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Research Article

GEOSPATIAL MAPPING AND DISTRIBUTION ANALYSIS OF COMMON SCAB DISEASE IN CORE POTATO-GROWING DISTRICTS OF PUNJAB, PAKISTAN

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ABSTRACT

Among vegetables, potato is the only crop that serves as a staple food for millions of people worldwide due to its rich nutritional profile. However, the sustainable production of potatoes is significantly challenged by various pathogens and pests. Among major viral, fungal, and bacterial diseases, common scab has emerged as a primary concern for potato crops. *Streptomyces scabies*, a phytopathogenic species of the *Streptomyces* genus, is considered the key pathogen in alkaline soils of Pakistan. There is a lack of reliable information regarding the incidence of common scab and the scab index in potato-growing areas of Punjab. To address this, a survey was conducted across four major districts to assess disease incidence, severity, and establish baseline data. A total of 110 locations were surveyed, of which 73 were found to be scab-infected. In Sahiwal, the scab index ranged from 10% to 52.5%; in Okara, from 10.25% to 55.8%; in Kasur, from 10% to 47.81%; and in Pakpattan, from 11.66% to a maximum of 46.6%. The highest disease severity was observed in Okara, while the lowest was recorded in Kasur. The relatively lower scab index compared to previous studies may be attributed to various management strategies implemented at farms during the crop season. This survey provides policymakers with critical data to develop effective strategies for combating common scab in the future.

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INTRODUCTION

Potato is one of the most widely produced and consumed vegetable crops worldwide. Although originally from Peru, the diverse soil and climate conditions in Pakistan make it possible to harvest three potato crops, autumn, spring, and summer, each year (Zaheer and Akhtar, 2016). Potatoes are recognized as a staple food in many countries due to their rich nutritional profile, including proteins, carbohydrates, vitamins, minerals, fiber, and energy (Enciso-Rodriguez et al., 2018).

Despite its importance for food security and market value, the potato crop is highly vulnerable to various diseases. These include viral infections such as potato leafroll virus (PLRV), PVX, and PVY; fungal diseases such as black scurf, late blight, early blight, dry rot, Fusarium wilt, and powdery scab; and bacterial diseases such as bacterial wilt, ring rot, soft rot, and common scab (Campos and Ortiz, 2020; Nisa et al., 2022).

Common scab, in particular, is an economically significant disease characterized by cracks on the surface of potato tubers, which can manifest as superficial, raised, or deep-pitted lesions (Kers et al., 2005; Loria et al., 2008). These symptoms result from the interaction between the potato and various phytotoxins, including thaxtomin, coronafacoyl, rotihibin, and concanamycin, which are produced by pathogens and naturally occurring non-ribosomal peptides (Haq et al., 2023). In Tasmania, Australia, common scab has caused significant losses, amounting to 3.66 million Australian dollars, representing a 4% loss to the potato industry (Wilson, 2004).

Common scab is primarily caused by various species of the genus *Streptomyces*, with *Streptomyces scabies* being the most prevalent pathogen. The key developmental stages of *S. scabies* include spore germination and mycelial growth for nutrient absorption. This actinobacterium can develop aerial hyphae that produce numerous spores, even under various nutritional and environmental stresses. *Streptomyces* spp. can have both beneficial effects, such as biocontrol of plant pathogens and biofertilization, or negative impacts, such as causing common scab (Haq et al., 2023). Pathogenic *Streptomyces* spp. spores can be transmitted through seeds, soil, and water to previously unaffected areas (Jansky et al., 2018).

In Pakistan, common scab was initially considered a minor issue. However, it has recently emerged as a major potato disease, with its severity and incidence increasing over time. Sarwar et al. (2016) were the first to report *S. turgidiscabiei* and *S. stelliscabiei* as causal agents of potato common scab in district Lahore, Punjab, Pakistan. Another study later identified *S. scabies* as the pathogen responsible for potato common scab in Punjab, Pakistan (Sarwar et al., 2017). However, there is a lack of information regarding the spread of the disease in other potato-growing areas of Punjab, as existing literature does not provide data on its incidence and severity. Therefore, a comprehensive survey was conducted to obtain real-time data on the occurrence and severity of common scab in the core potato-growing regions of Punjab, Pakistan. This information will be instrumental in developing effective disease management strategies in the future.

MATERIALS AND METHODS

Survey

The survey was conducted at the time of potato harvest during the 2022-23 season in the core districts of Punjab, Pakistan, including Sahiwal, Pakpattan, Okara, and Kasur. Potato fields with a multi-year history of potato cultivation were randomly selected. Tuber samples were also collected randomly.

To prepare a representative sample, four subsamples were taken from a single potato field. Each subsample consisted of five potato tubers, making a total of 20 tubers per representative sample. All 20 tubers were subjected to scab indexing, and the average scab index was calculated for each representative sample. Each sample was labeled according to its respective district and geographical coordinates.

Scab indexing

The scab index was measured according to Bjor and Roer (1980). The measurement was based on two scales: Scale A and Scale B.

Table 3.1. Scoring scales for potato common scab index.

Scale A	%age surface area covered
1	0-10%
2	10-25%
3	25-50%
4	50-75%
5	75-100%
Scale B	Lesion type
1	Superficial scab
2	Medium deep or raised scab
3	Deep scab

Scab index (SI) was calculated by using the following equation:

$$SI = \frac{\%\ \text{age surface area covered}}{15} \times \text{lesion type} \times 100$$

RESULTS

The survey was conducted in four major potato-growing districts of Punjab, and a total of 110 samples were tested to evaluate common scab disease. Lady Rosetta and Sante were identified as the most

prevalent potato cultivars in these core potato-growing districts. Moreover, Cardinal, Red Camel, Asterix, Kuroda, and Esmee were also among the cultivated potato varieties. Although all cultivars were susceptible to common scab infestation, Sante and Red Camel exhibited the highest levels of infestation. The geographical locations of the collected samples are presented in Figure 1.

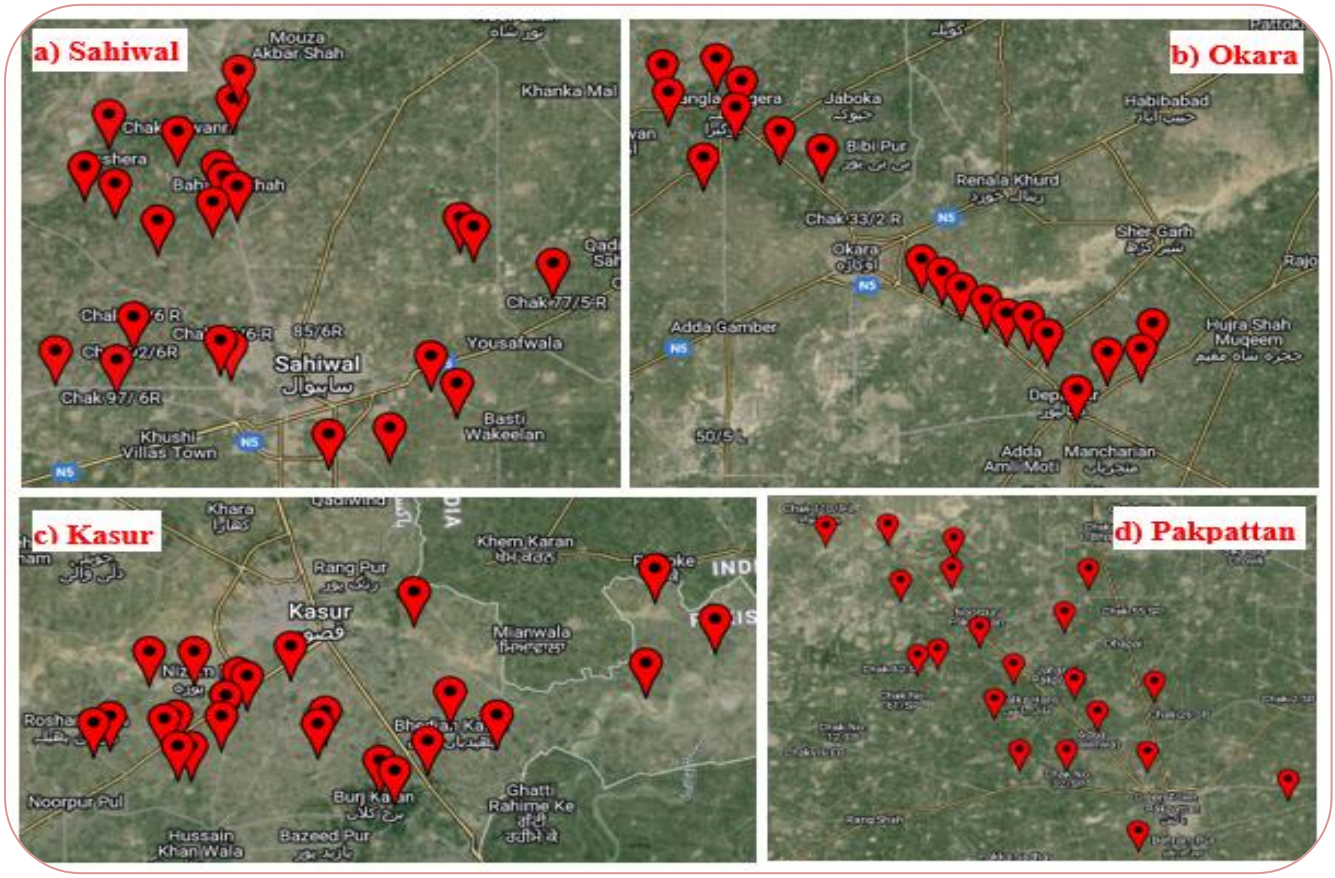

Figure 1. Geo-coordinates of samples collected from district Sahiwal, Okara, Pakpattan and Kasur.

District Sahiwal

In Sahiwal, 30 samples were tested for common scab infestation (Table 2). Of these, 21 samples tested positive, resulting in a disease incidence rate of 70% (Figure 2). Among the positive samples, the scab index ranged from a minimum of 10% to a maximum of 52.5%.

District Okara

In Okara, 28 samples were tested for common scab infestation (Table 3). Among them, 20 samples tested positive, leading to a disease incidence rate of 71.42%. The scab index in positive samples varied from 10.25% to 55.8%.

District Kasur

In Kasur, 23 samples were tested for common scab infestation (Table 4). Of these, 15 samples were positive, corresponding to a disease incidence rate of 65.21%. The scab index in positive samples ranged from 10% to 47.81%.

District Pakpattan

In Pakpattan, 29 samples were tested for common scab infestation (Table 5). Among them, 17 samples tested positive, resulting in a disease incidence rate of 58.62%. The scab index in positive samples ranged from 11.66% to 46.6%.

DISCUSSION

Common scab of potato has emerged as a major constraint to potato production and marketability. A survey was conducted in four districts of Punjab, which are considered the core potato-growing region of Pakistan. The objective was to establish baseline information on the incidence and severity of common scab in key potato-growing areas. This extensive survey covered four districts and 110 locations, with

recorded geographical coordinates. The highest disease incidence (71.42%) was observed in Okara district, followed by Sahiwal district (70%). The survey findings recorded a lower scab index (55.8%) compared to the previously reported disease index of 83% (Nisa et al., 2022).

Table 2. Prevalence of potato common scab in district Sahiwal.

Sample No.	Locality	Geo-coordinates	Scab Symptoms	Scab Index
SL-1	Aurangabad	30.79580, 73.07232	+ve	15%
SL-2	Aurangabad	30.79524, 73.07215	-ve	-
SL-3	Kitho Kae	30.78121, 73.07349	+ve	22.5%
SL-4	Kitho Kae	30.78086, 73.07381	-ve	-
SL-5	Bajwa Agri Farm	30.76550, 73.07043	+ve	20%
SL-6	58/GD	30.74464, 73.07228	+ve	33.3%
SL-7	Choukhandi	30.74429, 73.07221	+ve	41.6%
SL-8	59/GD	30.73344, 73.06953	+ve	26.25%
SL-9	Moza Bashera	30.77002, 73.01973	+ve	29.16%
SL-10	Abadi Wasiram	30.71453, 73.05813	-ve	-
SL-11	Abadi Wasiram	30.71453, 73.05809	+ve	30.4%
SL-12	66/GD	30.70511, 73.04766	+ve	19.29%
SL-13	Chak Chalanwali	30.70509, 73.04761	-ve	-
SL-14	Akbar Chowk Bypass	30.69488, 73.03784	+ve	31.7%
SL-15	Akbar Chowk Bypass	30.69486, 73.03783	-ve	-
SL-16	92/6R	30.97436, 73.03612	+ve	45.8%
SL-17	94/6R	30.66174, 73.04450	+ve	28.5%
SL-18	94/6R	30.66194, 73.06178	-ve	-
SL-19	97/6R	30.65551, 73.02084	+ve	27.33%
SL-20	Adda Boti Pal	30.66395, 73.99357	+ve	**$^{\alpha}$52.5%**
SL-21	97/9L	30.59366, 73.13590	+ve	27.23%
SL-22	92/9L	30.63798, 73.12166	+ve	17.82%
SL-23	87/9L	30.65813, 73.14027	-ve	-
SL-24	87/9L	30.65834, 73.13670	-ve	-
SL-25	PRI, 86/9L	30.67115, 73.16139	+ve	16.5%
SL-26	77/5R	30.68995, 73.19947	+ve	20.75%
SL-27	73/4R	30.71171, 73.19252	+ve	14.6%
SL-28	73/4R	30.72253, 73.19249	+ve	17.33%
SL-29	Admeer Chowk	30.77131, 73.19237	+ve	**$^{\beta}$10%**
SL-30	Admeer Chowk	30.79580, 73.07232	-ve	-

α = highest recorded scab index, **β** = lowest recorded scab index.

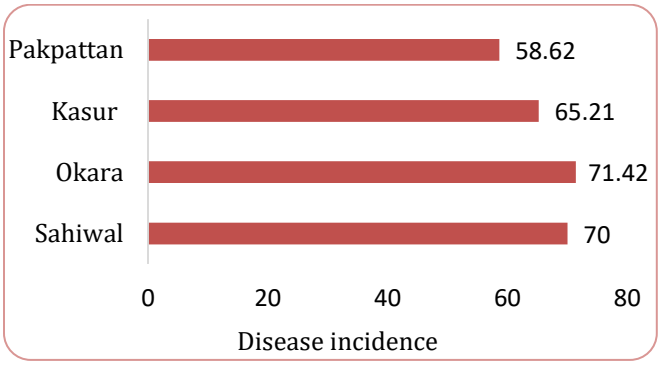

Figure 2. Scab Incidence of district Sahiwal, Okara, Pakpattan and Kasur.

Previously, Nisa et al. (2022) conducted a survey in the potato-growing regions of Punjab to assess the status of common scab. They surveyed 66 locations across nine districts and recorded the highest disease severity (62%) in Okara district and the highest disease index (83%) in Sahiwal district. A comparison of both surveys highlights two key points viz. the severity of common scab has increased compared to previous years, and variations in the disease index are likely influenced by interactions between the pathogen and climatic conditions, soil characteristics, crop management practices, and cropping patterns.

Table 3. Prevalence of potato common scab in district Okara.

Sample No.	Address	Geo-coordinates	Scab Symptoms	Scab Index
OK-1	Fatehpur	30.95176, 73.20810	+ve	$^{\beta}$ 10.25%
OK-2	Fatehpur	30.95243, 73.29228	-ve	-
OK-3	Gogera Khas	30.95377, 73.31090	+ve	27%
OK-4	Gogera Bangla	30.94596, 73.33542	-ve	-
OK-5	Nawan Kho	30.93745, 73.34550	+ve	20.8%
OK-6	Jhangpur	30.91592, 73.37150	+ve	48.7%
OK-7	Jhangpur	30.90771, 73.38142	+ve	35%
OK-8	24GD	30.89115, 73.40133	+ve	16.6%
OK-9	19GD	30.87221, 73.42442	+ve	35%
OK-10	49/2L	30.78012, 73.50897	-ve	-
OK-11	48/2L	30.76802, 73.53527	+ve	29.1%
OK-12	31/2L	30.75917, 73.54953	+ve	15%
OK-13	31/2L	30.74874, 73.57321	-ve	-
OK-14	40D	30.73875, 73.58535	+ve	26.66%
OK-15	39D	30.72619, 73.60038	+ve	10.75%
OK-16	39D	30.72619, 73.60038	-ve	-
OK-17	38D	30.71711, 73.61115	-ve	-
OK-18	Chorasta	30.70938, 73.62035	+ve	11.66%
OK-19	Sobaram	30.69248, 73.63931	+ve	18.4%
OK-20	Sobaram	30.69248, 73.63931	-ve	-
OK-21	Gujjar Chowk, Havelilakhah Bypass	30.69237, 73.64760	-ve	-
OK-22	Mirbaz	30.68167, 73.66837	+ve	32.3%
OK-23	Mir Amanullah	30.67965, 73.67589	+ve	28.9%
OK-24	Fareed Kot	30.67960, 73.67591	+ve	47%
OK-25	Fareed Kot	30.69341, 73.69759	+ve	$^{\alpha}$ 55.8%
OK-26	Muzharabad	30.69802, 73.70703	+ve	27.5%
OK-27	Sahlowal	30.70029, 73.71141	+ve	19.35%
OK-28	Sahlowal	30.71215, 73.73463	+ve	16.33%

α = highest recorded scab index, **β** = lowest recorded scab index.

Table 4. Prevalence of potato common scab in district Kasur.

Sample No.	Address	Geo-coordinates	Scab Symptoms	Scab Index
KR-1	Sehjra	31.12613, 74.61788	+ve	32%
KR-2	Dhupsari	31.10555, 74.64466	-ve	-
KR-3	Chanda Singh Wala	31.08328, 74.61548	+ve	27%
KR-4	Bhedian Kalan	31.06637, 74.52810	-ve	-
KR-5	Mahlem Kalan	31.05211, 74.54973	+ve	17.5%
KR-6	Burj Kalan	31.03402, 74.49720	+ve	**$^{\beta}$ 10%**
KR-7	Burj Kalan	31.03431, 74.49188	+ve	22.9%
KR-8	Basti Pir Shah	31.05005, 74.46768	+ve	36.6%
KR-9	Tullo wala	31.08137, 74.43523	+ve	20%
KR-10	Tullo wala	31.08108, 74.43644	-ve	-
KR-11	Nizampura	31.08475, 74.41463	+ve	54%
KR-12	Bahadur pura	31.06579, 74.40073	+ve	17.5%
KR-13	Bhalla	31.08652, 74.39301	-ve	-
KR-14	Patto Kalan	31.10842, 74.50750	+ve	20.4%
KR-15	Rohiwal	31.09089, 74.52929	+ve	22.5%
KR-16	Sheikh Umad Kuhna	31.06461, 74.42648	-ve	-
KR-17	Kotla Sheikh Natha	31.05299, 74.42768	-ve	-
KR-18	Shamaspura	31.05270, 74.39970	+ve	16.6%
KR-19	Bhuchke	31.03520, 74.41069	+ve	**$^{\alpha}$ 47.81%**
KR-20	Bhuchke	31.03932, 74.40777	-ve	-
KR-21	Dollay Wala	31.08490, 74.45532	-ve	-
KR-22	Bahmaniwala	31.06138, 74.47197	+ve	35.7%
KR-23	Ganda Singh Wala	31.03799, 74.52158	+ve	18.33%

α = highest recorded scab index, **β** = lowest recorded scab index.

Table 5. Prevalence of potato common scab in district Pakpattan.

Sample No.	Address	Geo-coordinates	Scab Symptoms	Scab Index
PK-1	79/D	30.54199, 73.19065	+ve	20.41%
PK-2	82/D	30.52385, 73.20813	-ve	-
PK-3	83/D	30.51945, 73.21096	-ve	-
PK-4	83/D	30.51945, 73.21096	+ve	15%
PK-5	79/D	30.51278, 73.21169	+ve	17.5%
PK-6	77/D	30.49632, 73.23228	-ve	-
PK-7	Hanan Khan Farm, Sahiwal road	30.48125, 73.24679	+ve	16.6%
PK-8	59/SP	30.47747, 73.25314	-ve	-
PK-9	Taik Chand	30.47049, 73.25957	+ve	**ᵝ 10%**
PK-10	58/SP	30.46126, 73.26830	+ve	33.75%
PK-11	58/SP	30.46126, 73.26830	-ve	-
PK-12	Baba Fareed Cold Store Haripur	30.45722, 73.27263	+ve	15%
PK-13	Malka Hans	30.43363, 73.29796	+ve	14.5%
PK-14	29/SP	30.39482, 73.33396	-ve	-
PK-15	Loharan wali Khoei	30.38137, 73.34956	+ve	15%
PK-16	36/SP	30.38412, 73.34694	+ve	11.66%
PK-17	30/SP	30.39234, 73.33954	-ve	-
PK-18	Gujjar Agri Farm	30.41855, 73.31339	-ve	-
PK-19	Chak Bhaiwal	30.42341, 73.30475	+ve	**ᵅ 46.6%**
PK-20	Adda Malka Hans	30.43412, 73.29125	+ve	11.66%
PK-21	Abadi Malka Hans	30.42582, 73.28724	-ve	-
PK-22	Noor Jang	30.44261, 73.28840	+ve	23.33%
PK-23	Gulshan Nagar	30.45382, 73.27604	+ve	11.66%
PK-24	Mufti Farm	30.45822, 73.27022	+ve	26.66%
PK-25	Kot Hukam Singh	30.46515, 73.26384	+ve	10.75%
PK-26	Kot Khoo Wala	30.47148, 73.23499	-ve	-
PK-27	Kot Khoo Wala	30.47148, 73.23499	+ve	39%
PK-28	84/D	30.50194, 73.22660	-ve	-
PK-29	84/D	30.54199, 73.19065	-ve	-

α = highest recorded scab index, **β** = lowest recorded scab index.

Crop management practices included irrigation frequency and quantity, soil fumigation, soil amendments such as sulfur, gypsum, green manuring, compost, and organic amendments, as well as crop rotation and mono/multi-cropping. Other factors involved the presence of antagonistic bacteria in the rhizosphere (Dees and Wanner, 2012; Braun et al., 2017). One of the key factors contributing to a low disease index is the host's immunity to disease-causing microorganisms (Haynes et al., 2010). Atiq et al. (2013) demonstrated in their study that different potato varieties exhibited varying responses to common scab infestation, with some varieties being susceptible while a few showed moderate resistance. Therefore, the widespread cultivation of moderately resistant cultivars, such as Lady Rosetta, can be associated with a lower scab index compared to previous surveys.

Plant disease incidence depends on the interaction between the pathogen, a susceptible host plant, and spatio-temporal environmental factors such as temperature range, relative humidity, soil moisture, soil pH, and soil microbial activity (Wanner et al., 2014). Similar findings have been reported regarding the occurrence and severity of common scab in different regions, which were influenced by the cropping system, soil moisture, soil texture, and soil pH (Keinath and Loria, 1991; Ruan et al., 2004; Rosenzweig et al., 2012).

A study on the identification of *Streptomyces* spp. revealed that the key species responsible for common scab disease in Pakistan is *S. scabies*, as Pakistani soils typically have an alkaline pH (>7.0). In contrast, *S. acidiscabies* and *S. griseoflavus* showed minimal infestation, as their favorable soil conditions are acidic (pH <7.0) (Ismail et al., 2020). The incidence of common

scab decreases with lower soil pH; when the soil pH drops below 5.2, phytopathogenic *Streptomyces* spp. are unable to cause disease symptoms (Hussain et al., 2017). The management of potato common scab through soil condition adjustments includes lowering soil pH, maintaining high soil moisture for 6 to 8 weeks after tuber initiation, practicing crop rotation with non-susceptible hosts, incorporating green manure, and using tolerant potato cultivars (Braun et al., 2017; Lankau et al., 2017). This highlights the significant role of soil pH in influencing disease incidence and severity.

Seed source is also a key factor in determining disease incidence and severity. Studies focusing on infected seed sources have shown that the incidence of common scab disease increases when infected seed tubers are used for cultivation (Santos-Cervantes et al., 2017). The use of *in vitro* developed mini-tubers as a seed source contributes to a lower disease incidence due to better morphophysiological and biochemical potential/performance (Rehman et al., 2019). Recently, a Korean agency developed infrastructure for potato seed production using aeroponics technology in Pakistan (Dogar et al., 2023). The availability of seed, ensured by aeroponics technology, can also be considered a significant factor in the lower scab index.

Integrated Disease Management (IDM) encompasses a range of practices, beginning with sustainable solutions such as mechanical and biological control, and concluding with the application of chemical pesticides as a last resort. These practices aim to manage both disease severity and incidence. Recently, an IDM-based strategy was implemented to control common scab in potatoes (Kumar et al., 2024). All these factors, whether individually or collectively, contribute to the final determination of disease incidence and scab index levels.

CONCLUSION

It is evident from the present study that disease incidence levels in the core potato-growing districts have increased significantly compared to previous years. Several factors, such as the use of spore-contaminated seeds and the movement of irrigation water from infected to healthy fields, could be responsible for the high disease incidence levels. However, in terms of disease severity, several management protocols have contributed to a lower scab index. One of the major factors was the widespread cultivation of moderately resistant varieties and the availability of disease-free seed, either from tissue culture or aeroponics. Furthermore, the development of deep pits on potato tubers highlights a serious concern regarding the control of common scab before it becomes a major threat. Thus, IDM strategies are urgently needed to contain common scab.

AUTHORS' CONTRIBUTION

MA and MS designed and supervised the study; IUH, GF and MAUH conducted surveys and recorded the data; FM, MZN and ZM compiled and organized the data; all the authors contribute equally to manuscript write up, formatting and proofread.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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