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# Efficacy of Integrated Disease Management Strategies for Bacterial Blight in Cowpea: Insights from a Three-Year Study

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## Abstract

Cowpea *(Vigna unguiculata)* crop is facing significant threats from bacterial blight caused by *Xanthomonas axonopodis* pv. *vignicola*, which can reduce yields by up to 80%. This study evaluated various treatments over three *Kharif* seasons (2020-2022) at Junagadh, India to manage this disease effectively. The results indicated that four foliar applications of copper oxychloride at 0.3% ($T_1$) achieved the lowest percentage disease index (PDI) of 10.50, significantly outperforming the control group (PDI: 38.23). Additionally, $T_1$ yielded the highest marketable pod yield of 102.31 q ha$^{-1}$, compared to only 40.12 q ha$^{-1}$ in the control. Economic analysis revealed $T_1$'s impressive benefit-cost ratio of 6.29, highlighting its financial viability. Conversely, treatments involving *Trichoderma viride* ($T_6$) resulted in a higher PDI of 32.08 and lower yields, suggesting limited effectiveness in this context. These findings underscore the importance of integrating chemical and biological control strategies to enhance cowpea productivity and sustainability, providing critical insights for farmers and policymakers in disease management practices.

**Key words**: Cowpea, Bacterial blight, Copper Oxychloride, Trichoderma viride, Disease management

## Introduction

Cowpea (*Vigna unguiculata*), commonly known as black-eyed pea, is a vital leguminous crop extensively cultivated worldwide, especially in arid and semi-arid regions. It serves as a key source of protein, dietary fiber, and essential nutrients for millions, particularly in developing countries. Renowned for its adaptability to diverse climates and poor soils, cowpea contributes significantly to food security and sustainable agriculture, especially in areas facing drought and soil degradation challenges (Mahadevakumar & Janardhana, 2014; Deepika et al., 2021; Herniter et al., 2020). In India, cowpea is grown over 1.5 million hectares with an annual production of about 1.5 million tonnes, predominantly in Maharashtra, Gujarat, and Uttar Pradesh (Kiran et al., 2018). Beyond its grains, its leaves are consumed as vegetables, and it is valued as a green manure crop for enhancing soil fertility through nitrogen fixation (Massey & Nautiyal, 2020; Jethwani et al., 2015). With 20-30% protein and abundant vitamins and minerals, cowpea is a nutritional cornerstone in rural diets where food diversity is limited (Jethwani et al., 2015; Kiran et al., 2018). Cowpea also bolsters smallholder farmers' livelihoods in developing countries by providing reliable food and income in drought-prone regions. Its role in intercropping systems, improving yields and economic resilience, further underscores its agricultural importance (Ayalew et al., 2021; Edema et al., 2023; Suhi et al., 2022). Additionally, its nitrogen-fixing ability enhances soil health, aligning with global goals for sustainable and eco-friendly farming (Nelson et al., 2021; Kiran et al., 2018).

Bacterial blight in cowpea, caused by *Xanthomonas axonopodis* pv. *vignicola*, poses a significant challenge to cowpea production, with severe economic and food security implications. This disease can cause yield reductions of up to 80% under conducive conditions (Agbicodo et al., 2010; Durojaye et al., 2019). Manifesting as leaf spots, wilting, and premature leaf drop, it compromises photosynthesis, stunts growth, and reduces pod formation (Dinesh et al., 2016; Nantale et al., 2023). The economic toll includes both direct losses from diminished yields and indirect costs such as reduced market value and expenditures on disease management. In regions like Uganda, where cowpea is a staple, the absence of resistant varieties exacerbates the issue, highlighting the need for sustainable disease management strategies (Nantale et al., 2023). Traditional practices without effective control measures perpetuate cycles of low productivity and financial hardship for farmers (Oguntade et al., 2022). Bacterial blight continues to pose a significant threat to cowpea production, highlighting the need for focused research on its effective and cost-efficient management to ensure sustainable agricultural practices for this crop.

Previous studies suggest that integrating biological control agents with strategic applications of fungicides and antibiotics offers an effective and sustainable solution for managing bacterial blight in cowpea crops. Biological agents like *Trichoderma spp*. enhance plant health and resilience against pathogens while reducing the reliance on chemical inputs (McKernan et al., 2022). Combining these agents with fungicides, such as copper-based compounds and systemic fungicides, has shown to effectively suppress disease when applied at optimal times (Capo & Blandino, 2021). Research indicates that integrating these strategies enhances disease control efficacy, minimizes resistance development in pathogens, and reduces environmental impacts (Bryukhanova, 2021; Kole et al., 2019). Studies also demonstrate the synergistic effects of microbial agents and fungicides in managing diseases like *Fusarium* wilt and Phytophthora blight, suggesting their potential adaptation for bacterial blight in cowpeas (Hong et al., 2013). Moreover, the dual action of antibiotics and fungicides provides a broad-spectrum defense against bacterial and fungal pathogens, making it especially beneficial in complex disease scenarios (Genet, 2023). Thus, this integrated management approach combines biological and chemical controls to achieve superior, economical, and sustainable disease management outcomes for cowpea farming.

The present study aims to evaluate the efficacy of biocontrol agents, commonly available fungicides, and antibiotics for managing bacterial blight disease in *Vigna unguiculata*, a critical leguminous crop extensively grown in arid and semi-arid regions. The treatments were applied as seed treatments, alone or in combination with foliar sprays, to assess their effectiveness over three consecutive years. This long-term study seeks to validate and provide an effective and economically viable management practices for the researchers, farmers and policy makers. By recommending sustainable disease management strategies, the study addresses the dual goals of enhancing crop productivity and reducing input costs. Ultimately, it contributes to the broader objectives of sustainable agriculture by reducing chemical dependency and promoting eco-friendly farming practices.

## 2. Materials and Methods

2.1 Experimental site and design

The Vegetable Research Station, Junagadh Agricultural University, Junagadh (Gujarat) is situated at an elevation of 61 meters above mean sea level on latitude of $21^{0}$.31’ N and longitude of $70^{0}$.33’ E. This station belongs to South Saurashtra Agro-climatic Zone-VII of Gujarat State. Total cultivated area of the station is 19 hectare. The average annual rainfall is 903 mm and distributed over a period of 38 days with peak rainfall in July and August. Physico-chemical properties of the soil is as mention in the Supplementary Table 1.

The study was carried out during *kharif* seasons with three consecutive years 2020-21, 2021-22 and 2022-23 at Vegetable Research Station, Junagadh Agricultural University, Junagadh. The experiment was laid out in a randomized block design (RBD) with three replications. The comprised of 7 treatments which was given below (Table No. 1). Experiment was conducted in a net plot size of 3 m × 2.4 m (40 plants/plot) and susceptible variety anand vegetable cowpea-1was used for the experiment. Sowing, spacing, fertilizer application and inter cultural operations were carried out as per the package of practice.

2.2 Isolation of *Xanthomonas axonopodis* pv. *vignicola*

Cowpea leaves exhibiting symptoms of common bacterial blight were collected from previous experimental trials conducted in the research field. The symptomatic leaves were transported to the laboratory in sterile plastic bags for further analysis. Surface sterilization was performed using 0.5% NaOCl, followed by three consecutive rinses with sterile distilled water. The leaves were then air-dried under ambient laboratory conditions. Small sections (1–2 mm) of infected leaf tissue were excised and inoculated onto nutrient agar (NA) medium, composed of 15.00 g $L^{-1}$ agar, 5.00 g $L^{-1}$ peptone, 5.00 g $L^{-1}$ sodium chloride (NaCl), 2.00 g $L^{-1}$ yeast extract, and 1.00 g $L^{-1}$ beef extract, procured from Sisco Research Laboratories Pvt. Ltd., India. The inoculated plates were incubated at 28°C for 48–72 hours to facilitate bacterial growth. To ensure purity, subculturing was performed, and the resulting pure isolate was maintained on NA slants for subsequent studies (Ganiyu et al., 2017).

2.3 Inoculation of *X. axonopodis* pv. *vignicola*

Plant was exposed to artificial inoculation by isolated pure culture of *X. axonopodis* pv. *vignicola*. Four foliar sprays of each treatment were given, the 1st foliar spray was given when the disease initiated and other foliar spray was given after 10 days interval.

2.4 Observation and analysis of the data

The observations were recorded on the severity of the disease on the basis of relative percentage of leaf area covered by the disease using 0 to 5 scale Shah et al., 1991(Supplementary Table 2) on randomly selected ten plants per plots and per cent disease intensity was worked out using Wheeler (1969) formula. Statistical analysis was carried out as per standard methods suggested by Panse and Sukhatme (1995).

$$PDI = \frac{\text{Sum of numerical disease rating}}{\text{No. of plants assessed x Maximum disease rating}} \times 100$$

The marketable pod yield (q $ha^{-1}$) of leguminous vegetable cowpea was recorded. Economic parameters such as per cent increase in pod yield over control and benefit cost ratio (BCR) were calculated by considering the cost of all inputs and outputs.

$$ICBR = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

**Table 1: The details of the treatments**

| Treatments | Details |
|---|---|
| $T_0$ | Seed treatment with *Trichoderma viride*@ 4g/kg + application of 50 kg FYM fortified with 5q neem cake and 2.5 kg *Trichoderma viride*/ha 15 days prior to sowing is (common in all treatment except control) |
| $T_1$ | Four foliar sprays of copper fungicide (copper oxychloride 50%WP @ 0.3% /copper hydroxide @ 0.2%) at 10 days interval started with the initiation of disease |
| $T_2$ | Four foliar sprays of streptocycline @100 ppm + carbendazim 12% + mancozeb 63% @0.2% at 10 days interval started with the initiation of disease |
| $T_3$ | Four Foliar sprays of streptocycline @100 ppm + tebuconazole 50% + trifloxystrobin 25%WG @ 0.1% at 10 days interval started with the initiation of disease |
| $T_4$ | Four foliar sprays of copper fungicide (Bordeaux mixture (0.8%) / copper oxychloride 50%WP @ 0.3% /copper hydroxide 77%WP @ 0.2%) and carbendazim 12%+ mancozeb 63% @0.2% inalternate spray at 10 days<br>at 10 days interval started with the initiation of disease |
| $T_5$ | Four foliar sprays of copper fungicide and tebuconazole 50% + trifloxystrobin 25% WG @0.1% in alternate spray at 10 days interval started with the initiation of disease |
| $T_6$ | Four foliar sprays of *Trichoderma viride*@ 2% at 10 days interval started with the initiation of disease |
| $T_7$ | Control |

## Result and Discussion

The results of the heatmap analysis presented in Figure 1 indicate the efficacy of various treatments on bacterial blight disease in cowpea over three consecutive *Kharif* seasons (2020, 2021, and 2022). The treatments varied significantly in their ability to reduce the percentage disease index (PDI), with the control group exhibiting the highest PDI across all years. Specifically, the treatment $T_1$, which involved four foliar sprays of copper oxychloride at 0.3%, demonstrated the lowest PDI (10.50) among the treatments, indicating its effectiveness in managing bacterial blight. In contrast, the treatment $T_6$, which utilized *Trichoderma viride*, resulted in the highest PDI (32.08), suggesting that while *Trichoderma* has beneficial properties, its application in this context may not be as effective as the chemical treatments employed. The pooled data across the three years reveal that treatments involving copper oxychloride consistently outperformed others, particularly $T_1$ and $T_3$, which also included fungicides like tebuconazole and trifloxystrobin. The combination of copper oxychloride with other fungicides ($T_4$ and $T_5$) showed moderate effectiveness, with pooled PDIs of 20.16 and 12.89, respectively. The control group, which received no treatment, had the highest PDI (38.23), underscoring the necessity of intervention in managing bacterial blight.

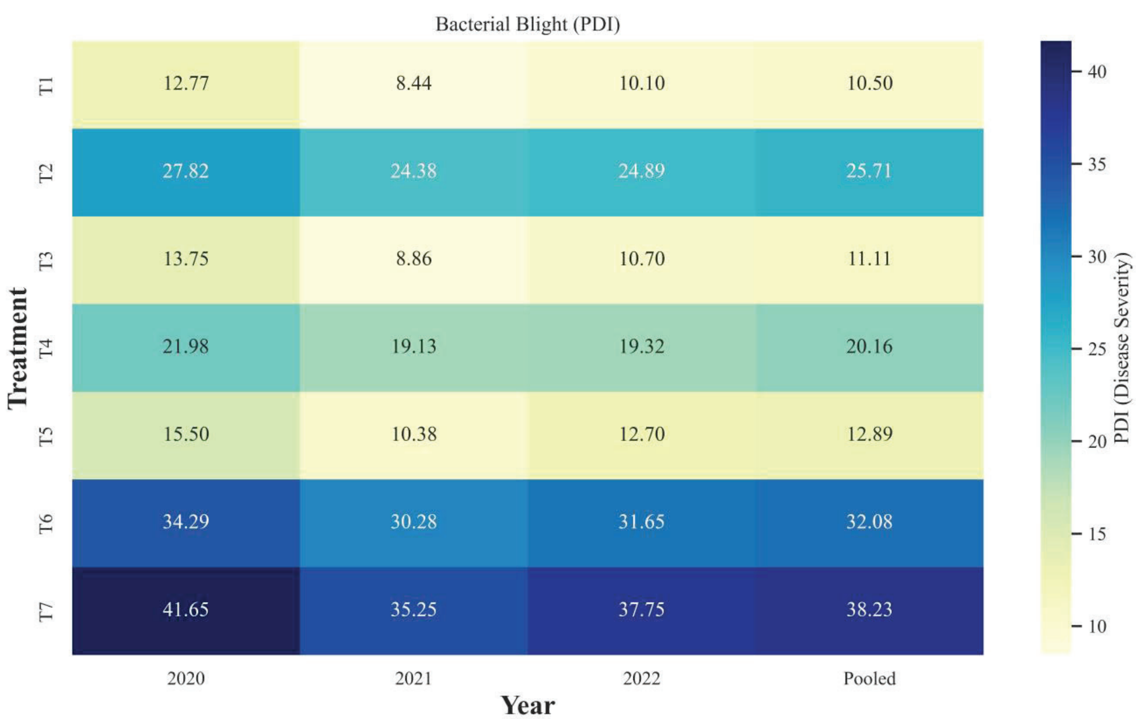


**Figure 1. Heatmap analysis on effects of different treatments on bacterial blight disease of leguminous vegetable cowpea**

The results underscore the importance of selecting appropriate treatments for managing bacterial blight in cowpea. The effectiveness of copper oxychloride aligns with previous findings that highlight its role as a contact fungicide with broad-spectrum activity against various plant pathogens, including those responsible for blight diseases (Jeyaraman & Robert, 2018; Khadka et al., 2020). The significant reduction in PDI observed with $T_1$ suggests that copper oxychloride can be a reliable option for farmers seeking to mitigate the impact of bacterial blight on cowpea crops. Conversely, the relatively high PDI associated with *Trichoderma viride* ($T_6$) raises questions about its efficacy in this specific application. While *Trichoderma* species are well-documented for their biocontrol capabilities and ability to promote plant growth (Hermosa et al., 2012; Hassan, 2024), the results indicate that they may not be sufficient as standalone treatments for bacterial blight. This observation is consistent with studies that emphasize the need for integrated disease management strategies, combining both biological and chemical controls to achieve optimal results (Rajeswari, 2019; Jat et al., 2022). Moreover, the findings suggest that the combination treatments ($T_4$ and $T_5$) could provide a balanced approach, leveraging the strengths of both chemical and biological agents. This is supported by research indicating that integrated approaches can enhance disease resistance and improve crop yields (Huma, 2022; Devi, 2024). The moderate effectiveness of these combinations highlights the potential for developing more sustainable agricultural practices that minimize reliance on chemical fungicides while still achieving effective disease control.

The analysis reveals that while copper oxychloride remains the most effective treatment for bacterial blight in cowpea, there is a need for further exploration into the synergistic effects of combining biological agents like *Trichoderma* with chemical fungicides.

The results presented in Figure 2 indicate a significant variation in marketable pod yield of cowpea across different treatments over three *Kharif* seasons. The treatment $T_1$, which involved four foliar sprays of copper oxychloride at 0.3%, yielded the highest average marketable pod yield of 102.31 q $ha^{-1}$. This treatment was notably more effective compared to the control group, which recorded an average yield of only 40.12 q $ha^{-1}$. The second-best treatment was $T_3$, which combined streptocycline with tebuconazole and trifloxystrobin, yielding an average of 97.02 q $ha^{-1}$. In contrast, treatments involving Trichoderma viride ($T_6$) and the control ($T_7$) exhibited the lowest yields, highlighting the efficacy of chemical fungicides in enhancing cowpea productivity under disease pressure.

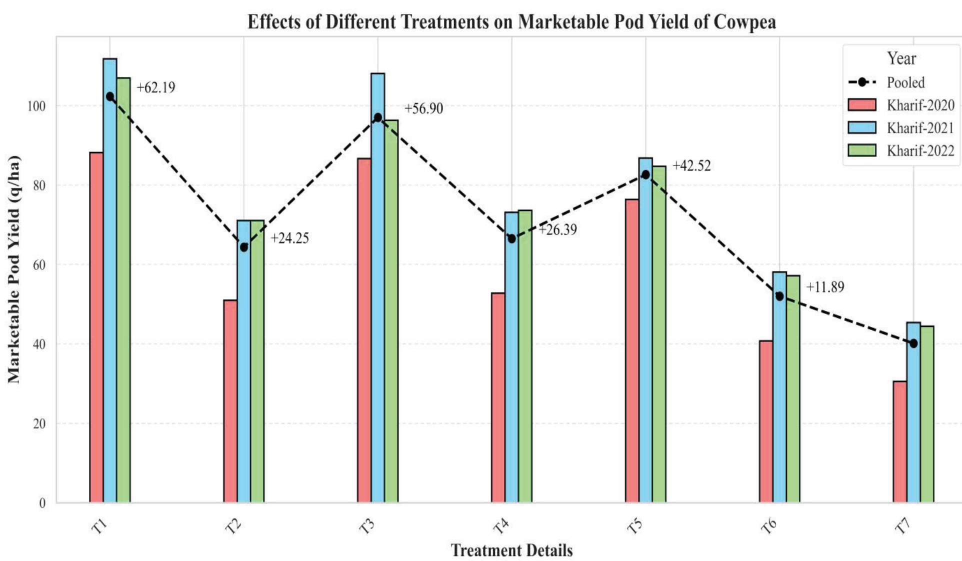


**Figure 2. Effects of different treatments on marketable pod yield of cowpea during 2020 to 2022**

The results show the importance of disease management in cowpea cultivation, particularly in the context of foliar applications. The superior performance of copper oxychloride aligns with findings from previous studies that have demonstrated its antifungal properties, which can effectively reduce disease incidence in crops like cowpea (Lombardo et al., 2023). Furthermore, the combination of streptocycline with other fungicides ($T_3$) also reflects the synergistic effects of using multiple active ingredients to combat pathogens, which has been supported by research indicating that integrated pest management strategies can lead to improved crop yields (Kamara et al., 2010). In terms of the treatments that yielded lower results, $T_2$ and $T_4$, which involved combinations of streptocycline with carbendazim and mancozeb, did not perform as well as expected. This may be attributed to the specific concentrations used or the timing of applications, as optimal timing and dosage are critical for the effectiveness of fungicides (Sakpal et al., 2021). The use of *Trichoderma viride* ($T_6$) also yielded one of the lowest results, which may suggest that while biological control agents can be effective, their performance can be inconsistent depending on environmental conditions and the specific pathogens present (Melo et al., 2021). The control treatment ($T_7$) demonstrated the detrimental effects of neglecting disease management, as it resulted in the lowest marketable pod yield. This finding is consistent with literature that emphasizes the role of pest and disease management in achieving sustainable crop production (Dzemo et al., 2010; Korat et al., 2023). The significant differences in yield across treatments highlight the potential for targeted interventions to enhance cowpea production, particularly in regions prone to disease outbreaks.

In final stage of the study, the economic analysis (Table 3) of different treatments for managing bacterial blight disease in cowpea provides critical insights into the effectiveness and financial viability of various interventions. The treatments exhibit a range of marketable pod yields, additional income, costs, and benefit-cost ratios (B:C ratios), which are essential for evaluating the economic feasibility of each treatment option.

**Table 5: Economics of different treatment for management of bacterial blight disease of leguminous vegetable cowpea**

| Sr. No. | Treatment | Marketable pod yield (kg/ha) | Pod yield increased over control (kg/ha) | Additional income (From column No.4) (Rs) | Cost of treatment (Pesticides, labour charge etc.) (Rs/ha) | Net realization (Rs) | B:C ratio | ICBR |
|---|---|---|---|---|---|---|---|---|
| **1** | **2** | **3** | **4** | **5** | **6** | **7 = (5-6)** | **8 = 7/6** | **9 = (5/6)** |
| 1. | $T_1$ | 10231 | 6219 | 93,285 | 12,800 | 80,485 | 6.29 | 1:7.29 |
| 2. | $T_2$ | 6437 | 2425 | 36,375 | 5,640 | 30,735 | 5.45 | 1:6.45 |
| 3. | $T_3$ | 9702 | 5690 | 85,350 | 27,375 | 57,975 | 2.12 | 1:3.12 |
| 4. | $T_4$ | 6651 | 2639 | 39,585 | 15,640 | 23,945 | 1.53 | 1:2.53 |
| 5. | $T_5$ | 8264 | 4252 | 63,780 | 36,775 | 27,005 | 0.73 | 1:1.73 |
| 6. | $T_6$ | 5201 | 1189 | 17,835 | 5,200 | 12,635 | 2.43 | 1:3.43 |
| 7. | $T_7$ | 4012 | - | - | - | - | - | - |

| | | | | |
|---|---|---|---|---|
| **Notes** | **1.** | Quantity of solution used for spraying = 500 liters/ha/spray | | |
| | **2.** | Number of pickings = 16 | | |
| | **3.** | Price of green cowpea pod = Rs. 15/kg | | |
| **Cost of inputs** | **1.** | **Cost of respective pesticide:** | | **Amount (Rs.)** |
| | 1. | Copper oxychloride 50% WP | : | Rs.900/kg |
| | 2. | Streptocycline (Streptomycin sulphate I.P. 90 w/w + Tetracycline hydrochloride I.P. 10 w/w) | : | Rs.350/60g |
| | 3. | Carbendazim 12% + Mancozeb 63%WP | : | Rs.420/kg |
| | 4. | Tebuconazole 50% + Trifloxystrobin 25% WG | : | Rs.900/100g |
| | 5. | *Trichoderma viride* | : | Rs.80/kg |
| | **2.** | **Labour charge for foliar spray** | : | Rs. 500/spray/ha |

Treatment $T_1$ stands out with the highest marketable pod yield of 10,231 kg ha$^{-1}$, resulting in an additional income of Rs. 93,285 after accounting for treatment costs of Rs. 12,800. This yields a net realization of Rs. 80,485, leading to an impressive B:C ratio of 6.29. Such high returns suggest that $T_1$ is a highly effective treatment option for managing bacterial blight in cowpea, aligning with findings that emphasize the importance of effective disease management strategies in enhancing crop yields and farmer income (Nantale et al., 2023; Nantale et al., 2023; Durojaye et al., 2019; Talaviya et al., 2024). Conversely, treatment $T_7$, which did not yield any marketable pods, highlights the potential risks associated with ineffective treatments. The absence of income and the lack of a B:C ratio indicate that this treatment is economically unviable. This underscores the necessity for farmers to select treatments based on empirical data regarding their effectiveness and economic returns (Antoine & Kerstin, 2018).

**Supplementary Table 1: Physico-Chemical Properties of the experimental field**

| Specification | Results |
|---|---|
| Texture class | Clay loam |
| pH (1:2.5) | 7.9 |
| EC (1:2.5) $dSm^{-1}$ | 0.72 |
| N kg $ha^{-1}$ | 252 |
| $P_2O_5$ kg $ha^{-1}$ | 48 |
| $K_2O$ kg $ha^{-1}$ | 315 |
| S mg $kg^{-1}$ | 18.54 |
| Fe mg $kg^{-1}$ | 8.13 |
| Mn mg $Kg^{-1}$ | 12.87 |
| Zn mg $kg^{-1}$ | 0.77 |
| Cu mg $kg^{-1}$ | 1.72 |

**Supplementary Table 2: Disease rating scale for bacterial blight of cowpea**

| Rating scale/grade | Per cent of leaf area infected |
|---|---|
| 0 | Free from disease (No visible infection) |
| 1 | 1-5% infection |
| 2 | 6-15% infection |
| 3 | 16-30% infection |
| 4 | 31-50% infection |
| 5 | >50% infection |

The economic performance of the other treatments varies significantly. For instance, $T_2$, with a marketable yield of 6,437 kg $ha^{-1}$, provides a B:C ratio of 5.45, which, while lower than $T_1$, still indicates a profitable intervention. In contrast, $T_5$ shows a concerning B:C ratio of 0.73, suggesting that the costs associated with this treatment outweigh the benefits, which could discourage its adoption among farmers (Owade et al., 2022). The analysis also reveals that treatments with lower costs, such as $T_2$, still manage to provide reasonable yields and income, suggesting that cost-effective management strategies can be beneficial for smallholder farmers who may have limited resources (Olum et al., 2021). This is particularly relevant in regions where cowpea is a staple crop, and economic sustainability is crucial for food security (Nantale et al., 2023; Durojaye et al., 2019).

The economic evaluation of treatments for bacterial blight in cowpea reveals significant variability in yield, income, and cost-effectiveness. Treatments like $T_1$ demonstrate the potential for high returns, while others like $T_7$ illustrate the risks of ineffective management strategies. This analysis emphasizes the need for targeted interventions based on empirical data to optimize both agricultural productivity and economic viability for farmers.

## Conclusion

The results of this study clearly demonstrate the significant impact of various treatments on managing bacterial blight disease in cowpea, particularly highlighting the superior efficacy of copper oxychloride. Treatment involved multiple applications of copper oxychloride, consistently resulted in the lowest PDI and the highest marketable pod yield across the three *Kharif* seasons, reinforcing its role as a reliable intervention for farmers facing bacterial blight challenges. The economic analysis further supports this, revealing a robust benefit-cost ratio for $T_1$, indicating not only its effectiveness in disease management but also its financial viability for farmers. Conversely, the use of *Trichoderma viride*, while beneficial in certain contexts, did not yield satisfactory results in this study, suggesting that biological agents may require integration with chemical treatments to achieve optimal disease control. The findings advocate for an integrated disease management approach that combines both chemical and biological strategies, as this could enhance disease resistance and improve overall crop productivity, aligning with contemporary agricultural practices aimed at sustainability. Future research should focus on exploring synergistic effects between biological agents and chemical fungicides to optimize treatment efficacy while minimizing reliance on chemical inputs, thereby promoting sustainable agricultural practices.

## References

Agbicodo, E., Fatokun, C., Bandyopadhyay, R., Wydra, K., Diop, N., Muchero, W., … & Linden, C. (2010). Identification of markers associated with bacterial blight resistance loci in cowpea [vigna unguiculata (l.) walp.]. Euphytica, 175(2), 215-226.

Antoine, F. and Kerstin, W. (2018). Effect of intercropping on the development of cassava bacterial blight. Journal of Experimental Biology and Agricultural Sciences, 6(3), 531-537.

Ayalew, T., Melese, L., & Yoseph, T. (2021). Assessment of the production and importance of cowpea [vigna unguiculata (l.) walp]: cases from selected districts of southern ethiopia. African Journal of Food Agriculture Nutrition and Development, 21(07), 18300-18318.

Bryukhanova, E. (2021). A feasibility study of new generation pesticides application. Journal of Siberian Federal University Biology, 14(4), 550-559.

Capo, L. and Blandino, M. (2021). Minimizing yield losses and sanitary risks through an appropriate combination of fungicide seed and foliar treatments on wheat in different production situations. Agronomy, 11(4), 725.

Deepika, Y., Mahadevakumar, S., Amruthesh, K., & Lakshmidevi, N. (2021). First report of nigrospora sphaerica associated with leaf spot disease of cowpea (vigna unguiculata) from india. Plant Disease, 105(2), 506.

Devi, T. (2024). Management of alternaria blight disease of mustard through biofungicides. Bio Web of Conferences, 110, 01004.

Dinesh, H., Lohithaswa, H., Viswanatha, K., Singh, P., & Rao, A. (2016). Identification and marker-assisted introgression of qtl conferring resistance to bacterial leaf blight in cowpea (vigna unguiculata (l.) walp.). Plant Breeding, 135(4), 506-512.

Durojaye, H., Moukoumbi, Y., Dania, V., Boukar, O., Bandyopadhyay, R., & Ortega-Beltran, A. (2019). Evaluation of cowpea (vigna unguiculata (l.) walp.) landraces to bacterial blight caused by xanthomonas axonopodis pv. vignicola. Crop Protection, 116, 77-81.

Dzemo, W., Niba, A., & Asiwe, J. (2010). Effects of insecticide spray application on insect pest infestation and yield of cowpea (vigna unguiculata (l.) walp.) in the transkei, south africa. African Journal of Biotechnology, 9(11), 1673-1679.

Edema, R., Adjei, E., Ozimati, A., Tusiime, S., Badji, A., Ibanda, A., … & Dramadri, I. (2023). Genetic diversity of cowpea parental lines assembled for breeding in uganda. Plant Molecular Biology Reporter, 41(4), 713-725.

Ganiyu, S. A., Popoola, A. R., Owolade, O. F., & Fatona, K. A. (2017). Control of common bacterial blight disease of cowpea (Vigna unguiculata [L.] Walp) with certain plant extracts in Abeokuta, Nigeria. Journal of Crop Improvement, 31(3), 280-288.

Genet, J. L. (2023). Understanding resistance to oxysterol binding protein inhibitor fungicides.

Hassan, N. (2024). First report isolation, molecular identification and biological control of pantoea leaf blight on phaseolus vulgaris caused by pantoea eucrina using trichoderma species in egypt. Svu-International Journal of Agricultural Sciences, 6(1), 25-35.

Hermosa, R., Viterbo, A., Chet, I., & Monte, E. (2012). Plant-beneficial effects of trichoderma and of its genes. Microbiology, 158(1), 17-25.

Herniter, I., Muñoz-Amatriaín, M., & Close, T. (2020). Genetic, textual, and archeological evidence of the historical global spread of cowpea (vigna unguiculata[l.] walp.). Legume Science, 2(4).

Hong, S., Kim, J., Yong-Ki, K., Jee, H., Shim, C., Kim, M., … & Yun, J. (2013). Control efficacy of mixing application of microbial and chemical fungicide against phytophthora blight of red-pepper. The Korean Journal of Pesticide Science, 17(4), 460-467.

Huma, Z. (2022). Efficacy of biocontrol agent (bca) trichoderma spp. against black scurf disease (rhizoctonia solani) of potato. P. Bulletin, 1(1).

Jat, A., Shekhawat, P., & Saini, K. (2022). Management of bacterial blight of clusterbean caused by xanthomonas axonopodis pv. cyamopsidis under field conditions. Legume Research - An International Journal.

Jethwani, P., Dutta, A., & Singh, R. (2015). Cowpea leaf powder : a cheap nutritional supplement for the vulnerable population. Food Science Research Journal, 6(2), 279-284.

Jeyaraman, M. and Robert, P. (2018). Bio efficacy of indigenous biological agents and selected fungicides against branch canker disease of (macrophoma theicola) tea under field level. BMC Plant Biology, 18(1).

Kamara, A., Ekeleme, F., Omoigui, L., Abdoulaye, T., Amaza, P., & Chikoye, D. (2010). Integrating planting date with insecticide spraying regimes to manage insect pests of cowpea in north-eastern nigeria. International Journal of Pest Management, 56(3), 243-253.

Khadka, R., Chaulagain, B., Subedi, S., Marasini, M., Rawal, R., Pathak, N., … & Sharma-Poudyal, D. (2020). Evaluation of fungicides to control potato late blight (phytophthora infestans) in the plains of nepal. Journal of Phytopathology, 168(5), 245-253.

Kiran, B., Kalegore, N., Suryavanshi, V., & Ghotmukale, A. (2018). Integrated nutrient management practices to enhance yield and quality of cowpea (vigna unguiculata l.). International Journal of Current Microbiology and Applied Sciences, 7(10), 1321-1325.

Kole, R., Roy, K., Panja, B., Sankarganesh, E., Manda, T., & Worede, R. (2019). Use of pesticides in agriculture and emergence of resistant pests. Indian Journal of Animal Health, 58(2-SPL), 53.

Korat, H., Mathukia, R., & Talaviya, H. (2023). Comparative evaluation of low-cost natural farming, organic farming and conventional farming in major crops of South Saurashtra region at Junagadh, Gujarat, India. Environment Conservation Journal, 24(3), 126-135.

Lombardo, M., Panebianco, S., Azzaro, A., Catara, V., & Cirvilleri, G. (2023). Assessing copper-alternative products for the control of pre- and postharvest citrus anthracnose. Plants, 12(4), 904.

Mahadevakumar, S. and Janardhana, G. (2014). First report of pestalotiopsis species causing leaf spot of cowpea (vigna unguiculata) in india. Plant Disease, 98(5), 686-686.

Massey, P. and Nautiyal, M. (2020). Development of short duration cowpea varieties. International Journal of Chemical Studies, 8(2), 246-248.

McKernan, K., Marsh, K., Cottrell, S., & Hom, S. (2022). Biocontrol agents and their influence on the cannabis testing space.

Mejía, C. and Espinel, C. (2022). In vitro versus in planta: comparing the compatibility of akanthomyces lecanii with pesticides against trialeurodes vaporariorum. Journal of Applied Entomology, 146(10), 1272-1280.

Melo, D., Silva, A., Alves, J., Albuquerque, J., Uchôa, S., & Gonçalves, A. (2021). Cowpea subjected to organic fertilization and management of the natural vegetation of the savannah of roraima. Revista Agro Mbiente on-Line, 15.

Nantale, G., Wasswa, P., Edgar, M., Richard, T., Paparu, P., & Dramadri, I. (2023). Combining ability of cowpea (vigna unguiculata (l) walp) genotypes for resistance to cowpea bacterial blight in uganda. American Journal of Agricultural Science Engineering and Technology, 7(1), 21-28.

Nantale, G., Wasswa, P., Tusiime, R., Muhumuza, E., Dramadri, I., & Paparu, P. (2023). Response of cowpea germplasm to bacterial blight in uganda. Journal of Scientific Agriculture, 17-27.

Nelson, W., Hoffmann, M., Vadez, V., Rötter, R., Koch, M., & Whitbread, A. (2021). Can intercropping be an adaptation to drought? a model-based analysis for pearl millet–cowpea. Journal of Agronomy and Crop Science, 208(6), 910-927.

Oguntade, O., Olufolaji, D., Oyetayo, V., Popoola, A., Kazeem, S., & Ayodele, M. (2022). Morphological and biochemical characterization of strains of xanthomonas axonopodis pv. vignicola isolated from cowpea grown in three agroecological zones in nigeria. Journal of Agriculture and Food Sciences, 19(2), 1-12.

Olum, S., Gellynck, X., Wesana, J., Odongo, W., Aparo, N., Aloka, B., … & Steur, H. (2021). Economic feasibility of iodine agronomic biofortification: a projective analysis with ugandan vegetable farmers. Sustainability, 13(19), 10608.

Owade, J., Abong, G., Okoth, M., & Mwang'ombe, A. (2022). A benefit-cost analysis approach for determining the optimal processing of micronutrient-enriched cowpea leaf soup mixes. Frontiers in Food Science and Technology, 2.

Panse, V. G. and Sukhatme, P. V. (1985). Statistical methods for agricultural workers 2nd ed. ICAR, New Delhi.

Rajeswari, P. (2019). Combination of trichoderma viride and pseudomonas fluorescens for the enhanced control of fusarium wilt disease caused by fusarium oxysporum infecting arachis hypogaea l.. Journal of Applied and Natural Science, 11(1), 138-143.

Sakpal, V., Jagtap, D., Upadhyay, L., Pinjari, S., More, S., Jadhav, M., … & Bodake, P. (2021). Effect of foliar application of different organic sources and levels of fertilizer on growth attributes, yield attributes, yield, quality and economics of cowpea (vigna unguiculata l.). Agricultural Science Digest - A Research Journal.

Suhi, A., Mia, S., Khanam, S., Mithu, M., Uddin, M., Muktadir, A., … & Jindo, K. (2022). How does maize-cowpea intercropping maximize land use and economic return? a field trial in bangladesh. Land, 11(4), 581.

Talaviya, H., Korat, H., Tripathi, K., Hasan, M., & Mahatma, M. K. (2024) Analytical Methods and Regulatory Perspectives on Residual Ethylene Oxide and Its Derivatives in Food Products. International Journal of Seed Spices, 14(1), 1-15.

Wheeler,B.E.J. (1969). Anintroductiontoplantdisease,JohnWileyPublishers, Phytopathol.,22: 837-845.

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