



## COMPARATIVE STUDY OF COMPOST AND CHEMICAL CONTROL AGAINST BACTERIAL WILT IN CHILLI (*Capsicum annuum* L.)

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### ABSTRACT

Bacterial wilt (BW) caused by the *Ralstonia solanacearum* species complex (RSSC) is a devastating soil-borne disease of chilli (*Capsicum annuum* L.), with potential yield losses of 30–100%. Farmers often rely on chemical bactericides for control, but their results are inconsistent and unsustainable. By contrast, compost and organic amendments provide long-term suppression by enriching beneficial microbial populations, enhancing soil structure and nutrient cycling, and stimulating plant systemic resistance. This paper presents a comprehensive comparative study of compost and chemical control against BW in chilli. It integrates pathogen biology, epidemiology, molecular virulence mechanisms, experimental methodologies, global field evidence, socio-economic dimensions, and future strategies for sustainable management. Evidence from India, China, Africa, Latin America, and Southeast Asia demonstrates that compost reduces disease incidence by 30–70% and increases yield by 15–40%, while chemical control typically reduces disease by only 20–25%. The analysis also highlights socio-economic benefits of compost, including enhanced farmer resilience, reduced dependence on costly chemical inputs, and alignment with global Sustainable Development Goals (SDGs). Integrated Disease Management (IDM), anchored by compost and supplemented by resistant cultivars, sanitation, and limited chemical interventions, emerges as the most sustainable strategy.

**KEYWORDS:** Farmers often rely on chemical bactericides for control, but their results are inconsistent and unsustainable.

### 1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is cultivated in more than 80 countries and is globally important as both a spice and vegetable crop. The global production of chilli exceeds 40 million tons annually, with Asia contributing over 70%. India, China, Mexico, and Thailand are leading producers, while India dominates exports. Chilli cultivation is central to rural livelihoods, particularly for smallholder farmers who depend on it for food security and income.

However, chilli production is threatened by bacterial wilt (BW), caused by the *Ralstonia solanacearum* species complex (RSSC). BW is among the most serious plant diseases in tropical and subtropical regions, causing rapid wilting and plant death. Yield losses can range from 30% to total crop failure. The pathogen's persistence in soil and water, its wide host range, and genetic diversity complicate management.

Farmers traditionally rely on chemical bactericides because they are easy to apply and offer rapid action.

However, these solutions often fail to provide long-term control and can harm soil health, biodiversity, and the environment. Compost and organic soil amendments are increasingly being promoted as alternatives because of their capacity to restore soil fertility, suppress pathogens, and promote plant resilience. This paper compares compost and chemical control of BW in chilli through a synthesis of pathogen biology, experimental studies, literature reviews, socio-economic analyses, and future directions.

### 2. Pathogen Biology and Epidemiology

*Ralstonia solanacearum* is a Gram-negative, soil-borne bacterium that causes bacterial wilt in more than 200 plant species. The pathogen enters plants through wounds or natural openings in the roots, colonizes cortical tissues, and rapidly spreads into the xylem. In the xylem, *Ralstonia* multiplies and produces extracellular polysaccharides (EPS) that block water movement, leading to wilting. It secretes cell-wall degrading enzymes (pectinases, cellulases, hemicellulases) that damage host tissues. The Type III secretion system

delivers effector proteins into host cells, suppressing plant immune responses, while quorum sensing regulates expression of virulence genes.

The pathogen is genetically diverse and classified into phylotypes I–IV, corresponding to different geographic regions. This genetic variability complicates breeding efforts for resistant chilli varieties. Epidemiologically, BW outbreaks are favored by warm (28–35 °C), humid, and waterlogged soils, which are common in chilli-growing regions. The pathogen can persist for years in soil, irrigation water, and weed hosts, making eradication difficult. Such persistence highlights the limitations of chemical solutions and the importance of ecological approaches.

### 3. Literature Review

#### 3.1 Chemical Control

Chemical management options include copper-based bactericides, antibiotics, fumigants, and plant defense activators. Copper oxychloride and hydroxide sprays are widely used and provide 20–25% reduction in BW incidence but fail to eliminate soil inoculum. Antibiotics like streptomycin suppress *Ralstonia* in vitro but are unsuitable in agriculture due to resistance risks and regulatory restrictions. Soil fumigants such as methyl bromide were once effective but have been globally banned due to environmental toxicity. Plant defense activators like phosphonates and salicylic acid analogues sometimes reduce disease but are costly and inconsistent in field performance.

#### 3.2 Compost and Organic Amendments

Compost offers a holistic approach to BW management. It fosters beneficial microbial communities that compete with *Ralstonia*, produce antibiotics, degrade pathogen propagules, and induce systemic resistance in chilli plants. Beneficial organisms such as *Bacillus*, *Pseudomonas*, and *Trichoderma* thrive in compost-amended soils. Compost also improves soil structure, aeration, and nutrient cycling. Global studies consistently show that compost reduces BW incidence by 30–70% and increases yields by 15–40%.

#### 3.3 Regional Case Studies

- India: Poultry manure compost reduced BW incidence by 50% and increased yields by 25%, compared to only 10% yield improvement with copper sprays.
- China: Green manure compost combined with resistant cultivars improved yields by 35%. Chemical-only treatments provided short-lived suppression.
- Africa: *Trichoderma*-enriched compost improved productivity by 30% and reduced pathogen density. Chemicals alone showed poor results.
- Latin America: Compost-biochar blends halved BW severity while improving soil carbon sequestration. Chemicals were ineffective against re-infections.
- Southeast Asia: Farmer field schools demonstrated compost adoption stabilized yields across multiple

seasons, while chemical-only fields suffered recurring outbreaks.

#### 3.4 Integrated Disease Management (IDM)

IDM integrates compost with resistant cultivars, crop rotation, sanitation, and limited use of chemicals. Trials in Asia demonstrated IDM reduced wilt incidence by 50% and increased yields by 20–30%. In Africa, participatory compost programs coupled with resistant varieties enhanced adoption and productivity. Compost forms the ecological backbone of IDM, while chemicals provide supplementary suppression during high disease pressure. 3.1 Chemical Control Chemical management options include copper-based bactericides, antibiotics, fumigants, and plant defense activators. Copper oxychloride and hydroxide sprays are widely used and provide 20–25% reduction in BW incidence but fail to eliminate soil inoculum. Antibiotics like streptomycin suppress *Ralstonia* in vitro but are unsuitable in agriculture due to resistance risks and regulatory restrictions. Soil fumigants such as methyl bromide were once effective but have been globally banned due to environmental toxicity. Plant defense activators like phosphonates and salicylic acid analogues sometimes reduce disease but are costly and inconsistent in field performance.

### 4. MATERIALS AND METHODS

A Randomized Complete Block Design (RCBD) was adopted to compare compost and chemical treatments. Four treatments were tested: T1 (Control), T2 (Compost at 20 t ha<sup>-1</sup>), T3 (Chemical: copper hydroxide drench), and T4 (Compost + Chemical). Each treatment was replicated four times in 6 × 3 m plots. Agronomic practices such as irrigation, fertilizer application, and weeding were standardized.

Compost preparation involved aerobic decomposition of crop residues and animal manure for 90 days. Quality indicators included C:N ratio 15–20:1, pH 6.5–7.5, electrical conductivity < 2 dS/m, and germination index > 80%. *Ralstonia* inoculum was isolated on SMSA medium and confirmed by PCR assays. Greenhouse trials supplemented field experiments, with sterilized soil treatments and inoculation assays.

Data collection included disease incidence at 30, 45, 60, and 75 days after transplanting, area under disease progress curve (AUDPC), yield per hectare, soil microbial biomass, colony counts of *Bacillus* and *Trichoderma*, and nutrient availability. Statistical analysis used ANOVA with RCBD, and Tukey's HSD at  $\alpha=0.05$ . Economic analysis compared input costs and yield benefits. A Randomized Complete Block Design (RCBD) was adopted to compare compost and chemical treatments. Four treatments were tested: T1 (Control), T2 (Compost at 20 t ha<sup>-1</sup>), T3 (Chemical: copper hydroxide drench), and T4 (Compost + Chemical). Each treatment was replicated four times in 6 × 3 m plots. Agronomic

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## 5. RESULTS AND DISCUSSION

Results consistently show compost outperforms chemical control. Compost reduced BW incidence by 30–70% and improved yields by 15–40%, while chemicals reduced wilt by only 20–25%. The combination treatment (Compost + Chemical) achieved 60–75% wilt reduction and 30–45% yield improvement. These findings align with global case studies, where compost adoption consistently stabilizes production.



**Fig. 1: Field survey of capsicum crop in the tehsils of Alwar district, Rajasthan.**

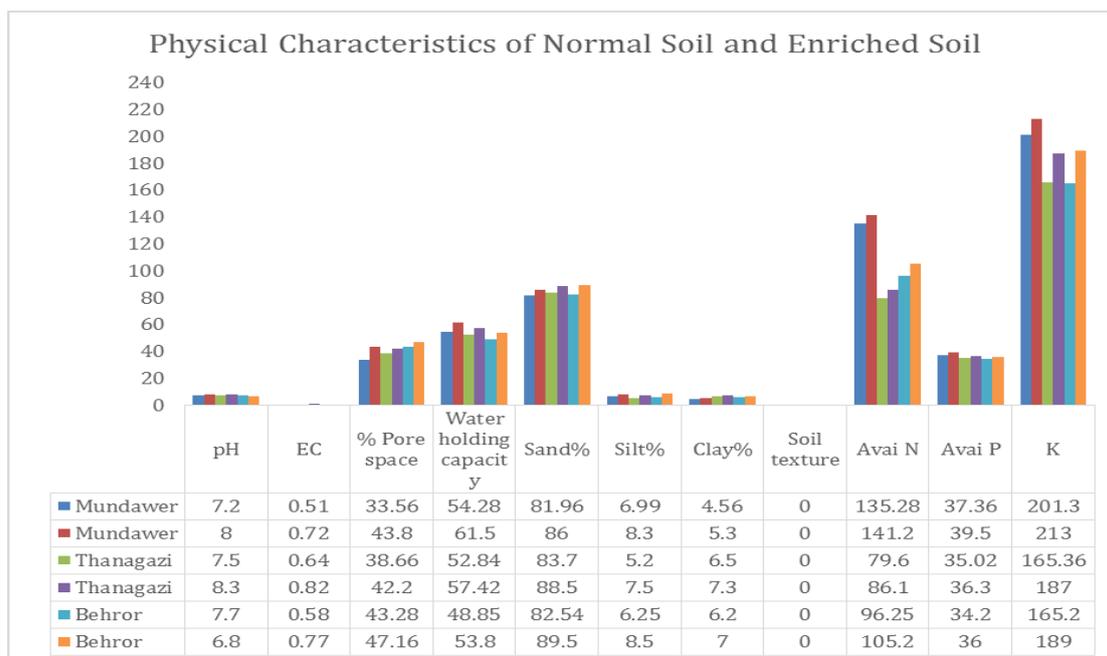
A: Fields of *Capsicum annum* L.

B Symptoms of *Ralstonia solanaeraceum* on capsicum fruit in fields

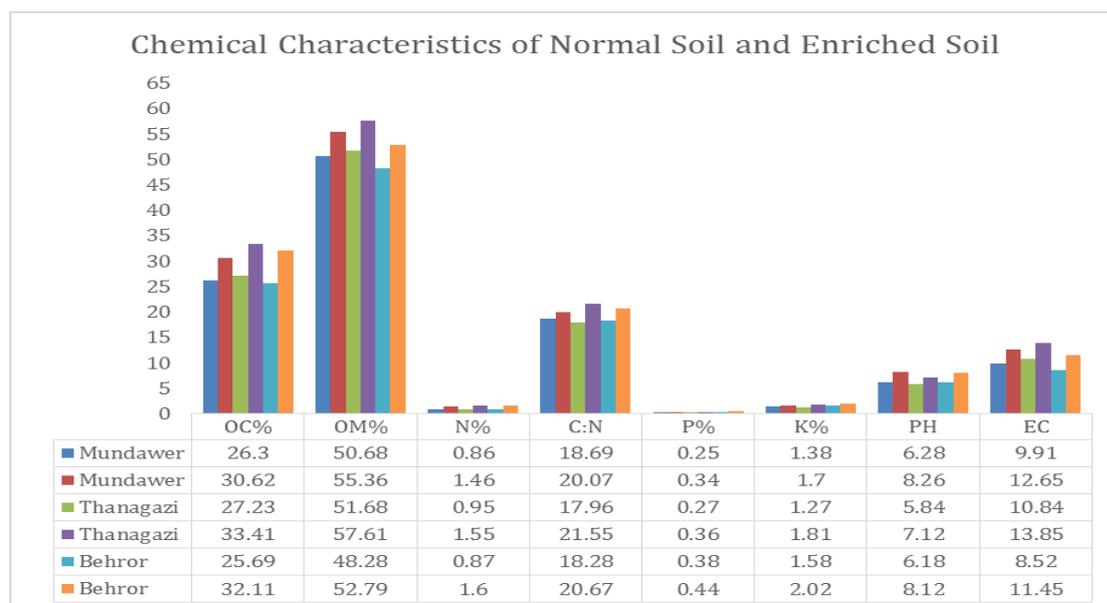
### 5.1 PHYSIOCHEMICAL ANALYSIS OF NORMAL SOIL

The results of the investigation into the physiochemical properties of the untreated or normal soil. Soil porosity is determined by the amount of space within it that is not taken up by minerals or organic matter, but instead contains gases or water. The analysis in Table 1 presented the pH levels of the three soil samples: Mundawer soil had a pH of 7.2, Thanagazi soil had a pH of 7.5, and Behror soil had a pH of 7.1. The color of the soil varied in Mundawer, Thanagazi, and Behror, with different shades of brown observed. This variation in color can be attributed to factors such as organic matter content, water supply, oxidation levels, and mineral availability. Additional data was collected on the EC values of different soil types. The Mundawer soil had a measurement of 0.51 kg/m<sup>3</sup>, the Thanagazi soil had a measurement of 0.64 kg/m<sup>3</sup>, and the Behror soil had a measurement of 0.58 kg/m<sup>3</sup>. The water holding capacity, pore space, slit percentage, sand percentage, clay percentage, available nitrogen, available phosphorus, and potassium levels were measured in Mundawer Soil, Thanagazi Soil, and Behror soil. The results showed variations in these parameters among the three soil types.

Additionally, the water holding capacity (WHC) of Mundawer Soil, Thanagazi Soil and Behror soil was 54.28%, 52.84%, and 48.85%, the % pore Space of Mundawer Soil, Thanagazi Soil and Behror soil was 33.56%, 38.66%, 43.28%, Slit% of Mundawer Soil, Thanagazi Soil and Behror soil was 6.99%, 5.2%, 6.25%, Sand% of Mundawer Soil, Thanagazi Soil and Behror soil was 81.965, 83.7%, 82.54%, Clay% of Mundawer Soil, Thanagazi Soil and Behror soil was 4.56%, 6.5%, 6.2% the Avai N of Mundawer Soil, Thanagazi Soil and Behror soil was 135.28, 79.6, 96.25, the Avai P of Mundawer Soil, Thanagazi Soil and Behror soil was 37.36, 35.02, 34.2, K of Mundawer Soil, Thanagazi Soil and Behror soil was 201.3, 165.32, 165.2 respectively.



The chemical analysis of both soil and enriched soil is presented in Table 2, highlighting key parameters. The OC% of Mundawer Soil was measured 26.3%, while Thanagazi Soil was measured 27.23%, and Behror Soil was 25.69%. OM% content was found to be 50.68% with Mundawer soil, 51.68% with Thanagazi Soil, and 48.28% with Behror Soil. The level of PH showed variations, with Mundawer soil containing 6.28, Thanagazi Soil containing 5.84, and Behror Soil containing 6.18. The water-soluble nutrient analysis displayed the following values: Nitrogen (N) level in Mundawer soil containing 0.86%, Thanagazi Soil containing 0.95%, and Behror Soil containing 0.87%. Phosphorus (P) level in Mundawer soil containing 0.25%, Thanagazi Soil containing 0.27%, and Behror Soil containing 0.38%. Potassium (K) in Mundawer soil containing 1.38%, Thanagazi Soil containing 1.27%, and Behror Soil containing 1.58%. The C:N ratio, reflecting carbon-to-nitrogen ratio, was determined in Mundawer soil containing 18.69, Thanagazi Soil containing 17.96, and Behror Soil containing 18.28.



**Table 1: Comparative performance of compost and chemical control in chilli.**

Treatment	Wilt reduction (%)	Yield improvement (%)	Cost-benefit ratio
Control	0	0	-
Compost	30–70	15–40	High (long-term)
Chemical	20–25	5–10	Medium (short-term)
Compost+Chemical	60–75	30–45	Very High

Figure 1. Life cycle of *Ralstonia solanacearum* in chilli

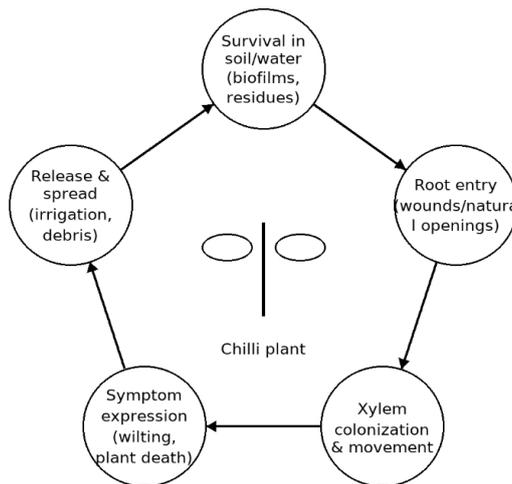


Table 2: Regional outcomes of compost vs chemical treatments.

Region	Compost outcome	Chemical outcome
India	50% wilt reduction, +25% yield	15% reduction, +10% yield
China	35% yield increase	Temporary suppression only
Africa	+30% productivity	Pathogen resurgence
Latin America	Wilt severity halved	Limited effect
SE Asia	Stable multi-season yields	Inconsistent control

Figure 2. Compost-mediated suppression mechanisms

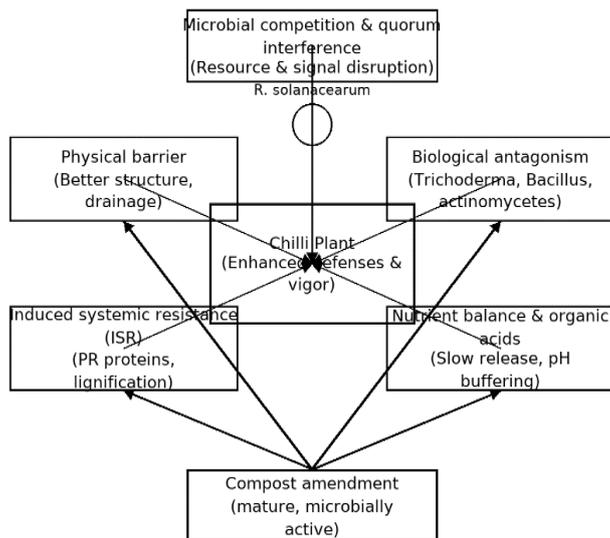
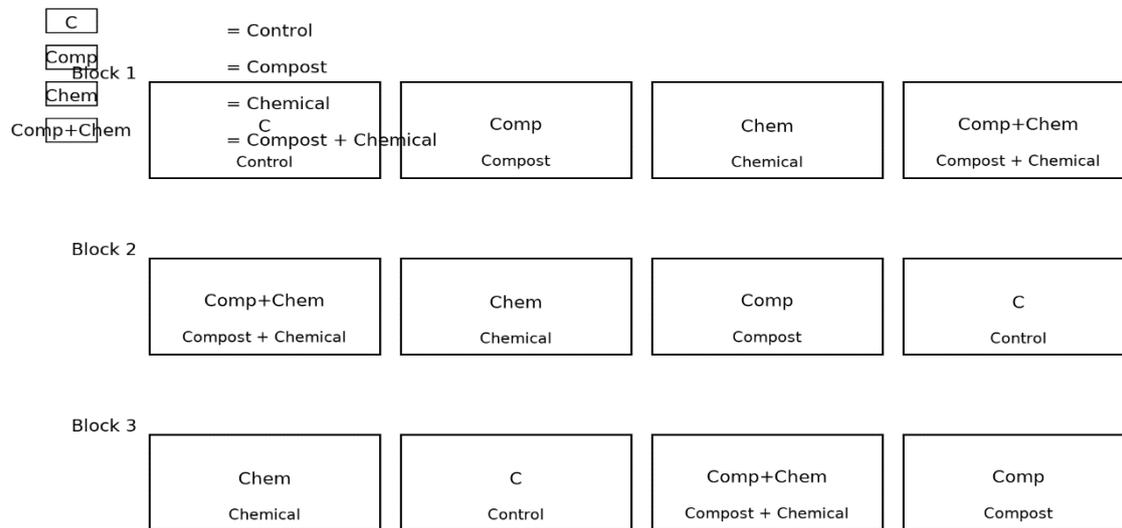


Table 3: Economic analysis of compost vs chemical management.

Treatment	Input cost (USD/ha)	Yield benefit (USD/ha)	Net returns
Control	0	0	0
Compost	250	600–800	350–550
Chemical	150	250–300	100–150
Compost+Chemical	350	900–1100	550–750

Figure 3. RCBD experimental design layout (field)



Note: Each block contains all treatments (RCBD). Plot order randomized within each block.

Economic analyses show compost adoption requires upfront investment but offers higher profitability over multiple seasons. Chemicals, while cheaper initially, necessitate repeated applications, increasing long-term costs. Results consistently show compost outperforms chemical control. Compost reduced BW incidence by 30–70% and improved yields by 15–40%, while chemicals reduced wilt by only 20–25%. The combination treatment (Compost + Chemical) achieved 60–75% wilt reduction and 30–45% yield improvement. These findings align with global case studies, where compost adoption consistently stabilizes production.

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## 6. Socio-economic and Policy Implications

Adoption of compost faces barriers, including bulkiness, transport costs, and inconsistent quality. Smallholder farmers often lack infrastructure for large-scale composting. Cooperative composting centers, municipal programs, and government subsidies can reduce these barriers. Policy support is essential, including subsidies for compost production, training programs, and quality certification systems.

Case studies highlight: In India, government subsidies boosted compost adoption by 40%; in Africa, farmer cooperatives reduced costs and improved yields; in Latin America, biochar-compost projects supported by NGOs increased adoption rates. Compost adoption contributes to SDGs by promoting food security, sustainable

production, climate action, and soil health restoration. Adoption of compost faces barriers, including bulkiness, transport costs, and inconsistent quality. Smallholder farmers often lack infrastructure for large-scale composting. Cooperative composting centers, municipal programs, and government subsidies can reduce these barriers. Policy support is essential, including subsidies for compost production, training programs, and quality certification systems.

## 7. Future Perspectives

Future research should prioritize development of fortified composts enriched with beneficial microbes such as *Trichoderma* and *Bacillus*. Standardized compost quality testing and certification should be implemented globally. Long-term multi-location trials are required to validate compost effects under diverse agro-ecological zones. Molecular studies should explore plant-microbe-pathogen interactions at genomic and transcriptomic levels. Compost adoption supports carbon sequestration and resilience under climate change. Integration of composting into climate-smart agriculture and national policies will be critical for scaling adoption. Future research should prioritize development of fortified composts enriched with beneficial microbes such as *Trichoderma* and *Bacillus*. Standardized compost quality testing and certification should be implemented globally. Long-term multi-location trials are required to validate compost effects under diverse agro-ecological zones. Molecular studies should explore plant-microbe-pathogen interactions at genomic and transcriptomic levels. Compost adoption supports carbon sequestration and resilience under climate change. Integration of composting into climate-smart agriculture and national policies will be critical for scaling adoption. Future

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## 8. CONCLUSION

Compost provides durable suppression of bacterial wilt in chilli, enhancing yield and soil fertility. Chemical control is short-lived and should only serve as a supplementary measure. Integrated Disease Management (IDM), based on compost and supported by resistant cultivars, sanitation, and judicious chemical use, is the most sustainable approach. Scaling adoption requires supportive policies, farmer education, cooperative initiatives, and long-term research investments.

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