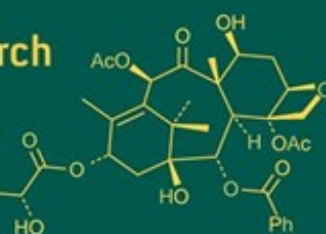
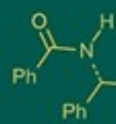


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Prevalence of bacterial wilt of chilli caused by *Ralstonia solanacearum* in major chilli-growing regions of Karnataka

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ABSTRACT

Bacterial wilt caused by *R. solanacearum* is an important soil-borne disease affecting chilli (*Capsicum annuum* L.) cultivation. A field survey was conducted across major chilli-growing areas of Karnataka to assess the prevalence and geographical distribution of bacterial wilt under different agro-ecological conditions. The survey covered 15 villages across seven districts, namely Chikballapur, Hassan, Dharwad, Gadag, Haveri, Bellary and Koppal. Disease incidence was recorded along with information on cultivated hybrids, soil types, crop growth stages and production ecosystems. The highest district mean disease incidence was recorded in Bellary (29.50%), followed by Dharwad (27.00%), Gadag (20.00%), Hassan (20.00%), Haveri (18.60%), Koppal (15.00%) and Chikballapur (10.00%). Among the surveyed villages, Bannihatti in Sandur taluk recorded the highest disease incidence (31.00%), followed by Sindigeri (30.00%) and Badanahatti (29.00%). The lowest incidence was observed at Thummanahalli in Chikballapur district (10.00%). Disease incidence varied across the surveyed locations, with comparatively higher levels observed in Bellary and Dharwad districts. Bacterial wilt was recorded in both irrigated and rainfed ecosystems and across red sandy clay, red sandy loam and black soils. The disease was also observed during vegetative, flowering and fruiting stages, indicating its occurrence throughout different phases of crop development. The findings demonstrate considerable geographical variation in bacterial wilt prevalence across major chilli-growing regions of Karnataka. The identified high-incidence locations provide a basis for targeted disease surveillance, pathogen characterization and the development of location-specific integrated management strategies for sustainable chilli production.

Keywords: *Capsicum annuum*, *Ralstonia solanacearum*, Bacterial wilt, Disease incidence, Karnataka, Disease surveillance

Introduction

Chilli (*Capsicum annuum* L.) is an economically important vegetable and spice crop cultivated extensively in tropical and subtropical regions of the world. It is valued for its culinary, nutritional and industrial applications, particularly as a source of capsaicinoids, carotenoids, vitamins and other bioactive compounds. India is a major producer and exporter of chilli, with Karnataka contributing substantially to its cultivation. However, chilli productivity is constrained by several biotic stresses, among which bacterial wilt is an important soil-borne disease. The disease causes sudden wilting, vascular dysfunction and eventual plant death, resulting in substantial economic losses under favourable environmental conditions (Hayward, 1991; Elphinstone, 2005) [2, 1].

Bacterial wilt is caused by members of the *Ralstonia solanacearum* species complex (RSSC), a group of genetically diverse, soil-borne bacterial pathogens with a broad host range. The pathogen enters plants primarily through root wounds and natural openings, colonizes the vascular tissues and multiplies within the xylem vessels, disrupting water transport and causing irreversible wilting. Its ability to survive in soil, infected plant residues, water and alternative hosts makes disease management particularly difficult. The pathogen exhibits considerable genetic and pathogenic variability, which may influence host adaptation, disease development and geographical distribution (Genin *et al.*, 2012) [3].

The occurrence and severity of bacterial wilt are influenced by interactions among the pathogen, host and environment. Soil temperature, moisture availability, drainage, cropping history and the presence of susceptible hosts can affect pathogen survival, dispersal and infection. Infected planting materials, contaminated irrigation water and movement of infested soil may further contribute to disease spread. The disease can occur in both rainfed and irrigated production systems, although its incidence may vary considerably among local

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tions depending on prevailing environmental conditions and cultivation practices (Elphinstone, 2005; EFSA PLH Panel, 2019) [1].

The genetic diversity of the pathogen further complicates the epidemiology of bacterial wilt. Members of the RSSC have historically been classified into four phylotypes based on their geographical origins and genetic relationships. Subsequent taxonomic investigations distinguished *R. solanacearum*, *R. pseudosolanacearum* and *R. syzygii* as separate species within the complex. This diversity highlights the importance of understanding regional pathogen populations and their distribution for developing effective disease management strategies (Safni *et al.*, 2014; Genin *et al.*, 2012) [4, 3].

Karnataka encompasses diverse agro-climatic regions characterized by variations in rainfall, soil characteristics, irrigation practices and cropping systems. These differences may contribute to spatial variation in the occurrence and severity of bacterial wilt in chilli-growing areas. Although the disease is recognized as an important constraint in solanaceous crops, location-specific information on its prevalence across major chilli-producing districts of Karnataka is essential for identifying disease-prone areas and prioritizing management interventions. Systematic field surveys provide an opportunity to document disease incidence under prevailing cultivation conditions and establish baseline information for subsequent epidemiological investigations. Such information is particularly relevant for soil-borne pathogens that persist in the production environment and affect multiple economically important crops (Hayward, 1991; EFSA PLH Panel, 2019) [2].

Considering the importance of bacterial wilt in chilli production, the present investigation was undertaken to assess its prevalence in major chilli-growing areas of Karnataka. The survey covered 15 villages distributed across seven districts, namely Chikballapur, Hassan, Dharwad, Gadag, Haveri, Bellary and Koppal. Disease incidence was

documented along with information on cultivated hybrids, soil types, crop growth stages and production ecosystems. The study aimed to determine the geographical variation in bacterial wilt incidence, identify high-incidence locations and generate baseline information for future pathogen characterization and the development of location-specific disease management strategies.

Materials and Methods

Survey of bacterial wilt in chilli

A roving survey was undertaken in major chilli-growing areas of Karnataka to assess the prevalence and geographical distribution of bacterial wilt. The survey covered 15 villages across seven districts, namely Chikballapur, Hassan, Dharwad, Gadag, Haveri, Bellary and Koppal (Fig. 1). Survey locations were selected to represent different chilli-growing regions, soil types and cultivation practices. At each location, the cultivated chilli hybrid or variety, geographical coordinates, crop area, soil type, crop growth stage and production ecosystem were documented. Geographical coordinates were recorded in degrees, minutes and seconds and expressed as latitude and longitude. The surveyed fields represented both irrigated and rainfed ecosystems, with crops at vegetative, flowering and fruiting stages.

Assessment of disease incidence

Bacterial wilt incidence was assessed by recording the number of wilt-affected and total chilli plants in the surveyed fields. Plants exhibiting characteristic symptoms, including sudden wilting, loss of turgidity and progressive collapse, were considered presumptively affected. The percentage of disease incidence was calculated using the following formula, consistent with the field-survey approach described for bacterial wilt by Hayward (1991) [2] and subsequent epidemiological investigations.

$$\text{Disease incidence (\%)} = \frac{\text{Number of wilt-affected plants}}{\text{Total number of plants observed}} \times 100$$

The mean disease incidence for each district was calculated from the village-level incidence values:

$$\text{Mean incidence (\%)} = \frac{\sum_{i=1}^n I_i}{n}$$

where I_i represents the disease incidence in the i^{th} surveyed village and n denotes the number of villages surveyed within the district.

Identification of bacterial wilt symptoms

Disease identification in the surveyed fields was based on characteristic bacterial wilt symptoms, including drooping of leaves, sudden wilting and vascular discoloration. The diagnostic characteristics were interpreted with reference to the EPPO diagnostic protocol for the *Ralstonia solanacearum* species complex (EPPO, 2022) [5].

Visual symptoms alone cannot conclusively establish the identity of the causal bacterium. Laboratory confirmation should therefore be reported only for samples subjected to diagnostic testing. The bacterial streaming test, isolation on suitable bacteriological media and molecular identification are recognized approaches for confirming infection by members of the *Ralstonia solanacearum* species complex (EPPO, 2022) [5].

Compilation and analysis of survey data

Village-wise disease incidence values were compiled and grouped according to district, taluk, cultivated hybrid, soil type, crop growth stage and ecosystem. District-wise mean incidence was calculated using

the arithmetic mean of the corresponding village observations. The geographical distribution of disease was examined by comparing incidence across surveyed locations, and villages recording relatively higher disease incidence were identified as potential disease hotspots. The survey data were summarized using descriptive statistics. Differences in disease incidence among districts and production environments were interpreted descriptively, without assuming statistical significance.

Results

Prevalence of bacterial wilt of chilli in major chilli-growing areas of Karnataka

A roving survey conducted across seven major chilli-growing districts of Karnataka revealed considerable variation in the prevalence of bacterial wilt (Table 5). The survey covered 15 villages distributed across Chikballapur, Hassan, Dharwad, Gadag, Haveri, Bellary and Koppal districts. Disease incidence ranged from 10.00 to 31.00 per cent across the surveyed locations, indicating variation in disease occurrence among the chilli-growing regions.

Among the surveyed districts, Bellary recorded the highest mean disease incidence (29.50%), followed by Dharwad (27.00%). Hassan and Gadag recorded a mean incidence of 20.00 percent each, while Haveri registered 18.50 per cent. Comparatively lower disease incidence was observed in Koppal (15.00%), whereas Chikballapur recorded the lowest incidence (10.00%). The district-wise distribution indicated comparatively greater disease prevalence in Bellary and Dharwad than in the other surveyed districts.

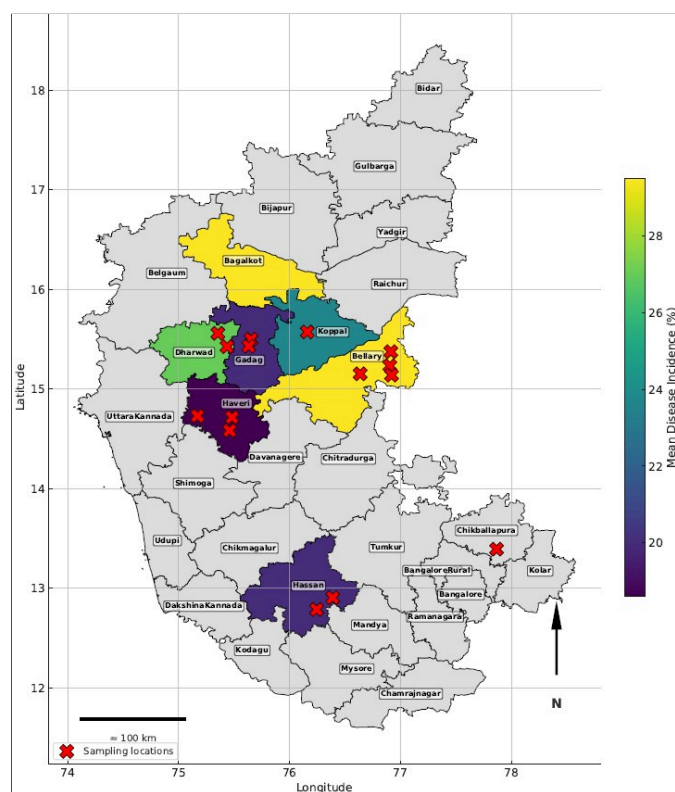


Figure 1. Spatial distribution of mean bacterial wilt incidence and sampling locations of *R. solanacearum* in major chilli-growing districts of Karnataka.

In Bellary district, the highest disease incidence was recorded at Bannihatti village of Sandur taluk (31.00%), followed by Sindegeri (30.00%), Badanahatti (29.00%) and Somasamudra (28.00%). All four surveyed locations recorded incidence above 25.00 per cent. Similarly, Dharwad district exhibited relatively high disease incidence, ranging from 26.00 to 28.00 per cent. The maximum incidence was observed at Bennur (28.00%), followed by Annigeri (27.00%) and Yaliwal (26.00%).

In Hassan district, bacterial wilt incidence varied from 18.00 per cent at Somadevarapura to 21.00 per cent at Uvrigowdanahalli. Gadag district recorded an incidence of 19.00 per cent at Bentur and 21.00 per cent at Kurkote. In Haveri district, Motebennur and Akki Alur registered disease incidences of 18.00 and 19.00 per cent, respectively. Koppal

district recorded 15.00 per cent incidence at Kuknoor, while Thummanahalli in Chikballapur district exhibited the lowest incidence of 10.00 per cent among all surveyed locations.

Figure 2. District wise MDI (A) and village wise DI (%) (B) of chilli bacterial wilt caused by *R. solanacearum* of different districts of Karnataka

Occurrence of bacterial wilt under different cultivation conditions

Bacterial wilt was observed across different chilli hybrids and varieties, soil types, crop growth stages and production ecosystems. The surveyed locations included red sandy clay, red sandy loam and black soils, with disease incidence recorded under both irrigated and rainfed conditions.

The highest incidence (31.00%) was observed in the S-5531 hybrid cultivated under rainfed conditions in red sandy loam soil at Bannihatti. In contrast, the lowest incidence (10.00%) was recorded in the Kranti hybrid grown under rainfed conditions in red sandy clay soil at Thummanahalli. Disease incidence was recorded during vegetative, flowering and fruiting stages, demonstrating its occurrence across different phases of chilli crop development.

The survey revealed that bacterial wilt was prevalent across all seven districts, with marked geographical variation in disease incidence. Bellary and Dharwad recorded comparatively higher disease incidence, while Chikballapur exhibited the lowest incidence among the surveyed districts.

Discussion

The present investigation revealed considerable geographical variation in the prevalence of bacterial wilt of chilli across seven major chilli-growing districts of Karnataka. Disease incidence ranged from 10.00 to 31.00 per cent, indicating that bacterial wilt was prevalent across the surveyed regions, although its occurrence varied among locations. Such spatial variation is consistent with the complex epidemiology of bacterial wilt, which is influenced by interactions among pathogen populations, susceptible hosts, soil characteristics and environmental conditions. Hayward (1991) [2] described the importance of temperature, soil moisture and host susceptibility in bacterial wilt development, while Genin *et al.* (2012) [3] highlighted the extensive genetic and pathogenic diversity within the *Ralstonia solanacearum* species complex. The observed differences among survey locations may therefore reflect variation in local pathogen populations, cropping practices and environmental conditions rather than the influence of any single factor.

Bellary recorded the highest mean disease incidence (29.50%), with Bannihatti (31.00%), Sindegeri (30.00%) and Badanahatti (29.00%) representing the most affected survey locations. Dharwad also exhibited comparatively high incidence (27.00%), whereas Chikballapur recorded the lowest incidence (10.00%). The concentration of higher incidence in Bellary and Dharwad suggests that local production environments may favour disease establishment or persistence. Vailleau *et al.* (2023) [6] explained that the extensive host range, environmental persistence and diverse virulence mechanisms of *Ralstonia* contribute to its successful establishment in different agricultural environments. Similarly, Zong *et al.* (2023) [7] emphasized that pathogen survival and disease development are influenced by interactions among environmental conditions, cropping systems and management practices. However, the present survey did not quantify soil inoculum density, temperature or cropping history; therefore, the factors responsible for the higher incidence in these districts require further investigation.

The occurrence of bacterial wilt across red sandy clay, red sandy loam and black soils indicates that the disease was not restricted to a particular soil type. Higher incidence was recorded in several fields with red sandy loam and black soils, although the observations do not establish a direct relationship between soil texture and disease development. Soil properties can influence bacterial wilt through their effects on water availability, nutrient balance, root growth and microbial interactions. A meta-analysis of 406 observations from 55 studies demonstrated that soil nutrient status was associated with bacterial wilt suppression, particularly through the influence of soil organic carbon, available phosphorus and nutrient balance. The findings suggest that soil characteristics should be considered alongside pathogen population density and host susceptibility when interpreting geographical variation in disease incidence.

Table 1. The prevalence of bacterial wilt of chilli in major chilli growing areas of *Karnataka*.

District	Taluk	Village	Hybrid /Local	Latitude	Longitude	Crop Area (ha)	Soil type	Crop Stage	Ecosystem	Disease Incidence (%)	Mean Incidence (%)
Chikkaballapur	Sidlaghatta	Thummanahalli	Kranti	13°23'29"N	77°51'54"E	0.8	Red sandy clay	Flowering	Rainfed	10	10
Hassan	Channarayapatna	Somadevarapura	Ulka	12°54'18"N	76°23'17"E	1.2	Red sandy loam	Fruiting	Irrigated	18	20
	Holenarasipur	Uvvigowdanahalli	Ulka	12°47'11"N	76°14'36"E	1.0	Red sandy loam	Vegetative	Irrigated	21	
Dharwad	Kundgol	Yaliwal	Vasu	14°34'57"N	75°27'33"E	0.7	Black soil	Fruiting	Rainfed	26	27
	Kundgol	Bennur	Vasu	15°33'31"N	75°21'11"E	0.9	Black soil	Flowering	Rainfed	28	
	Navalgund	Annigeri	Vasu	15°25'30"N	75°26'07"E	1.5	Black soil	Fruiting	Irrigated	27	
Gadag	Gadag	Bentur	F1-8777	15°29'54"N	75°39'07"E	1.1	Black soil	Fruiting	Irrigated	19	20
	Gadag	Kurkote	Vasu	15°25'43"N	75°37'52"E	0.6	Black soil	Vegetative	Rainfed	21	
Haveri	Byadagi	Motebennur	Byadagi	14°42'54"N	75°28'48"E	2.0	Black soil	Fruiting	Irrigated	18	18.6
	Hangal	Akki Alur	Vasu	14°43'44"N	75°10'12"E	0.9	Black soil	Flowering	Rainfed	19	
Bellary	Bellary	Somasamudra	S-5531	15°13'58"N	76°54'12"E	1.3	Red sandy loam	Fruiting	Irrigated	28	29.5
		Sindegeri	S-5531	15°22'28"N	76°54'44"E	0.8	Red sandy loam	Vegetative	Rainfed	30	
	Kurugodu	Badanahatti	S-5531	15°08'19"N	76°55'07"E	1.0	Black soil	Fruiting	Irrigated	29	
	Sandur	Bannihatti	S-5531	15°09'06"N	76°38'08"E	1.5	Red sandy loam	Fruiting	Rainfed	31	
Koppal	Koppal	Kuknoor	Local Red	15°34'21"N	76°09'32"E	1.8	Black soil	Fruiting	Irrigated	15	15

The presence of bacterial wilt under both irrigated and rainfed ecosystems demonstrates its occurrence under contrasting water-management conditions. In Bellary, disease incidence ranged from 28.00 to 29.00 per cent in irrigated fields and from 30.00 to 31.00 per cent in rainfed fields. This variation suggests that irrigation status alone cannot explain the observed disease distribution. Water availability may influence pathogen movement, root infection and plant physiological responses, while contaminated irrigation water can serve as a pathway for pathogen dissemination. The review of bacterial wilt in *Capsicum* by An insight into the problem of bacterial wilt in *Capsicum* spp. with special reference to India describes the importance of contaminated water, infected soil and planting materials in pathogen transmission. These findings emphasize the need to consider water source, drainage and field sanitation when investigating disease occurrence in different production ecosystems.

Bacterial wilt was recorded during vegetative, flowering and fruiting stages, indicating that chilli plants remained susceptible to disease occurrence throughout different phases of crop development. The observed incidence during fruiting is particularly important because infection at this stage may affect reproductive development and marketable yield. Following root infection, *Ralstonia* colonizes the vascular system and interferes with water transport, resulting in wilting and progressive plant collapse. Vaillau *et al.* (2023) [6] described the involvement of multiple virulence mechanisms in vascular colonization and disease development, while Wang *et al.* (2023) [7] discussed the difficulties associated with managing the pathogen after systemic infection. However, the present survey was conducted across fields at different growth stages and did not follow individual crops over time; therefore, the observations cannot establish a stage-specific progression of bacterial wilt.

The occurrence of bacterial wilt in different chilli hybrids and varieties indicates that the disease affected diverse planting materials under field conditions. The highest incidence was recorded in S-5531 at Bannihatti, whereas Kranti at Thummanahalli recorded the lowest incidence. These observations should not be interpreted as evidence of differences in genetic resistance because the cultivars were grown at different locations and were not evaluated under uniform disease pressure. Host resistance is influenced by interactions among plant genotype, pathogen diversity and environmental conditions. Vaillau *et al.* (2023) [6] highlighted the importance of environmental stability in bacterial wilt resistance, while Du *et al.* (2023) [8] emphasized the need to identify and utilize durable resistance sources in solanaceous crops. Comparative screening of the surveyed chilli genotypes under controlled inoculation and replicated field conditions would help determine whether the observed differences reflect host resistance or variation in local disease pressure.

The geographical variation observed in the present study also has implications for understanding pathogen persistence and developing location-specific management strategies. The comparatively higher incidence in Bellary and Dharwad identifies these districts as priority areas for further disease surveillance and pathogen characterization. The persistence of *Ralstonia* in soil and its interactions with indigenous microbial communities complicate disease management, particularly in fields with a history of susceptible crops. Ding *et al.* (2023) [9] demonstrated that bacterial wilt suppressiveness in compost-amended systems was associated with rhizosphere microbial communities, while Han *et al.* (2026) [10] highlighted the importance of pathogen environmental adaptation and ecological interactions in determining disease management outcomes. These findings suggest that investigations of pathogen diversity, soil microbial communities and cropping history in high-incidence locations could provide additional information for developing sustainable management practices.

The present survey provides baseline information on the geographical distribution of bacterial wilt across major chilli-growing regions of Karnataka. However, the limited number of surveyed fields and the absence of repeated seasonal observations restrict the interpretation of district-level differences. Moreover, soil physicochemical properties,

pathogen inoculum density and climatic variables were not quantitatively assessed. Consequently, the observed associations between disease incidence and cultivation conditions should be considered descriptive rather than causal. Further investigations involving multi-season surveys, molecular characterization of pathogen populations and replicated evaluation of chilli genotypes would help clarify the factors governing disease distribution. Integration of these findings with resistant cultivars, appropriate cultural practices and effective biological agents could contribute to the development of location-specific bacterial wilt management strategies, as discussed by Wang *et al.* (2023) [7] and Vaillau *et al.* (2023) [6].

Conclusion

The present study revealed considerable geographical variation in the prevalence of bacterial wilt of chilli across major chilli-growing regions of Karnataka, with disease incidence ranging from 10.00 to 31.00 per cent. Bellary recorded the highest mean disease incidence (29.50%), followed by Dharwad (27.00%), whereas Chikkaballapur exhibited the lowest incidence (10.00%). Among the surveyed villages, Bannihatti in Bellary district recorded the highest incidence (31.00%), indicating its importance as a priority location for further disease surveillance. The occurrence of bacterial wilt across different soil types, crop growth stages and production ecosystems highlights its widespread distribution under diverse cultivation conditions. The findings provide baseline information for identifying high-incidence areas and prioritizing pathogen characterization, resistance screening and location-specific disease management interventions. Further investigations involving multi-season surveillance and molecular characterization of pathogen populations are essential for understanding disease epidemiology and developing effective, sustainable management strategies for chilli bacterial wilt in Karnataka.

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