RESEARCH ARTICLE Agricultural Science Digest, Volume 45 Special Issue: 104-108 (November 2025)

Survey of Charcoal Rot Disease of Strawberry in Maharashtra

S.D. Sorate[1], S.S. Kamble[1], M.S. Desai[2], A.A. Jagtap[3]

10.18805/ag.D-6247

ABSTRACT

Background: Charcoal rot disease, caused by the soil-borne pathogen *Macrophomina phaseolina*, poses a significant threat to strawberry cultivation in Maharashtra, India. This study highlights critical factors contributing to disease spread, including climate variables, soil characteristics and farming practices. We propose a comprehensive set of recommendations for improved disease management, aiming to enhance strawberry production and economic outcomes for farmers in Maharashtra.

Methods: This study presents an extensive survey of charcoal rot incidence, severity and management practices in the region. Through rigorous field surveys conducted across 100 strawberry farms during 2020 - 2022 laboratory analyses of 2000 plant samples and detailed interviews with 300 local farmers, we identified the prevalence of the disease, its impact on yield and quality and the effectiveness of current management strategies.

Result: Our findings reveal that 47% of surveyed farms reported charcoal rot incidence, with an average Disease Severity Index of 3.4 on a 5-point scale. Affected farms experienced yield reductions of 18-35% and significant decreases in fruit quality, with economic losses estimated at 150,000-400,000 per hectare. Chemical treatments and crop rotation are commonly employed, their effectiveness varies considerably. Integrated disease management practices showed the most promise in reducing disease severity, with a 40% reduction in DSI compared to conventional methods.

Key words: Charcoal rot, Disease survey, Economic impact, Integrated pest management, *Macrophomina phaseolina*, Strawberry.

INTRODUCTION

Strawberry (*Fragaria* × *ananassa*) has emerged as a high-value fruit crop in Maharashtra, India, with cultivation expanding rapidly over the past decade. making it the second-largest strawberry-producing state in India after Himachal Pradesh. This growth has been driven by increasing domestic demand, favorable agro climatic conditions in certain regions of Maharashtra and the crop's potential for high returns per unit area.

In the year 2004 there was 529.000 - acres land under the cultivation of strawberry. Mainly strawberry cultivation in India is in Kashmir, Punjab, UP, HP, Maharashtra, Tamil Nadu and Karnataka state. Now strawberry is cultivating under an eye of commercial base in Kashmir- Shrinagar, Gulmarg; Punjab- Jalandhar, Gurudaspur; UP- Meerat, Muzzafarnagar, Dehradun, Saharanpur, Nainital, Faizabad; Karnataka- Banglore and Tamil Nadu- Ooty. Maharashtra-Nashik, Dhule, Pune, Satara; Strawberry cultivation done mostly on hilltops. Mahabaleshwar region has about 1500-1800- acre land under the cultivation of strawberry (Jadhav 2013).

Strawberry charcoal rot caused by *Macrophomina phaseolina* classified as one of the most destructive diseases. The optimum conditions for the disease development is high temperature, shortage in soil water supply, sandy soil and stressed plants (Mihail, 1989). Survival and longevity of *M. phaseolina microslerotia* and the infected plant debris can help in consequently infection of strawberry plants season after season and increased the challenges in charcoal rot control programme (Dhingra and Sinclair, 1975).

Macrophomina phaseolina is one of the pathogen that causes charcoal rot of *Vigna radiate* L. Wilczek resulting the great economic loss (Gupta *et al*., 2015). The disease is particularly problematic in regions with high temperatures and drought stress, conditions that are becoming more common in Maharashtra due to climate change.

Dry root rot of chickpea is an important soil-borne disease in arid and semi arid region of Rajasthan. A roving survey was conducted during *rabi* season 2014-15 and 2015-16 in major chickpea growing districts revealed that dry root rot was major disease problem in Jaisalmer, Jodhpur, Jhunjhunu, Churu and Bikaner districts (Pratap and Godara, 2022).

Strawberry charcoal rot disease caused by *M. phaseolina* (Tassi.) considered an economically significant challenge and limitation factor in the regions of strawberry production worldwide (Chamorro *et al*., 2016). Primary infection by

[1]Department of Botany Dahiwadi College, Dahiwadi, Satara-415 508, Maharashtra, India.
[2]Department of Botany, Karmaveer Hire College, Gargoti, Kolhapur-416 209, Maharashtra, India.
[3]Department of Botany, Sharadchandra Pawar Mahavidyalaya, Lonand, Satara-415 521, Maharashtra, India.

Corresponding Author: S.S. Kamble, Department of Botany Dahiwadi College, Dahiwadi, Satara-415 508, Maharashtra, India. Email: simrankamble814@gmail.com

How to cite this article: Sorate, S.D., Kamble, S.S., Desai, M.S. and Jagtap, A.A. (2025). Survey of Charcoal Rot Disease of Strawberry in Maharashtra. *Agricultural Science Digest*. **45 (Special Issue):** 104-108. doi: 10.18805/ag.D-6247.

Submitted: 18-11-2024 **Accepted:** 06-03-2025 **Online:** 05-06-2025

M. phaseolina mainly occurs in root, but pathogenesis and sclerotium formation may extend above ground. Sclerotia also may form in live host tissues without visible symptoms (Kending *et al*., 2000). Sclerotia are the resting structures of the pathogen in soil and infested plant debris (Papa*viz*as, 1977).

Charcoal rot in strawberry usually occurs after the plants are well established and begin to produce fruit: the roots become necrotic, initially older leaves wilt, turn greyish-green and dry up, but in time all the foliage collapses and dries up (Hajlaoui *et al*., 2015).

Despite its significant economic impact, there is limited research on the prevalence and management of charcoal rot in Maharashtra's strawberry cultivation. A literature review revealed only few published studies are on charcoal rot in Indian strawberries in the past decade, none of which focused specifically on Maharashtra. This knowledge gap hampers the development of effective disease management strategies and puts the region's strawberry industry at risk.

Therefore, this study aims to address this critical issue by:

1. Surveying the incidence and severity of charcoal rot across major strawberry-growing areas in Maharashtra.
2. Assessing the impact of the disease on crop yield, fruit quality and economic outcomes for farmers.
3. Evaluating the effectiveness of current management practices employed by farmers.
4. Investigating the relationship between environmental factors, farming practices and disease incidence.
5. Providing evidence-based recommendations for improved disease control and prevention.

By conducting this comprehensive survey, we seek to provide valuable insights that will inform better disease management practices, enhance strawberry production and contribute to the sustainable growth of the strawberry industry in Maharashtra (Choudhary and Singh, 2021).

MATERIALS AND METHODS

Study area and sampling

The survey was conducted across seven major strawberry-growing districts in Maharashtra: Pune, Nashik, Sangli, Satara, Ahmednagar, Kolhapur and Solapur during 2020-2022. The collected samples brought to currently working research laboratory of Dahiwadi College, Dahiwadi. Within each district, strawberry farms were selected using a stratified random sampling method to ensure representation of different farm sizes and management practices. A total of 100 farms were surveyed, with the number of farms per district proportional to the district's strawberry cultivation area. The survey was carried out during two consecutive growing seasons from November 2020 to February 2022 to account for inter-annual variability.

Data collection

Field surveys

At each farm, 200 strawberry plants were randomly selected and examined for symptoms of charcoal rot. Disease incidence and severity were recorded using standardized protocols.

Plant sample analysis

20 potentially infected plant samples were collected from each farm (total 2000 samples) and analyzed in the laboratory to confirm the presence of *M. phaseolina*. Isolation and identification of the pathogen were performed using selective media and molecular techniques (ITS sequencing).

Farmer interviews

Structured interviews were conducted with 300 strawberry farmers (three from each surveyed farm) to gather information on management practices, perceived disease impact, socio-economic factors and historical farm data.

Environmental data

Climate data (temperature, rainfall, humidity) for each surveyed location were obtained from the nearest weather stations. Soil samples were collected and analyzed for physical and chemical properties.

Pathogenicity test

symptoms of the charcoal rot were occurred in inoculated pots. Isolate were reisolated from strawberry plants in the inoculated pots, Koch's postulates fulfilled.

Disease assessment

Disease incidence was calculated as the percentage of plants showing charcoal rot symptoms. Disease severity was assessed using a 0-5 scale:
0 = No symptoms.
1 = Slight root discoloration.
2 = Moderate root rot, slight crown discoloration.
3 = Severe root rot, moderate crown rot.
4 = Severe crown rot, plant wilting.
5 = Plant death.

Mathematical formulations

1. Disease severity index (dsi)

The DSI was calculated using the following formula:

$$DSI = \frac{\Sigma \text{ Disease rating} \times \text{Number of plants in each rating}}{\text{total number of plants} \times \text{Maximum disease rating}} \times 100$$

2. Prevalence rate

Prevalence rate was calculated as:

$$\text{Prevalence rate} = \frac{\text{Number of farms with charcoal rot}}{\text{Total number of farms surveyed}} \times 100$$

3. Yield loss estimation

Yield loss was estimated using the formula:

$$\text{Yield loss (\%)} = \frac{\text{Expected yield - Actual yield}}{\text{Expected yield}} \times 100$$

4. Economic loss calculation

Economic loss per hectare was calculated as:

Economic loss = (Yield loss × Price per kg × Expected yield per hectare) + Additional management costs

RESULTS AND DISCUSSION

Prevalence and severity of charcoal rot

Our comprehensive survey revealed that charcoal rot is a widespread and significant problem in Maharashtra's strawberry cultivation. Out of the 100 farms surveyed, 47 farms (47%) reported the presence of charcoal rot symptoms. The prevalence varied considerably across districts, with Pune showing the highest prevalence (68%) and Ahmednagar the lowest (28%) (Table 1).

The average disease severity index (DSI) across all surveyed farms was 3.4, indicating moderate to severe disease pressure. However, there was considerable variation in severity both within and between districts (Fig 1).

The occurrence of high DSI values shows that the disease has the potential to cause significant outbreaks under favorable conditions. Temporal analysis of disease progression showed that charcoal rot incidence typically increased rapidly from 60 days after planting, reaching peak levels around 120 days. The logistic growth model provided a good fit to the observed disease progress curves ($R^2 = 0.89$), with an average rate of disease increase (r) of 0.058 per day.

Impact on yield, fruit quality and economic outcomes

Charcoal rot had a substantial impact on strawberry yield and fruit quality. Farms affected by the disease reported an average yield loss of 26.7% (95% CI: 23.8% - 29.6%). There was a strong positive correlation between disease severity and yield loss ($r = 0.82$, $p<0.001$).

The economic impact of charcoal rot was significant. Based on current market prices and production costs, we estimated the average economic loss due to charcoal rot at ₹ 275,000 per hectare, with a range from ₹ 150,000 to ₹ 400,000 depending on disease severity and market conditions.

In addition to reduced yield, farmers reported several quality issues in affected crops.

- 88% of affected farms noted smaller fruit size (average reduction of 22% in fruit weight).
- 75% reported reduced sweetness (average decrease of 1.5 °Brix in total soluble solids).
- 62% observed shorter shelf life of harvested fruit (1-2 days less than unaffected fruit).

These quality issues further compounded the economic impact of the disease, as lower-quality fruit fetched lower prices in the market. On average, affected farms reported a 15-20% reduction in price per kilogram for their produce.

Management practices and their effectiveness

The survey revealed a diverse range of management practices employed by farmers to control charcoal rot (Table 2).

The chemical pesticides are the first choice for farmers to control plant pathogens in order to obtain abundant crop yield (Junaid *et al.*, 2013). Different nitrogen sources tested both in solid media and liquid broth, peptone was identified as best nitrogen source for maximum mycelial growth and mycelia weight (7.47 cm and 7.77 g) reported by (Bhupati and Theradimanl, 2018).

Integrated disease management (IDM) practices, although used by only 42% of farms, showed the highest effectiveness in reducing disease incidence (60% reduction) and the best cost-effectiveness ratio. IDM typically involved a combination of cultural practices, biological control and judicious use of chemicals.

Statistical analysis using GLMMs showed that farms employing IDM had significantly lower disease severity (mean DSI = 2.1) compared to those relying solely on chemical control (mean DSI = 3.7) ($p<0.001$).

Table 1: Prevalence of charcoal rot across surveyed districts.

District	Number of farms surveyed	Farms with charcoal rot	Prevalence rate (%)
Pune	25	17	68
Nashik	20	11	55
Sangli	15	7	47
Satara	12	5	42
Kolhapur	10	4	40
Solapur	10	3	30
Ahmednagar	8	2	28
Total	100	47	47

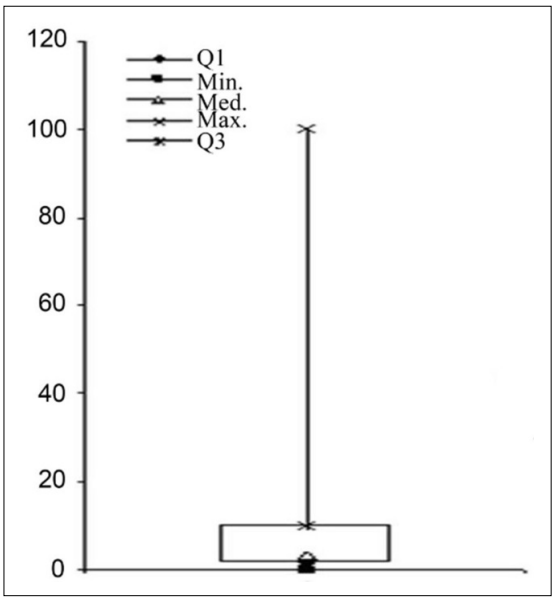


Fig 1: Box plot showing the distribution of disease severity Index across districts.

Table 2: Management practices and their effectiveness.

Management practice	Farms using (%)	Disease reduction (%)	Cost-effectiveness ratio
Chemical fungicides	85	35	1.8
Crop rotation	68	42	2.3
Soil solarization	45	50	2.7
Biological control agents	38	38	2.1
Resistant varieties	25	55	3.2
Integrated disease management	42	60	3.5

Factors contributing to disease spread

Principal Component Analysis and Structural Equation Modeling revealed several key factors contributing to the spread and severity of charcoal rot:

a) Climate

Temperature and rainfall were significant predictors of disease incidence. Farms located in areas with mean annual temperatures above 25°C and annual rainfall below 800 mm showed 1.8 times higher disease incidence.

b) Soil characteristics

Sandy soils (>60% sand content) were associated with 1.5 times higher disease severity compared to loamy soils. Soil pH also played a role, with more acidic soils (pH<6.0) showing higher disease incidence.

c) Irrigation practices

Farms using drip irrigation showed 30% lower disease incidence compared to those using flood irrigation ($p<0.01$). The timing of irrigation also mattered, with early morning irrigation associated with lower disease severity.

d) Crop history

Farms that had previously grown susceptible crops (*e.g.*, soybeans, sunflowers) in the past 3 years showed 1.7 times higher charcoal rot incidence.

e) Planting density

Higher planting densities (>50,000 plants/ha) were associated with increased disease severity, likely due to creating a more favorable microclimate for the pathogen.

CONCLUSION

This comprehensive survey of charcoal rot disease in Maharashtra's strawberry cultivation has revealed the significant and widespread threat posed by *Macrophomina phaseolina* to the region's strawberry industry. With a 47% prevalence rate and substantial impacts on yield, fruit quality and economic outcomes, the disease represents a major challenge for farmers and the agricultural sector.

While chemical fungicides remain the most widely used management practice, their moderate effectiveness and potential environmental impacts suggest the need for alternative approaches. The laboratory experiments were carried out to study the effect of different salts on seed borne *M. phaseolina* and *Fusarium sp*. as an alternative to synthetic fungicides for the control of charcoal rot and wilt disease in blackgram (Indra *et al*., 2019)

Based on these findings, we recommend:

1. Promoting the widespread adoption of integrated disease management practices, tailored to local conditions and farm characteristics.
2. Investing in the development and distribution of resistant strawberry varieties suited to Maharashtra's climate.
3. Implementing a comprehensive farmer education program on disease symptoms, epidemiology and best management practices.
4. Establishing a statewide monitoring and early warning system for disease outbreaks, incorporating climate data and predictive modeling.
5. Encouraging the adoption of water-efficient irrigation systems and optimizing irrigation timing to reduce disease risk.
6. Supporting further research on novel biological control agents and environmentally friendly fungicides.
7. Developing policies to support farmers in transitioning to more sustainable and resilient strawberry production systems.

By implementing these recommendations and continuing to build our understanding of charcoal rot disease, we can work towards a more resilient and productive strawberry industry in Maharashtra, benefiting farmers, consumers and the broader agricultural sector.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Bhupati, P. and Theradimanl, M. (2018). *In vitro* studies of carbon, nitrogen sources and pH on mycelia growth black gram root rot caused by *Macrophomia phaseolina*. *The Pharma Innovation Journal.* **7(6):** 33.

Chamorro, M., Seijo, T.E., Noling, J.C., B. De los Santos and Peres, N.A. (2016). Efficacy of fumigant treatments and inoculums placement on control of *Macrophomina phaseolina* in Strawberry beds. *Crop Protection.* **90:** 163-169.

Choudhary, D. and Singh, N. (2021). Advances in strawberry disease management: Focus on charcoal rot. *Horticultural Science*. **58(3):** 342-350. doi: 10.21273/HORTSCI15634-21.

Dhingra, O.D. and Sinclair, J.B. (1975). Survival of *Macrophomina phaseolina* sclerotia in soil: Effects of soil moisture, carbon: Nitrogen ratios, carbon sources and nitrogen concentrations. *Phytopathology*. **65:** 236-240.

Gupta, P., Chakraborty, D. and Mittal, R.K. (2015). Antifungal activity of medicinal plants leaf extracts on growth of *Macrophomina phaseolina*. *Agricultural Science Digest.* **35:** 211-214. doi: 10.5958/0976-0547.2015.00048.8.

Hajlaoui, M.R., Mnari-Hattab, M., Sayeh, M., Zarrouk, I., Jemmali, A. and Koike, S.T. (2015). First report of *Macrophomina phaseolina* causing charcoal rot of strawberry in Tunisia. *New Dis. Rep.* **32(14):** 2044-0588.

Indra, N., Kavyashree, A.S., Swetha, D., Asmina, M. and Shalini (2019). Fungitoxic effect of inorganic salts for the management of seed borne *Macrophomina phaseolina* and *Fusarium* sp. causing charcoal rot and wilt disease in blackgram. *Indian Journal of Agricultural Research.* **53:** 208-212. doi: 10.18805/IJARe.A-5146.

Jadhav, M.T. (2013). A study of cultivation and marketing of strawberry in Satara district. Ph. D Thesis S. P. University of Pune. pp: 29: 48.

Junaid, J.M., Dar, N.A., Bhat ,T.A., Bhat, A.H. and Bhat, M.H. (2013). Commercial biocontrol agents and their mechanism of action in the management of plant pathogens. *International Journal of Modern Plant and Animal Sciences.* **1(2):** 139-157.

Kending, S.R., Rupe, J.C. and Scott, H.D. (2000). Effect of irrigation and soil water stress on densities of *Macrophomia phaseolina* in soil and roots of two soyabean cultivars. *Plant Dis.* **84:** 895-900.

Mihail, H.D. (1989). *Macrophomina phaseolina*: Spatio-temporal dynamics of inoculums and of disease in a highly susceptible crop. *Phytopathology.* **79:** 848e855.

Papaviza, G.C. (1977). Some factors affecting survival of sclerotia of *Macrophomia phaseolina* in soil. *Soil Biol. Biochem.* **9:** 337-341.

Pratap, M. and Godara, S.L. (2022). Occurrence distribution of dry root rot of chickpea caused by *Macrophomina phaseolina* (Tassi) Goid. in aride region of Rajasthan. *Legume Research.* **45:** 639-645. doi: 10.18805/LR-4429.