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Status, Distribution and Pathogen Associated with Storage Rot of Garlic in Himachal Pradesh

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Abstract

A field and laboratory survey was conducted in January 2023 to assess the incidence and aetiology of garlic storage rot in nine major garlic-producing districts of Himachal Pradesh. Garlic bulbs representing both local and improved cultivars were collected from 3 to 6 sites per district for evaluation. Results indicated that storage rot incidence was considerably higher in local cultivars (29.76%) compared to improved cultivars (14.35%), suggesting their greater susceptibility. The highest disease incidence was recorded in Kangra (44.00% local; 27.67% improved) and Bilaspur (45.33% local), while the lowest was observed in Lahaul-Spiti (9.08% local; 4.50% improved) and Kinnaur (18.09% local; 6.67% improved), reflecting a possible influence of altitude and environmental conditions. Pathogen isolation from 25 bulbs per district revealed Fusarium as predominant (46.55%), with the highest isolation in Kinnaur (66.66%), Mandi (55.55%), and Kangra (52.17%). The study emphasises *Fusarium* dominance, varietal susceptibility and environmental influence in garlic storage rot.

Keywords: Fusarium, Garlic, Fungal pathogens, Himachal Pradesh, Storage

Garlic (*Allium sativum* L.) is commonly referred to as "Laba" in Newari and "Lehsun" in Nepali and is grown in almost all parts of the world. Garlic is widely used as both a food ingredient and a medicinal plant across the globe. Garlic is an essential ingredient in kitchens worldwide, with global production of 28.67 million tonnes, with India contributing 3.26 million tonnes. Madhya Pradesh is the leading producer in India (Anonymous 2024). In Himachal Pradesh, garlic is grown across an area of 354 thousand hectares, producing 2.836 million tonnes, with major production concentrated in the districts of Sirmaur, Kullu, and Solan, with Sirmaur being the leading district (NHB 2018-19).

In Himachal Pradesh, garlic is planted in October-November in the low hills. In the mid-hills is planted early in September-October, and in the hills, it is planted during April. Despite garlic's numerous benefits, its storage remains a significant challenge. Garlic is highly susceptible to deterioration during storage, especially when kept for extended periods, typically 9-10 months, resulting in a loss of both culinary and health qualities (Ludlow *et al.* 2021), besides a reduction in shelf-life during storage due to rotting, sprouting and drying (Sharma *et al.* 2010). One of the major issues in garlic cultivation and trade worldwide is the difficulty in maintaining its quality during long-term storage. Among the most detrimental factors are fungal diseases that impact garlic during harvesting, post-harvesting, processing and marketing, ultimately affecting the quality and export potential of the crop. Regional surveys in Himachal Pradesh have documented several foliar and bulb pathogens of Alliums, including *Alternaria* and *Stemphylium* sp. This underlines the local prevalence of these fungal pathogens (Katoch and Kumar 2016).

Garlic is particularly vulnerable to fungal pathogens such as *Fusarium oxysporum* (causing dry rot).

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Common storage rot pathogens include *Sclerotium cepivorum* (white rot), *Aspergillus niger* (black mold), *Penicillium hirsutum* (blue mold rot), *Botrytis allii* (neck rot), and *Pyrenochaeta terrestre* (pink rot) (Mishra *et al.* 2013). These pathogens cause significant degradation during the storage phase, leading to softening, discolouration and unpleasant odours, which in turn degrade the marketable quality of the crop. Genotype screening in Himachal Pradesh also indicates that Allium genotypes differ in biotic stress responses, supporting our approach of comparing local vs improved cultivars in the present study (Parwan *et al.* 2025). Earlier studies on onion and garlic in Himachal Pradesh have shown that different genotypes respond differently to biotic stresses, such as resistance to *Thrips tabaci* (Thakur 2020). This supports our focus on comparing local and improved cultivars for their susceptibility to storage pathogens in the present study. Regional studies on seed and storage of garlic show that *Fusarium* spp. and other storage-associated fungi are important in this state's agro-ecosystems, providing local context for the predominance of *Fusarium.* (Sood *et al.* 2024).

MATERIALS AND METHODS

Diseased Samples

Survey on Incidence and Distribution of Storage Rot

A systematic survey was conducted during January 2023 to assess the incidence and distribution of garlic storage rot in nine major garlic-growing districts of Himachal Pradesh, namely Kangra, Una, Bilaspur, Hamirpur, Kullu, Mandi, Chamba, Solan, and Sirmaur. In each district, 3-6 representative locations were selected, and garlic bulbs were collected from farmer storage structures and local markets. Depending on availability, 100-300 bulbs per district were examined for rot symptoms such as discolouration, shrivelling, and fungal growth.

At each site, the sampled bulbs were categorised into local cultivars (traditional landraces) and improved cultivars (widely adopted hybrids). For each varietal group, 50 bulbs were examined in three independent replications, making a total of 150 bulbs per cultivar per site. The number of infected bulbs was recorded separately for local and improved cultivars, and the percentage incidence was calculated using the formula given by Wheeler (1969):

$$\text{Storage rot incidence} = \frac{\text{No. of garlic bulbs infected}}{\text{Total number of garlic bulbs inspected}} \times 100$$

District-level figures (total bulbs examined and infected) were obtained by pooling values from all sites within the district. The mean incidence values of local and improved cultivars across replicates were used for statistical comparison.

Isolation and Identification of Pathogens

To determine the dominance of pathogens associated with storage rot, 25 symptomatic bulbs per district were collected. For each district, isolations were performed in three replications to ensure reliability. Small fragments from infected cloves were surface-sterilised in 1% sodium hypochlorite for 2 min, rinsed thrice in sterile distilled water, and placed aseptically on Potato Dextrose Agar (PDA) (Gálvez and Palmero 2021). Plates were incubated at 25 ± 1°C for 5-7 days, and emerging colonies were purified using hyphal-tip or single-spore methods.

Identification of fungal species was based on cultural and morphological features, further verified using standard taxonomic keys (Barnett and Hunter 1972). The frequency of each pathogen (*Fusarium, Penicillium, Alternaria, Sclerotium* and *Aspergillus*) was calculated as the proportion of positive isolations from replicated samples.

Statistical Analysis

Analysis of Variance (ANOVA) was done as per the standard procedure given by Gomez and Gomez (1984) to explain the treatment differences.

RESULTS AND DISCUSSION

A comprehensive survey (Table 1) was conducted in January 2023 to assess the prevalence of garlic rot across nine major garlic-producing districts of Himachal Pradesh, *viz*., Kangra, Una, Bilaspur, Hamirpur, Kullu, Mandi, Chamba, Solan and Sirmaur (Figure 1). The overall mean incidence was notably higher in the local cultivars (29.76%) as compared to the improved cultivars (14.35%), which meant that improved cultivars

Table 1. Status and distribution of storage rot of garlic in Himachal Pradesh

Districts	No. of bulbs examined	No. of bulbs found infected	Locations	Coordinates		Local cultivar	Improved cultivar
				Latitude	Longitude		
Kangra	300	250	Palampur	32.1100°	76.5300°	44.00	40.00
			Malan	32.1570°	76.4270°	52.00	32.00
			Samloti	32.1556°	76.2527°	36.00	38.00
			Nagrota	32.0600°	76.2700°	76.00	10.00
			Bhawarna	32.0442°	76.4925°	66.00	18.00
			Jamanabad	32.1195°	76.2660°	60.00	28.00
Una	150	90	Haroli	31.4750°	76.1350°	44.00	16.00
			Gagret	31.6667°	76.1167°	50.00	10.00
			Bangana	31.5860°	76.3380°	36.00	24.00
Bilaspur	150	95	Berthin	31.4200°	76.7200°	48.00	16.00
			Ghumarwin	31.4370°	76.7130°	52.00	12.00
			Jhandutta	31.4540°	76.6500°	36.00	26.00
Hamirpur	250	100	Nadaun	31.7833°	76.3500°	33.87	6.45
			Bamsan	31.7830°	76.4830°	29.03	11.29
			Bhoranj	31.7000°	76.6500°	24.19	16.13
			Hamirpur	31.6842°	76.5213°	30.64	9.68
Kullu	250	90	Kullu	31.9578°	77.1095°	20.97	12.69
			Banjaar	31.6380°	77.3490°	22.58	14.52
			Bajaura	31.8700°	77.1350°	27.42	9.68
			Naggar	32.0610°	77.1280°	19.35	17.74
Mandi	200	75	Sundernagar	31.5333°	76.8833°	20.00	16.00
			Balh	31.6667°	76.9167°	18.00	18.00
			Chauntrah	31.8361°	76.7127°	22.00	14.00
			Padhar	31.4560°	76.7590°	26.00	16.00
Chamba	150	50	Chamba	32.5537°	76.1250°	18.00	14.00
			Battiyat	32.4960°	76.0900°	30.00	4.00
			Mehla	32.6050°	76.1250°	18.00	16.00
Solan	100	40	Solan	30.9070°	77.0970°	26.47	14.70
			Kandaghat	30.9716°	77.0918°	23.53	11.76
			Dharampur	30.9090°	76.9740°	35.29	5.88
Shimla	100	30	Nerwa	30.9550°	77.6390°	10.00	7.50
			Rampur	31.4500°	77.6300°	15.00	8.50
			Narkanda	31.2600°	77.4550°	24.04	8.27
Lahaul & Spiti	100	30	Kukumseri	32.6991°	76.6870°	9.08	4.50
Kinnaur	100	35	Chitkul	31.3508°	78.4366°	26.18	9.20
			Raksham	31.3923°	78.3538°	10.00	4.20
Sirmaur	100	30	Nahan	30.5599°	77.2955°	16.00	14.00
			Ponta Sahib	30.4367°	77.6246°	22.00	8.00
Mean						**29.76**	**14.35**
C.D ($_{P=0.05}$)						**2.563**	**1.391**

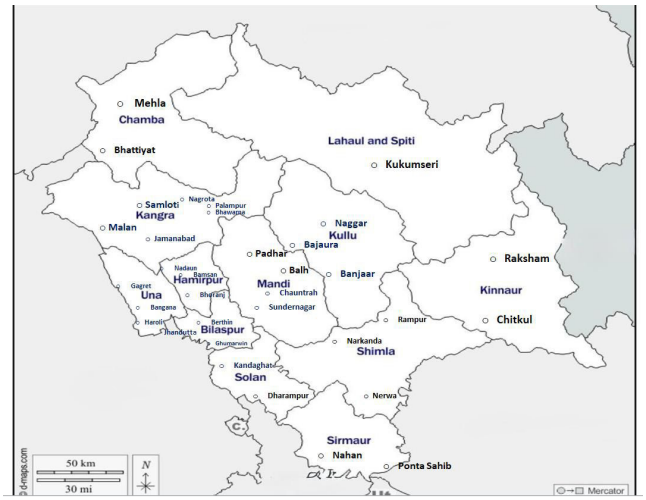


Figure 1. Mapping of garlic rot incidence across different districts of Himachal Pradesh

were more resistant to storage rot. Kangra recorded the highest incidence, as the mean values reached around 44.00 per cent in local varieties and 27.67 per cent in improved cultivars. Una and Bilaspur exhibited moderately high incidences (43.33% and 45.33% in local varieties, respectively), while Hamirpur, Kullu and Mandi showed lower infection rates (ranging between 20-23% in local varieties). The lowest incidences were observed in Lahaul-Spiti (9.08% in local and 4.50% in improved cultivars) and Kinnaur (18.09% in local and 6.67% in improved cultivars), which suggests that the higher altitudes with lower temperatures may provide less favourable conditions for disease development.

Local garlic cultivars showed significantly higher storage rot incidence compared to improved cultivars, which proves the relative resistance of the improved cultivars against storage rot pathogens. This observation is supported by earlier findings that cultivar resistance can influence the prevalence of *Fusarium* dry rot (Gálvez and Palmero 2021). Districts such as Kangra, Una and Bilaspur exhibited the highest rot incidences in local varieties, whereas Lahaul and Spiti and Kinnaur recorded the lowest rot incidences. This trend suggests that cooler places may restrict pathogen development. Similar patterns have been reported in studies on postharvest losses, where temperature and humidity during storage were shown to play a pivotal role in the severity of garlic rot (Llamas *et al.* 2013, Shagun *et al.* 2024).

The consistently lower incidence among improved cultivars across all surveyed districts indicates that breeding for resistance is an important means to combat post-harvest losses in garlic. The use of resistant cultivars has been widely recognised as an important basis of sustainable management strategies against Fusarium (Gálvez and Palmero 2021). High storage rot incidence observed in places with low to mid-rise elevation may reflect the higher temperatures prevalent in such areas, which ultimately leads to high humidity and more conducive conditions for the fungal infection to prolific in garlic bulbs during storage (Llamas *et al.* 2013). Another study conducted by Desta (2021) shows that high storage temperature and relative humidity favour garlic rot and decay, and that optimal conditions (-1 to 0°C with 60-70 % RH) can extend garlic storage life.

The highest *Fusarium* incidence was recorded in Kinnaur (66.66%) and Mandi (55.55%) followed by Kangra (52.17%), Lahaul-Spiti (50.00%), Sirmaur (48.14%), Chamba (48.00%), Shimla (44.44%), Solan (44.00%), Hamirpur (38.46%), Una (33.33%), and Bilaspur (32.85%) (Table 2, Figure 2). *Penicillium* emerged as the second most prevalent pathogen after *Fusarium,* particularly found in districts like Lahaul-Spiti (40.00%), Shimla (33.33%), Mandi (22.22%) and Solan (26.00%). *Alternaria* was isolated at lower frequencies across all districts, a maximum of 13.33 per cent in Una and ranging between 8 to 12 per cent elsewhere. *Sclerotium* was notably high in Shimla (22.22%), Kullu (22.50%) and Chamba (12.00%). *Aspergillus* exhibited the lowest incidence compared to all other fungi (Bilaspur 14.28%; Una 13.33%; Solan 10.00% and Kangra 6.52%).

These findings are consistent with earlier reports indicating *Fusarium proliferatum* and *F. oxysporum* as the major post-harvest pathogens of garlic worldwide, contributing significantly to storage losses. Postharvest losses of garlic bulbs due to *F. proliferatum* and related species have been estimated at approximately 56.11 per cent, with *F. proliferatum* found in over 85 per cent of symptomatic cloves (Gálvez and Palmero 2021), and infection levels rise from 11 to 32 per cent over six months of storage at 25 ± 5 °C in Egypt (Gasser *et al.* 2025). The high prevalence of *Fusarium* in districts like Kinnaur and Mandi may be attributed to cooler climatic conditions. Similar observations were reported by Gasser *et al.* (2025a), who recorded that hidden *Fusarium* infections in planting material often

Table 2. Dominance of the pathogen associated with storage rot of garlic in different districts of Himachal Pradesh

Districts	No. of bulbs examined	Storage rot incidence (%)				
		Fusarium	***Alternaria***	***Penicillium***	***Sclerotium***	***Aspergillus***
Kangra	25	52.17	10.86	21.74	8.69	6.52
Una	25	33.33	13.33	30.00	10.00	13.33
Bilaspur	25	32.85	8.57	32.85	11.42	14.28
Hamirpur	25	38.46	9.23	30.76	15.38	6.15
Kullu	25	45.00	10.00	22.50	22.50	-
Mandi	25	55.55	11.11	22.22	11.11	-
Chamba	25	48.00	12.00	28.00	12.00	-
Lahual Spiti	25	50.00	-	40.00	10.00	-
Solan	25	44.00	10.00	26.00	10.00	10.00
Shimla	25	44.44	-	33.33	22.22	-
Kinnaur	25	66.66	-	33.33	-	-
Sirmaur	25	48.14	7.40	25.92	11.11	7.40
Mean		**46.55**	**10.27**	**28.88**	**12.22**	**9.61**
C.D ($_{p=0.05}$)		**2.717**	**1.412**	**1.599**	**1.729**	**1.603**

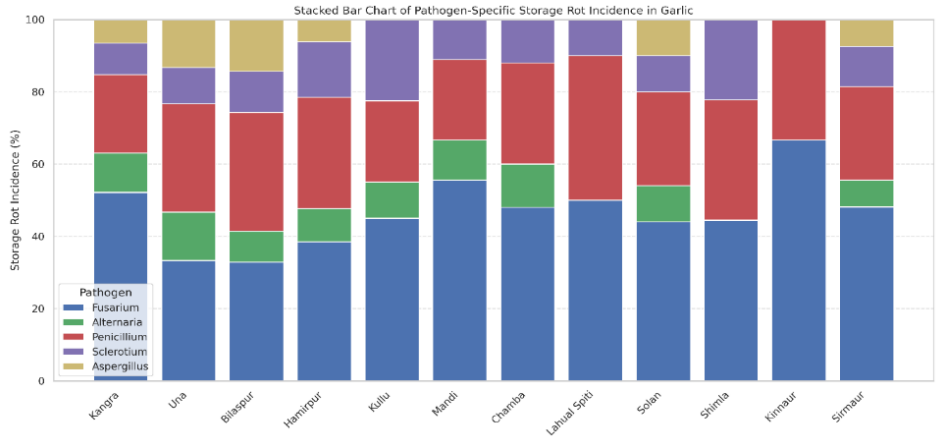


Figure 2. Stacked bar chart depicting the cumulative incidence (%) of fungal pathogens associated with garlic storage rot in different districts of Himachal Pradesh

led to high storage rot incidences. Sarpkaya (2025) further noted that *F. proliferatum* can cause postharvest losses exceeding 30 per cent in garlic under favourable conditions, supporting the trends observed in this study. *Penicillium* was found to be the second most frequent pathogen, but it was distributed in fewer districts as compared to *Fusarium*. This result agrees with the findings of Stošić *et al.* (2025), who identified several *Penicillium* species associated with blue mold rot in garlic as secondary pathogens. Lower incidence rates of *Alternaria*, *Sclerotium* and *Aspergillus* are indicative of these fungal genera being opportunistic pathogens which colonise garlic bulbs primarily when storage conditions, such as humidity, temperature conditions, align with mechanical damage to the bulbs and create a conducive environment for infection (Shagun *et al.* 2024).

CONCLUSION

There is a wide variability in storage rot incidence across districts and between crop varieties. The mean

storage rot incidence higher in local cultivars was higher than the improved cultivars, suggesting that improved cultivars offer more resistance. Among different districts, Kangra recorded the maximum rot incidence. At the same time, Lahaul and Spiti and Kinnaur recorded the least amount of rot incidence. The data indicated that storage rot was highest in mid and low hill areas, where climatic conditions (temperature and humidity) were more conducive for pathogen development. While areas at a higher altitude provided relatively unfavourable conditions and lower rot incidence. Across all districts, improved cultivars showed a lower incidence than local varieties. *F. oxysporum* was the most dominant pathogen. Its occurrence peaked in Kinnaur, followed by Mandi. *Penicillium* was the second most prevalent pathogen, while *Alternaria* and *Aspergillus* were sporadic in occurrence, and recorded at low frequencies mainly in Bilaspur, Una and Solan.

Conflict of interest: The authors declare that they have no competing interests.

REFERENCES

Anonymous 2024. India: Garlic production by state. Statista. Available at: https://www.statista.com/statistics/744339/india-garlic-production-by-state/

Barnett HL and Hunter BB 1972. Illustrated genera of imperfect fungi. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/19721103191

Desta B 2021. Effect of harvesting time, curing and storage methods on storage of garlic. Open Biotechnology Journal **15**: 36-45. https://doi.org/10.2174/1874070702115010036

Gálvez L and Palmero D 2021. Fusarium dry rot of garlic bulbs caused by *Fusarium proliferatum*: A review. Horticulturae **8(7):** 628. https://doi.org/10.3390/horticulturae8070628

Gasser K, Steinkellner S and Hage-Ahmed K 2025. Fusarium dry rot in garlic: Hidden infection of planting material leading to high infestation rates during storage of the resulting harvest. Journal of Crop Health **77**: 132. https://doi.org/10.1007/s10343-025-01202-z

Gomez KA and Gomez AA 1984. *Statistical procedures for agricultural research* (2nd ed.). New York: John Wiley and Sons.

Katoch S and Kumar S 2016. Status, distribution and symptomatology of Stemphylium blight of garlic in Himachal Pradesh. Himachal Journal of Agricultural Research **42(2):** 184-186.

Llamas P, Paton G, Díaz G, Serna G and Sáez B 2013. The effects of storage duration, temperature and cultivar on the severity of garlic clove rot caused by *Fusarium proliferatum*. Postharvest Biology and Technology **78**: 34-39. https://doi.org/10.1016/j.postharvbio.2012.12.003

Ludlow RA, Pacenza M, Chiappetta A, Christofides SR, Evans G, Graz M, Marti G, Rogers HJ and Müller CT 2021. Storage time and temperature affects volatile organic compound profile, alliinase activity and postharvest quality of garlic. Postharvest Biology and Technology **177**: 111533. https://doi.org/10.1016/j.postharvbio.2021.111533

Mishra RK, Jaiswal RK, Kumar P and Gupta RP 2013. Occurrence of rot of garlic caused by Fusarium solani during storage. Indian Phytopathology **66(1):** 114.

NHB 2018-2019. Area and production, Himachal Pradesh 2018-19. Available at: https://www.nhb.gov.in/statistics/State_Level/2018-19%20(3rd%20Adv.Est_.)%20-%20Website.pdf

Parwan S, Banyal DK and Sharma S 2025. Epidemiological factors affecting purple blotch (Alternaria porri) progression in garlic. Himachal Journal of Agricultural Research **51(1):** 137-143.

Sarpkaya K 2025. Effect of *Fusarium proliferatum* infection on physiological, phytochemical, and nutrient responses in garlic. PeerJ **13**: e19601. https://doi.org/10.7717/peerj.19601 PMid:40552038 PMCid:PMC12184669

Shagun S, Bains A, Sridhar K, Dhull SB, Patil S, Gupta VK, Chawla P and Sharma M 2024. A comprehensive review on impact of post-harvest management and treatment practices on the quality of garlic (*Allium sativum* L) during storage. Scientia Horticulturae **337**: 113586. https://doi.org/10.1016/j.scienta.2024.113586

Sharma A, Sharma KC, Singh Y and Pathania NK 2010. Effect of pre-harvest treatments and indigenous practices on enhancing storage life of garlic (*Allium sativum* L.). Indian J Agric Sci **80(1):** 72-75.

Sood V, Singh A, Sood S, Sood VK, Sharma S and Sood T 2024. Morpho-cultural variability of Fusarium solani isolates causing root rot of okra in low and mid hills of Himachal Pradesh. Himachal Journal of Agricultural Research **50(1):** 75-82.

Stošić S, Ristić D, Trkulja N and Živković S 2025. *Penicillium* species associated with postharvest blue mold rots of garlic in Serbia. Plant Disease **109**: 149-161. https://doi.org/10.1094/PDIS-04-24-0890-RE PMid:39219004

Thakur S, Bala K, Sood AK and Singh Y 2020. Screening of onion and garlic genotypes for resistance against *Thrips tabaci* Lindeman in mid-hill regions of Himachal Pradesh. Himachal Journal of Agricultural Research **46(2):** 162-168.

Wheeler BEJ. 1969. An introduction to plant diseases. p 374. Available at: https://www.cabidigitallibrary.org/doi/full/10.5555/19700305235