. cepivorum* infects only *Allium* spp. and does not thrive as a saprophyte, the long-term persistence of this pathogen in the soil is attributed to the survival capacity of its sclerotia (11, 22).

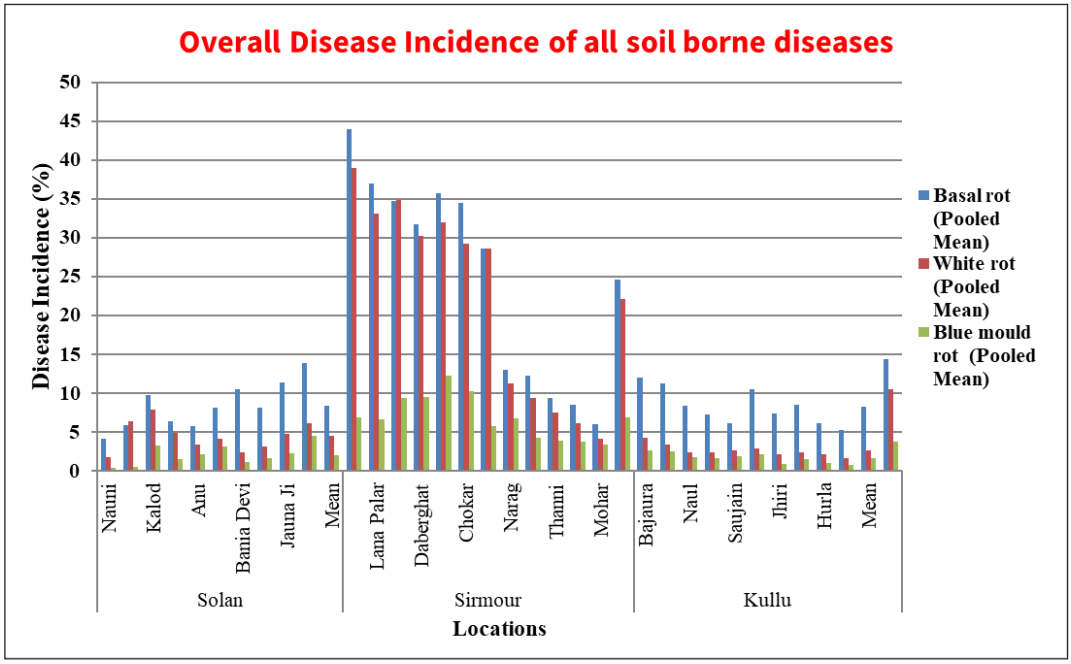

Fig. 4. Disease incidence of all soil borne diseases.

In onions, white rot reduces both quality and marketable bulb yield (30). Reported prevalence rates of white rot range from 37 % to 42 %, with associated yield reductions of 5 % to 50 %. Under favorable field conditions and with a high sclerotia load, the disease can result in crop loss (100 %). Blue mold rot has also been shown to significantly impact garlic production. In Argentina, it resulted in a 15 % reduction in the total harvest yield of red garlic due to pathogenic decay in the field (31).

Conclusion

It is concluded from the present study that the soil-borne diseases of garlic, basal rot, white rot and blue mould rot, were prevalent in all three districts of Himachal Pradesh, namely, Solan, Sirmour and Kullu. Among these, basal rot recorded the highest disease incidence, particularly in Sirmour district, followed by white rot and blue mould rot in Solan and Kullu districts, respectively. Therefore, it is recommended that management strategies for these soil-borne diseases be implemented to enhance garlic production and, consequently, improve farmers' income.

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Authors' contributions

AK led the writing of the original draft, developed the methodology, performed formal analysis and investigation, contributed to data curation and visualization and secured funding for the study. MG conceptualized the research, provided supervision, contributed to data curation and participated in reviewing and editing the manuscript. SKS co-drafted the manuscript, contributed to methodology and visualization and assisted in data curation and editing. AS contributed to the conceptual framework, supported methodology development and involved in data curation. SD participated in data collection and actively involved in the experimental investigation. All authors have read and approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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