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# Soil physicochemical characteristics and their influence on the prevalence of *Ralstonia solanacearum* in diseased banana plantations across selected tehsils of Jalgaon District, India

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**Abstract**
Bacterial wilt, caused by *Ralstonia solanacearum*, poses a significant threat to banana cultivation globally. This study aims to explore how soil physicochemical parameters, particularly pH and water holding capacity (WHC), influence the susceptibility of banana plantations to this pathogen. A total of 68 composite soil samples were collected from three major banana-growing tehsils in the Jalgaon district of Maharashtra, India. The results demonstrated considerable variability in pH (ranging from 5.7 to 8.3) and WHC (from 35.45% to 52.40%) across the sampled sites. Soils exhibiting high WHC and near-neutral pH (such as CH07, BH05, and PC07) were linked to more favorable conditions for plant growth and lower incidences of wilt. Conversely, sites characterized by high alkalinity or low WHC (like BH10, PC10, and CH09) appeared to create environments that promote pathogen persistence and increase host susceptibility. These findings highlight the crucial role of effective soil management in reducing *R. solanacearum* infections. By integrating region-specific soil assessments with targeted amendments, it may be possible to enhance the resilience of banana cropping systems. A combination of high WHC and near-neutral pH can help alleviate bacterial symptoms in banana plants, while high alkalinity or low WHC may foster conditions favorable to bacterial proliferation. Implementing soil monitoring and modifying soil properties could serve as effective preventive strategies against bacterial wilt in susceptible areas. Furthermore, the study reinforces emerging research on the interplay between soil health, microbial community complexity, and disease suppression. Overall, profiling soil physicochemical properties can be a valuable tool in integrated disease management strategies aimed at sustaining banana production in wilt-prone agro-ecological zones.

**Keywords:** *Ralstonia solanacearum*, banana wilt, water holding capacity, soil pH, Jalgaon, soil health, disease ecology

## Introduction
Bacterial wilt caused by *Ralstonia solanacearum* is a significant threat to banana cultivation worldwide (Peeters *et al.*, 2013) [14]. This soil-borne pathogen affects over 200 plant species and is considered a species complex (Meng, 2013) [12]. In bananas, it causes Moko disease, characterized by yellowing, wilting, and vascular discoloration (Premabati & Mandal, 2020) [15]. Other bacterial diseases affecting bananas include Xanthomonas wilt and Erwinia-associated diseases. Accurate pathogen identification is crucial for disease management, with molecular diagnostics and innovative agronomic practices being key strategies (Donoso and Valenzuela, 2018) [6]. Control measures include using resistant cultivars, strict sanitation practices, and integrating cultural practices with diagnostic tools and breeding techniques. However, infected fields can rarely be reused, even after crop rotation, highlighting the persistent nature of this pathogen (Peeters *et al*., 2013; Premabati & Mandal, 2020) [14, 15].
*Ralstonia solanacearum* is a notorious bacterial plant pathogen responsible for causing severe wilt disease in various economically significant crops. This bacterium, which is transmitted through soil and water, infiltrates plant roots, proliferates within the xylem, and ultimately leads to the death of the host. *R. solanacearum* demonstrates remarkable resilience, allowing it to endure harsh environmental conditions until it encounters a new host. Effective control strategies encompass integrated disease management aimed at minimizing the pathogen's survival and spread. The development of host-plant resistance, judicious cropping systems, soil amendments, and the use of biological control methods involving antagonistic rhizobacteria (Hayward, 1991) [7].

Soil pH and water-holding capacity (WHC) play a critical role in determining the survival of pathogens in the soil. Acidic conditions typically enhance pathogen survival and sporulation, with optimal pH values ranging from 3.9 to 5.5 (Wetzel and McBride, 2020) [19]. Additionally, soil moisture content is essential, as higher WHC tends to support pathogen persistence; however, excessively high moisture levels can be harmful (Specht & Murray, 1989) [18]. Jalgaon district in Maharashtra is a prominent banana-producing region, holding the top position in India for both production and cultivated area. The capacity for banana cultivation in this district is significant enough to potentially position it as the world's seventh-largest banana producer if treated as a separate country (Chavan & Nile, 2012; Jadhav *et al.*, 2020) [5, 8]. This study aims to offer region-specific insights into soil-pathogen interactions and to support targeted soil management strategies that can help mitigate disease risks.

## Materials and Methods

- **Study Area:** The research was conducted in the Jalgaon district of Maharashtra, India, a region well-known for its banana cultivation. Jalgaon is situated between latitudes 20°32′N and 21°18′N and longitudes 74°55′E and 76°28′E, featuring a diverse range of agro-climatic zones. The district experiences a tropical monsoon climate, characterized by average annual rainfall of 600-700 mm, primarily occurring from June to September. Temperatures in the region vary from 10 °C in winter to over 42 °C during the peak of summer. The soil types are diverse, ranging from black cotton soils to mixed red loam varieties, each exhibiting different drainage and fertility characteristics. This study focused on banana plantations located in various tehsils, including Chalisgaon, Bhadgaon, and Pachora, where there have been frequent reports of bacterial wilt caused by *Ralstonia solanacearum*.
- **Sample Description:** A total of 68 composite soil samples were collected from three prominent banana-growing tehsils: Chalisgaon (N=21), Bhadgaon (N=17), and Pachora (N=30). Each sample consisted of soil from the rhizosphere zone (0-30 cm depth) of visibly diseased banana plants, as well as from nearby asymptomatic plants for comparative control. The samples were carefully labeled, transported in sterile containers, and stored at 4 °C until further analysis. Sampling locations were geo-tagged using GPS for spatial mapping purposes.
- **Soil Physicochemical Analysis:** Each soil sample was air-dried, ground, and sieved through a 2 mm mesh prior to analysis. Soil pH was measured using a digital pH meter in a 1:2.5 soil-to-water suspension, following the protocol established by Jackson (1973) [10]. The Water Holding Capacity (WHC) was evaluated gravimetrically using the Keen-Raczkowski box method (Anbarasu *et al.* 2024) [1]. Soil texture classification was performed using the hydrometer method (Bouyoucos, 1962) [3] and categorized according to USDA soil taxonomy. All procedures were executed in triplicate to ensure the accuracy of the data. All quantitative soil parameters were statistically analyzed.

## Results and Discussion

This study investigates how variations in soil properties contribute to the susceptibility of banana crops to bacterial wilt. Particular focus is placed on two critical parameters, soil pH and water holding capacity (WHC), as these play an essential role in determining soil health, nutrient bioavailability, and pathogen proliferation. In Chalisgaon, (Table 1) the WHC ranged from 38.20% to 46.10%, with an average of 42.44%. Sample CH07 (Hingone Kh) demonstrated the highest WHC at 46.10% and a soil pH of 6.5, which aligns closely with agronomic recommendations for the 'Grand Naine' variety, known to thrive in loamy, well-drained soils with a slightly acidic to neutral pH (5.5-6.5). Conversely, sample CH09 (Munkheda Bk) exhibited the lowest WHC at 38.20% and the lowest pH at 5.7. This may limit nutrient availability and suggests a need for soil amendments to enhance moisture retention and fertility.

In Bhadgaon, (Table 2) a broader range of soil pH was noted, from slightly acidic (5.9) to notably alkaline (8.3), with an average pH of 7.1. The alkaline samples, such as BH05, BH07, BH12, and BH13, may restrict the bioavailability of essential micronutrients like iron and zinc, potentially increasing susceptibility to physiological stress and disease. WHC values in this taluka varied from 35.92% to 52.40%, with sample BH05 achieving the highest WHC, indicating favorable moisture retention, especially in dry conditions. In contrast, samples BH09 and BH10 recorded WHC values below 38%, raising concerns about insufficient water retention and increased vulnerability of banana plants to water stress.

In Pachora, (Table 3) WHC values ranged from 35.45% to 49.62%, averaging 42.39%. Sample PC07 recorded the highest WHC at 49.62%, reflecting excellent moisture-holding potential. In contrast, sample PC10 showed the lowest WHC at 35.45%, indicating inadequate soil moisture retention. Such conditions may necessitate additional irrigation or soil amendment strategies to sustain productive banana cultivation. The pH range in Pachora (5.8-7.9) also shows slight deviations from the optimal range, with acidic conditions in some samples potentially affecting nutrient solubility and uptake. Overall, the data suggest that while most samples from the three talukas fall within the acceptable pH range for banana cultivation, several outliers particularly in Bhadgaon require corrective soil management practices. Soils with high WHC, such as those in samples CH07, BH05, and PC07, provide favorable conditions for banana production, whereas low WHC sites may compromise plant resilience unless supplemented with improved irrigation and organic matter.

The present study investigates the influence of soil physicochemical parameters, particularly pH and water holding capacity (WHC), on the susceptibility of banana plantations to bacterial wilt caused by *Ralstonia solanacearum* in the Jalgaon district, specifically in the talukas of Chalisgaon, Bhadgaon, and Pachora. These soil characteristics play a crucial role in nutrient availability, root zone conditions, and the survivability of pathogens. Overall, the findings suggest that high WHC combined with near-neutral pH can help mitigate bacterial wilt symptoms in banana plants, whereas high alkalinity or low WHC may create conditions conducive to *R solanacearum* proliferation. Implementing soil monitoring and amending soil properties could serve as effective preventive strategies against bacterial wilt in susceptible areas. Recent studies have highlighted the complex interplay between soil properties, microbial communities, and the occurrence of bacterial wilt caused by *Ralstonia solanacearum*.

**Table 1:** Physicochemical Soil Properties (pH and WHC) of diseased banana plantations across Chalisgaon Tehsil, Jalgaon District, India

| Sr. No. | Sample Code | Location Site | Variety of Banana | Soil Type | pH | WHC (%) |
|---|---|---|---|---|---|---|
| 1 | CH01 | Tirpole | Shrimantti | Black | 6.5 | 44.20 |
| 2 | CH02 | Waghadu | Shrimantti | Regur | 6.1 | 40.55 |
| 3 | CH03 | Waghali | Jain Tissue | Loamy | 5.9 | 39.80 |
| 4 | CH04 | Vadale-Vadali | Grand naine | Black | 6.3 | 42.20 |
| 5 | CH05 | Beldarwadi | Jain Tissue | Black | 6.4 | 43.35 |
| 6 | CH06 | Bhamare | Agrostar | Black | 6.5 | 44.55 |
| 7 | CH07 | Hingone Kh | Plantics | Regur | 6.5 | 46.10 |
| 8 | CH08 | Gorakhpur | Plantics | Black | 6.2 | 42.20 |
| 9 | CH09 | Munkheda Bk | Agrostar | Loamy | 5.7 | 38.20 |
| 10 | CH10 | Patonda | Safed vel | Loamy | 6.1 | 41.40 |
| 11 | CH11 | Patna | Shrimantti | Black | 6.2 | 42.20 |
| 12 | CH12 | Pimparkhede | Jain Tissue | Black | 6.4 | 43.80 |
| 13 | CH13 | Mandurne | Madhukar | Regur | 6.5 | 45.30 |
| 14 | CH14 | Dahiwad | Madhukar | Black | 6.6 | 45.60 |
| 15 | CH15 | Jamada | Jain Tissue | Black | 6.4 | 44.20 |
| 16 | CH16 | Malshevage | Mahalakshmi | Loamy | 6.3 | 43.80 |
| 17 | CH17 | Varthan | Mahalakshmi | Black | 6.2 | 41.90 |
| 18 | CH18 | Tamaswadi | Madhukar | Regur | 6.1 | 40.30 |
| 19 | CH19 | Ranjangaon | Shrimantti | Black | 6.1 | 40.85 |
| 20 | CH20 | Sangavi | Safed vel | Regur | 5.8 | 38.65 |
| 21 | CH21 | Kherde | Agrostar | Black | 6.2 | 42.10 |
| Range | — | — | — | — | 5.7–6.6 | 38.20–46.10 |
| Average | — | — | — | — | 6.2 | 42.44 |

**Table 2:** Physicochemical Soil Properties (pH and WHC) of diseased banana plantations across Bhadgaon Tehsil, Jalgaon District, India

| Sr. No. | Sample Code | Location Site | Variety of Banana | Soil Type | pH | WHC (%) |
|---|---|---|---|---|---|---|
| 1 | BH01 | Umarkhed | Basrai | Black | 6.5 | 42.36 |
| 2 | BH02 | Umarkhed | Madhukar | Black | 6.8 | 44.22 |
| 3 | BH03 | Varkhed | Plantics | Loamy | 7.8 | 46.87 |
| 4 | BH04 | Varkhed | Grand naine | Deep Black | 6.9 | 45.63 |
| 5 | BH05 | Tandulwadi | Jain Tissue | Regur | 8.3 | 52.40 |
| 6 | BH06 | Tandulwadi | Robusta | Black | 6.4 | 41.54 |
| 7 | BH07 | Girad | Plantics | Regur | 8.1 | 50.65 |
| 8 | BH08 | Girad | Safed vel | Black | 7.5 | 43.21 |
| 9 | BH09 | Vasantwadi | Agrostar | Sandy | 6.4 | 35.92 |
| 10 | BH10 | Vasantwadi | Safed vel | Sandy | 5.9 | 37.24 |
| 11 | BH11 | Kolgaon | Shrimantti | Black | 6.8 | 41.68 |
| 12 | BH12 | Kolgaon | Jain Tissue | Deep Black | 7.6 | 45.63 |
| 13 | BH13 | Savade | Robusta | Regur | 8.2 | 49.95 |
| 14 | BH14 | Savade | Madhukar | Deep Black | 6.7 | 46.82 |
| 15 | BH15 | Malgaon | Jain Tissue | Deep Black | 7.5 | 44.61 |
| 16 | BH16 | Malgaon | Mahalakshmi | Loamy | 6.9 | 45.70 |
| 17 | BH17 | Nimbhora | Robusta | Deep Black | 6.4 | 45.90 |
| Range | — | — | — | — | 5.9–8.3 | 35.92–52.40 |
| Average | — | — | — | — | 7.1 | 44.72 |

**Table 3:** Physicochemical Soil Properties (pH and WHC) of Diseased Banana Plantations across Pachora Tehsil, Jalgaon District, India

| Sr. No. | Sample Code | Location Site | Variety of Banana | Soil Type | pH | WHC (%) |
|---|---|---|---|---|---|---|
| 1 | PC01 | Jamne | Plantics | Loamy | 7.8 | 45.60 |
| 2 | PC02 | Jamne | Plantics | Sandy | 5.8 | 36.45 |
| 3 | PC03 | Dongargaon | Agrostar | Deep Black | 6.9 | 44.25 |
| 4 | PC04 | Dongargaon | Basrai | Black | 6.5 | 43.10 |
| 5 | PC05 | Galan Kh | Shrimantti | Sandy | 6.2 | 35.68 |
| 6 | PC06 | Galan Bk | Basrai | Black | 6.8 | 42.35 |
| 7 | PC07 | Nandra | Robusta | Regur | 7.9 | 49.62 |
| 8 | PC08 | Nandra | Madhukar | Deep Black | 6.4 | 46.72 |
| 9 | PC09 | Dighi | Agrostar | Black | 6.7 | 43.26 |
| 10 | PC10 | Dighi | Agrostar | Sandy | 6.3 | 35.45 |
| 11 | PC11 | Shahapure | Shrimantti | Deep Black | 7.3 | 45.68 |
| 12 | PC12 | Shahapure | Jain Tissue | Black | 6.5 | 41.95 |
| 13 | PC13 | Sangameswar | Grand naine | Sandy | 5.9 | 36.47 |
| 14 | PC14 | Sangameswar | Jain Tissue | Deep Black | 6.8 | 43.84 |
| 15 | PC15 | Ozar | Robusta | Black | 6.3 | 42.73 |
| 16 | PC16 | Ozar | Plantics | Loamy | 7.5 | 46.72 |
| 17 | PC17 | Lasgaon | Safed vel | Deep Black | 6.8 | 47.53 |
| 18 | PC18 | Lasgaon | Agrostar | Sandy | 6.1 | 36.24 |
| 19 | PC19 | Lohare | Safed vel | Deep Black | 6.4 | 45.63 |
| 20 | PC20 | Lohare | Safed vel | Sandy | 6.0 | 38.62 |
| Range | — | — | — | — | 5.8–7.9 | 35.45–49.62 |
| Average | — | — | — | — | 6.6 | 42.39 |

Soil nutrient status, particularly phosphorus, organic carbon, and nitrogen content and ratios, significantly influence disease suppression (Cao *et al.*, 2022; Jayaraman *et al*., 2021) [4, 9]. Soil moisture has been identified as a crucial predictor of disease outcomes, with optimal conditions around 60% of maximum water holding capacity (Jiang *et al*., 2021; Rasheed *et al.* 2022) [11, 17]. Microbial network analysis revealed that bacterial wilt-susceptible soils have less complex microbial interactions and fewer key microorganisms compared to healthy soils (Qi *et al*., 2019; Zhang *et al.*, 2020) [16, 20]. These findings suggest that managing soil properties and microbial communities could be effective in controlling bacterial wilt. The pathogen's genomic studies have advanced our understanding of its classification, host range, and virulence factors, potentially leading to improved disease ccontrol strategies (Peeters *et al*., 2013; Morris and Moury, 2019) [14, 13].

## Conclusion

This study confirms that soil pH and water-holding capacity (WHC) are critical factors influencing the prevalence of *Ralstonia solanacearum* in banana plantations. Soils with near-neutral pH and high WHC provide a natural defense against bacterial wilt. In contrast, alkaline soils and those with low moisture retention increase plant susceptibility to the disease. Implementing site-specific soil management practices can significantly mitigate disease risk. Moreover, incorporating soil monitoring into disease control strategies is essential for sustainable banana cultivation.

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## Conflict of Interest

The authors declare that there is no conflict of interest.

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