**Efficacy of eco-compatible inputs for managing Black Scurf Disease of Potato (*Solanum tuberosum L*.) incited by *Rhizoctonia solani kuhn***

 **Abstract**

Black scurf disease caused by *Rhizoctonia solani* significantly impacts potato (*Solanum tuberosum* L.) production, causing substantial yield losses. This study evaluated integrated management strategies combining biological and chemical components for black scurf control under field conditions. *In vitro* screening demonstrated that 3% boric acid achieved 89.87% inhibition of fungal growth, while *Trichoderma harzianum* showed 85.24% growth inhibition in dual culture assays. Field trials were conducted during Rabi 2024–25 using a randomized complete block design with seven treatments and three replications. The most effective treatment comprised soil application of spent mushroom substrate + seed treatment with *T. harzianum* + foliar application of 2% boric acid, which significantly improved germination (89.70%), plant height (61.3 cm at 63 DAS), and yield (10.9 kg plot⁻¹) compared to untreated controls (5.7 kg plot⁻¹), representing a 91.22% yield increase. This treatment reduced disease incidence to 15% and severity to below 12%, achieving 81.54% disease control efficacy with a Black Scurf Disease Index of 3.53 compared to 21.49 in controls. These findings establish integrated management strategies as effective sustainable alternatives to conventional chemical control methods for black scurf disease management in potato cultivation.

**Keywords:** *Rhizoctonia solani*, biocontrol, integrated disease management, *Trichoderma harzianum*, boric acid, sustainable.

**1. Introduction**

Potato (Solanum tuberosum L.), commonly referred to as the "King of Vegetables," is one of the most significant agricultural commodities globally, holding a vital place in human diets due to its nutritional value, affordability, and versatility. Ranking third after rice and wheat in global consumption, the potato has become a cornerstone for food security, particularly in developing countries where it plays a crucial role in combating hunger and malnutrition (Amarananjundeswara *et al*., 2018).

Despite its widespread cultivation and consumption, potato production faces severe threats from multiple pathogens, pests, and environmental stresses. Among the various diseases affecting potato crops, black scurf disease, caused by the soil-borne fungus *Rhizoctonia solani* Kuhn , emerges as one of the most destructive disease-causing substantial yield losses, often exceeding 30% under favourable conditions for the pathogen (Civitarese, 2023; Chaudhary *et al*., 2024).

The economic losses of black scurf disease are profound, impacting both quantitative and qualitative aspects of potato production. Furthermore, the extensive use of chemical fungicides to control black scurf has raised significant environmental and health concerns. Residues from synthetic fungicides not only degrade soil health and biodiversity but also pose risks to human health through direct exposure or consumption of contaminated produce (Beyuo *et al*., 2024). The continuous use of chemical fungicides also causes the pathogen to develop resistance against them therefore reducing their effectivity(Rafiq *et al*., 2024).

Eco-compatible strategies incorporating biological control agents, organic amendments and minimal chemical inputs have shown considerable promise in recent research. Biological control agents, particularly beneficial fungi such as *Trichoderma harzianum*, have demonstrated significant efficacy against *Rhizoctonia solani* by suppressing pathogen growth and enhancing plant resistance through induced systemic resistance (Wilson *et al*., 2008). Organic amendments such as farmyard manure, neem cake, and spent mushroom substrates contribute to improved soil structure, fertility, and microbial diversity, which collectively suppress pathogen populations and support healthier plant growth (Chaudhari *et al*., 2021).

The research entitled "Efficacy of eco-compatible inputs for managing Black Scurf Disease of Potato (*Solanum tuberosum* L.) incited by *Rhizoctonia solani* Kühn" addresses the growing demand for environmentally sustainable alternatives to chemical-intensive disease control in potato production.

**2.Materials and Methods**

**2.1 Experimental Site and Location**

The field trials were conducted at the research farm of the Department of Plant Pathology, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh situated at 26.45°N latitude and 80.31°E longitude, approximately 152.4 meters above mean sea level.

**2.2 Isolation and Purification of the Pathogen**

Diseased potato tubers and stems exhibiting black scurf symptoms were collected from the Vegetable Research Farm at Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Small tissue pieces (2–3 mm) from the diseased-healthy tissue interface were excised, washed under running tap water, and surface-sterilized with 1% sodium hypochlorite for 30 seconds under aseptic conditions. After three rinses with sterile distilled water, the sterilized sclerotia were transferred onto Potato Dextrose Agar (PDA) medium using sterile forceps. Inoculated plates were incubated at 25±1°C for 6-7 days, and the isolated fungus was purified using hyphal tip and sectional cut methods with 3 mm sections for subculturing.

**2.3 Maintenance of the Pathogen**

The pathogen cultures were maintained on sterilized Potato Dextrose Agar (PDA) medium by inoculating each plate with pieces from 7-day-old fungal cultures grown at 25±1°C. Isolates were stored at 4°C and regularly sub-cultured onto fresh PDA medium to ensure continuous growth and viability of the fungal strain.

**2.5 *In vitro* efficacy of Fungicides**

The in vitro efficacy of chemical fungicides against *Rhizoctonia solani* was evaluated using the poisoned food technique. Three fungicides were tested: Boric Acid (1%, 2%, and 3%), Mancozeb (0.05%, 0.1%, and 0.2%), and Monceren (0.05%, 0.1%, and 0.2%). Percentage inhibition of mycelial growth was calculated using Vincent's (1927) formula:

PI = [(C-T)/C] × 100

where PI = percent inhibition, C = colony diameter in control (mm), T = colony diameter in treatment (mm).

**2.6 *In vitro* efficacy of *Trichoderma harzianum***

The antagonistic potential of *Trichoderma harzianum* against *Rhizoctonia solani* was evaluated through dual culture assays. Treatments included simultaneous inoculation of both fungi, sequential inoculation with 24-hour intervals, and variations in inoculation points and *Trichoderma* culture age. Inoculated plates were incubated at 28°C and observed at 48, 96, and 144-hour intervals. Percentage inhibition was calculated using Vincent's formula:

I = [(C-T)/C] × 100

where I = percent inhibition, C = radial growth of pathogen in control (mm), T = radial growth in treatment (mm).

**2.7 Field Experiment**

A field experiment was conducted during Rabi 2024–2025 using Randomized block design with seven treatments and three replications. Experimental plots (1.75 × 1.5 m) were planted with potato variety **'Kufri Sindhuri'** at 60 × 20 cm spacing. Seed tubers (20–30 g) were treated with *Trichoderma harzianum* or 2% boric acid by dipping for 20 minutes, then air-dried overnight before planting. Organic amendments (farmyard manure, neem cake, spent mushroom substrate) were incorporated as per treatment requirements along with seed treatments and foliar applications. Recommended fertilizer doses and standard agronomic practices were followed throughout the growing period.

**2.8 Observations and Statistical Analysis**

Each treatment was replicated thrice and the values are means ± SE. The data were computed using SPSS software version 21.

**3. Results and Discussion:**

**3.1 *In vitro* efficacy of Fungicides Against *Rhizoctonia solani* (Poisoned Food Technique)**

The results as observed from Table 1 revealed that Boric Acid at 3% concentration was most effective against *Rhizoctonia solani*, limiting mycelial growth to 8.9 mm and achieving 89.87% inhibition compared to untreated control (87.88 mm). Mancozeb (0.2%) and Monceren (0.2%) demonstrated comparable efficacy with growth inhibition to 10.9 mm (87.59%) and 11.5 mm (86.89%), respectively. Boric Acid showed concentration-dependent response with 2% and 1% concentrations achieving 85.83% (13.2 mm) and 81.11% (16.6 mm) inhibition, respectively. Lower concentrations of Mancozeb (0.1% and 0.05%) exhibited moderate efficacy with 77.24% (20.0 mm) and 70.75% (25.7 mm) inhibition, while Monceren at similar concentrations showed relatively lower performance with 69.73% (26.6 mm) and 69.16% (27.1 mm) inhibition. These results are in accordance with results obtained by Kumar *et al*., 2018, Debbarma *et al*., 2021, in control of *Rhizoctonia solani* by *in vitro* use of fungicides.

**3.2 *In vitro* Evaluation of *Trichoderma harzianum* Against *Rhizoctonia solani* (Dual Culture Assay)**

The results as observed from Table 2 demonstrated significant antagonistic activity of *Trichoderma harzianum* against *Rhizoctonia solani*, with efficacy varying by inoculation strategy. Multiple inoculation points (T5) achieved maximum inhibition of 85.24%, restricting pathogen growth to 16.67 mm compared to control (88.88 mm). Pre-inoculation of *T. harzianum* by 24 hours (T3) resulted in 69.77% inhibition, followed by simultaneous inoculation on modified medium (T4, 65.77%) and standard simultaneous inoculation (T1, 62.57%). Culture age variation (T6) showed 60.01% inhibition, while 24-hour pre-inoculation of *R. solani* (T2) was least effective with 49.54% inhibition. Similar results were obtained by various researchers such as Andrés *et al*. (2022), Almaghasla *et al*. (2023) confirming the biocontrol potential of *T. harzianum* in controlling *Rhizoctonia solani*.

**3.3 Comparative study of fungicides, bio-agents and organic amendments on germination and plant height of potato at different days after sowing**

 The results as observed from Table 3 demonstrates significant treatment effects on germination and plant growth parameters. The integrated treatment comprising spent mushroom substrate + *Trichoderma harzianum* seed treatment + 2% boric acid foliar spray achieved maximum germination (89.70%) and plant height (61.3 cm at 63 DAS). Similarly, neem cake + *T. harzianum* seed treatment + boric acid foliar application resulted in 80.67% germination and 60.1 cm plant height at 63 DAS. In contrast, untreated control exhibited significantly lower germination (75.33%) and reduced plant height (47.1 cm), demonstrating the efficacy of integrated eco-compatible approaches for enhanced crop establishment and growth. Kumar & Sinha(2020) also reported that the antifungal and soil-conditioning properties of neem cake, coupled with the antagonistic potential of *Trichoderma harzianum*.

**3.4 Comparative study of fungicides, bio-agents and organic amendments on size and number of potatoes at Tuber formation stage (52 DAS)**

 The result from Table 4 demonstrated significant treatment effects on tuber production and quality at 52 DAS. The integrated treatment (spent mushroom substrate + *T. harzianum* seed treatment + 2% boric acid foliar spray) achieved maximum yield of 1105 g plot⁻¹, representing 72.66% increase over untreated control (670 g plot⁻¹). This treatment produced optimal tuber size distribution with reduced small tubers (195 g) and enhanced medium (550 g) and large tubers (360 g). Neem cake + boric acid treatment yielded 900 g plot⁻¹ (40.63% increase), while FYM + *T. harzianum* treatment produced 862 g plot⁻¹ (34.69% increase). Previous findings by Dell & Huang, 1997; Harman *et al*., 2004 also supported that integrated bio-organic approaches significantly enhance early tuber yield and quality compared to conventional practices.

**3.5 Comparative study of fungicides, bio-agents and organic amendments on size and number of tubers after harvesting (110 DAS)**

The results as observed from Table 5 and final harvest assessment (110 DAS) revealed maximum treatment efficacy with spent mushroom substrate + *T. harzianum* + boric acid achieving highest yield of 10.9 kg plot⁻¹, representing 91.22% increase over untreated control (5.7 kg plot⁻¹). Medium-sized tubers contributed significantly to total productivity (5454.88 g). Other integrated treatments (neem cake or FYM + *T. harzianum* or boric acid) yielded 7.5-8.71 kg plot⁻¹, substantially exceeding control performance. Similar results were obtained by Pathma & Sakthivel, 2012; Gupta & Sharma, 2019 demonstrating superior efficacy of integrated management approaches for enhanced potato productivity.

**3.6 Comparative study of fungicides, bio-agents, and organic amendments in managing the black scurf disease of potato under field conditions**

 The results as observed from Table 6 demonstrates disease assessment across four growth stages (45, 60, 75, and 90 DAS) and revealed that spent mushroom substrate + *T. harzianum* seed treatment + boric acid spray achieved optimal disease management with lowest incidence (15%) and severity progression (3.6% to 12%). This treatment demonstrated 81.54% disease control efficacy with minimum Black Scurf Disease Index (BSDI) of 3.53 compared to untreated control (76% incidence, 19.5-65% severity progression, BSDI 21.49). Other integrated treatments (neem cake or FYM + *T. harzianum* or boric acid) showed intermediate performance, significantly reducing disease parameters compared to control. Similar results were obtained by various researchers such as Larkin and Brewer (2020), Mwangi *et al*., (2024) in role of integrated bio-organic approaches in effectively suppressing black scurf disease of potato.

**Conclusion:**

The study demonstrates that integrated eco-friendly management strategies effectively control black scurf disease in potato while enhancing productivity. The combination of spent mushroom substrate + *Trichoderma harzianum* seed treatment + 2% boric acid foliar spray achieved optimal results in disease reduction compared to untreated control. The findings establish integrated bio-organic approaches as viable sustainable alternatives for black scurf management in potato cultivation.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Option 2:

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc. have been used during the writing or editing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology

Details of the AI usage are given below:

1. No, I have not used AI for writing for this research paper.

**References :**

1. Almaghasla, M. I., El-Ganainy, S. M., and Ismail, A. M. (2023). Biological activity of four *Trichoderma* species confers protection against *Rhizoctonia solani*, the causal agent of cucumber damping-off and root rot diseases. Sustainability, **15**(9), 7250.
2. Amarananjundeswara, H., P.S. Prasad, Soumya Shetty and Sandhya, G.C. 2018. Evaluation of Promising Potato Varieties for Yield Potentiality and Late Blight Disease Tolerance in Southern Dry Zone of Karnataka, India. Int.J.Curr.Microbiol.App.Sci. **7**(2): 341-350.
3. Andrés, P. A., Alejandra, P. M., Benedicto, M. C., Nahuel, R. I., and Clara, B. M. (2022). A comparative study of different strains of *trichoderma* under different conditions of temperature and ph for the control of *Rhizoctonia solani*. Agricultural Sciences, **13**(6), 702-714.
4. Beyuo, J., Sackey, L. N., Yeboah, C., Kayoung, P. Y., & Koudadje, D. (2024). The implications of pesticide residue in food crops on human health: a critical review. Discover Agriculture, **2**(1), 123.
5. Chaudhari, S., Upadhyay, A., & Kulshreshtha, S. (2021). Influence of organic amendments on soil properties, microflora and plant growth. In Sustainable Agriculture Reviews 52 (pp. 147-191). Cham: Springer International Publishing.
6. Chaudhary, S., Lal, M., Sagar, S., Sharma, S., & Kumar, M. (2024). Black scurf of potato: Insights into biology, diagnosis, detection, host-pathogen interaction, and management strategies. Tropical Plant Pathology, **49**(2), 169-192.
7. Civitarese, V. (2023). First report of *Rhizoctonia solani* associated with black scurf of potato tubers in Lesotho. *International Journal of Phytopathology*, ***12***(1), 87–97.
8. Debbarma, M., Rajesh, T., and Devi, R. K. T. (2021). *In-vitro* Efficacy of Fungicides against *Rhizoctonia solani* Causing Banded Leaf and Sheath Blight of Maize. International Journal of Plant and Soil Science, 232–236.
9. Dell, B., & Huang, L. (1997). Physiological response of plants to low boron. Plant and soil, **193**(1), 103-120.
10. Harman, G. E., Howell, C. R., Viterbo, A., Chet, I., and Lorito, M. (2004). *Trichoderma* species-Opportunistic, avirulent plant symbionts. Nature Reviews Microbiology, **2**(1), 43–56.
11. Kumar, A., Thapa, R. S., Mazeed, A., Singh, S., Shukla, G., Kumar, R., and Kumar, M. (2018). Inhibtory effect of commercial fungicides against virulent isolate of *Rhizoctonia solani.* Journal of Pharmacognosy and Phytochemistry, **7**(3), 1861-1863.
12. Kumar, R., Singh, R., Mishra, P., Singh, H., Kumar, A., Kumar, A., and Prajapati, M. K. (2023). Comparative Study of Fungicides, Bio-Agents, and Organic Amendments for Management of Black Scurf of Potato. Environment and Ecology, **41**(3), 1337-1342.
13. Larkin, R. P., and Brewer, M. T. (2020). Effects of crop rotation and biocontrol amendments on Rhizoctonia disease of potato and soil microbial communities. Agriculture, **10**(4), 128.
14. Mwangi, R. W., Mustafa, M., Kappel, N., Csambalik, L., & Szabó, A. (2024). Practical applications of spent mushroom compost in cultivation and disease control of selected vegetables species. Journal of Material Cycles and Waste Management, **26**(4), 1918-193.
15. Pathma, J., and Sakthivel, N. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential **1**(1), 26.
16. Rafiq, M., Shoaib, A., Javaid, A., Perveen, S., Umer, M., Arif, M., & Cheng, C. (2024). Exploration of resistance level against Black Scurf caused by *Rhizoctonia solani* in different cultivars of potato. Plant Stress, 12, 100476.
17. Vincent, J. M. (1927). Distortion of fungal hyphae in the presence of certain inhibitors. Nature, 159, 850.
18. Wilson, P. S., Ahvenniemi, P. M., Lehtonen, M. J., Kukkonen, M., Rita, H., & Valkonen, J. P. T. (2008). Biological and chemical control and their combined use to control different stages of the *Rhizoctonia* disease complex on potato through the growing season. Annals of Applied Biology, **153**(3), 307-320.

**Table-1 :** **Efficacy of fungicides against *Rhizoctonia solani* using Poisoned Food Technique**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.No.** | **Chemical** | **Concentration** **(%)** | **Radial mycelial growth at different intervals (mm)** | **Per cent inhibition over control** |
|  **1 DAI** |  **3 DAI** |  **5 DAI** |  **7 DAI** |
| **T1** | Boric Acid | 1 | 3.2 | 7.2 | 14.5 | 16.6 | 81.11 |
| **T2** | Boric Acid | 2 | 2.6 | 5.6 | 11.1 | 13.2 | 85.83 |
| **T3** | Boric Acid | 3 | 1.5 | 3.9 | 7.8 | 8.9 | **89.87** |
| **T4** | Mancozeb | 0.05 | 5.0 | 9.8 | 19.6 | 25.7 | 70.75 |
| **T5** | Mancozeb | 0.1 | 4.0 | 8.3 | 17.2 | 20.0 | 77.24 |
| **T6** | Mancozeb | 0.2 | 2.2 | 5.0 | 9.6 | 10.9 | 87.59 |
| **T7** | Monceren | 0.05 | 5.2 | 9.9 | 20.1 | 26.6 | 69.73 |
| **T8** | Monceren | 0.1 | 4.5 | 8.8 | 18.7 | 23.3 | 73.48 |
| **T9** | Monceren | 0.2 | 2.4 | 5.5 | 10.3 | 11.5 | 86.89 |
| **T10** | Control | — | 9.0 | 24.8 | 61.8 | 87.88 | 00.00 |
| **C.V.** |  |  | 8.047 | 8.636 | 9.355 | 8.821 | - |
| **SE(m)** |  |  | 0.184 | 0.443 | 1.034 | 1.434 | - |
| **C.D.** |  |  | 3.125 | 1.326 | 3.084 | 4.293 | - |

|  |  |  |  |
| --- | --- | --- | --- |
|  |  |  **Radial mycelial growth (mm)** |  |
| **S.No.** | **Treatment details** | **1 DAI** | **3 DAI** | **5 DAI** | **7 DAI**  | **Per cent Inhibition over control** |
| T1 | Simultaneous inoculation (Pathogen + Antagonist) | 6.6 | 15.5 | 26.7 | 33.33 | 62.57 |
| T2 | 24-hour head start to *Rhizoctonia solani* | 9.0 | 21.0 | 35.5 | 44.84 | 49.54 |
| T3 | 24-hour head start to *Trichoderma harzianum* | 5.3 | 12.8 | 21.9 | 26.86 | 69.77 |
| T4 | Simultaneous inoculation on modified medium | 6.1 | 13.7 | 23.8 | 30.48 | 65.77 |
| T5 | Multiple inoculation points of *Trichoderma harzianum* | 3.3 | 7.8 | 13.5 | 16.67 | **85.24** |
| T6 | Variation in culture age of *Trichoderma harzianum* | 7.1 | 16.4 | 28.4 | 35.54 | 60.01 |
| T7 | Control  | 17.7 | 40.0 | 70.5 | 88.88 | 0.00 |
| **C.V.** |  | 6.233 | 6.146 | 6.077 | 6.186 |  - |
| **SE(m)** |  | 0.283 | 0.645 | 1.104 | 1.411 |  - |
| C.D. |  | 1.882 | 2.009 | 3.440 | 4.396 |  - |

T**able -2 : Efficacy of *Trichoderma harzianum* against *Rhizoctonia solani* using dual culture technique**

**Table-3 : Comparative efficacy of fungicides, bio-agents and organic amendments on germination and plant height of potato at different days after sowing**

|  |  |  |
| --- | --- | --- |
|  |  |  **Plant height (cm)** |
| **Treatment** | **Germination** **(%)** |  **7 DAS** |  **14 DAS** |  **21 DAS** |  **28 DAS** |  **35 DAS** |  **42 DAS** |  **49 DAS** |  **56 DAS** |  **63 DAS** | **Per cent increase over control** |
| **T1** | 84.67 | 1.3 | 6.4 | 12.6 | 20.3 | 29.6 | 38.7 | 46.8 | 53.2 | 59.0 | 25.27 |
| **T2** | 83.33 | 1.2 | 5.9 | 11.5 | 18.9 | 27.1 | 36.0 | 43.5 | 49.6 | 55.3 | 17.39 |
| **T3** | 80.67 | 1.4 | 6.7 | 13.1 | 21.1 | 30.4 | 39.5 | 47.5 | 54.1 | 60.1 | 27.61 |
| **T4** | 85.67 | 1.1 | 5.5 | 10.8 | 17.5 | 25.3 | 33.8 | 40.9 | 47.0 | 52.2 | 10.83 |
| **T5** | **89.70** | 1.5 | 7.0 | 13.5 | 21.7 | 31.2 | 40.7 | 48.6 | 55.4 | 61.3 | **30.13** |
| **T6** | 87.82 | 1.3 | 6.1 | 12.0 | 19.7 | 28.5 | 37.0 | 44.8 | 51.3 | 57.0 | 21.02 |
| **T7** | 75.33 | 1.0 | 5.0 | 9.7 | 15.9 | 23.0 | 30.5 | 36.7 | 42.4 | 47.1 |  - |
| **C.V.** |  | **6.585** | **5.137** | **5.645** | **5.596** | **5.465** | **5.503** | **5.522** | **5.569** | **5.552** |  - |
| **SE(m)** |  | **0.048** | **0.181** | **0.387** | **0.624** | **0.880** | **1.163** | **1.407** | **1.622** | **1.795** |  - |
| **C.D.** |  | **0.149** | **0.563** | **1.207** | **1.943** | **2.740** | **3.622** | **4.438** | **5.052** | **5.121** |  - |

T1: Soil Application of FYM + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T2: Soil Application of FYM + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T3: Soil Application of Neem Cake + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T4: Soil Application of Neem Cake + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T5: Soil Application of Spent Mushroom Substrate + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T6: Soil Application of Spent Mushroom Substrate + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T7: Control

**Table-4 : Comparative efficacy of fungicides, bio-agents and organic amendments on size and number of potatoes at Tuber Formation Stage (52 DAS)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S.No.** | **Small** **(<25 g)** | **Medium**  **(25-50 g)** | **Large** **(>50 g)**  |  **Total Yield** **(g/plot)** | **Per cent increase Over Control** |
| **No. of tubers** | **Wt. of tubers (g)**  | **Number of tubers** | **Wt. of tubers (g)** | **No. of tubers** | **Wt. of tubers (g)** |
| **T1** | 7 | 290 | 4 | 415 | 1 | 157 | 862 | 34.69 |
| **T2** | 8 | 305 | 3 | 370 | 1 | 85 | 760 | 18.75 |
| **T3** | 9 | 325 | 3 | 320 | 1 | 75 | 720 | 12.50 |
| **T4** | 6 | 230 | 4 | 435 | 2 | 235 | 900 | 40.63 |
| **T5** | 5 | 195 | 5 | 550 | 3 | 360 | **1105** | **72.66** |
| **T6** | 6 | 220 | 5 | 510 | 2 | 205 | 935 | 46.09 |
| **T7** | 7 | 340 | 3 | 250 | 1 | 80 | 670 | - |
| **C.V.** | **5.618** | **8.332** | **5.418** | **9.729** | **7.128** | **6.058** | **10.457** | **-** |
| **SE(m)** | **0.223** | **0.013** | **0.121** | **0.023** | **0.065** | **1.054** | **0.014** | **-** |
| **C.D.** | **0.694** | **0.039** | **0.377** | **0.072** | **0.203** | **0.865** | **4.625** | **-** |

T1: Soil Application of FYM + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T2: Soil Application of FYM + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T3: Soil Application of Neem Cake + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T4: Soil Application of Neem Cake + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T5: Soil Application of Spent Mushroom Substrate + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T6: Soil Application of Spent Mushroom Substrate + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T7: Control

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **S.No.** | **Total Yield** **( kg/plot )** | **Small** **(<25 g)** | **Medium** **(25-50 g)** | **Large****(>50 g)** | **Per cent increase over control** |
|  |  | **Number of tubers** | **Weight of tubers** **(g)** | **Number of tubers** | **Weight of tubers** **(g)** | **Number of tubers** | **Weight of tubers** **(g)** |
| **T1** | 7.5 | 75 | 1530.08  | 100 | 3756.65  | 30 | 2213.27 | 31.57 |
| **T2** | 6.55 | 82 | 1648.25  | 87 | 3276.57  | 22 | 1655.18  | 14.91 |
| **T3** | 6.15 | 92 | 1846.79 | 82 | 3080.89  | 16 | 1222.32  | 7.89 |
| **T4** | 7.88 | 59 | 1189.72  | 116 | 4337.37  | 32 | 2352.91  | 38.24 |
| **T5** | 10.9 | 54 | 1096.44  | 145 | 5454.88 | 58 | 4348.68 | 91.22 |
| **T6** | 8.71 | 65 | 1317.87  | 128 | 4799.96 | 35 | 2592.17  | 52.80 |
| **T7** | 5.7 | 86 | 1719.43 | 76 | 2855.84 | 15 | 1124.73 | - |
| **C.V.** | **5.524** | **5.700** | **5.711** | **5.593** | **5.583** | **5.521** | **5.462** | - |
| **SE(m)** | **0.243** |  **1.412** | **0.146** | **2.182** | **3.245** | **0.947** | **2.943** | - |
| **C.D.** | **0.758** | **1.193** | **4.324** | **3.534** | **4.258** | **2.951** | **4.153** | - |

**Table -5 : Comparative efficacy of fungicides, bio-agents and organic amendments on size and number of tubers after harvesting (100 DAS)**

T1: Soil Application of FYM + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T2: Soil Application of FYM + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T3: Soil Application of Neem Cake + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T4: Soil Application of Neem Cake + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T5: Soil Application of Spent Mushroom Substrate + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T6: Soil Application of Spent Mushroom Substrate + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T7: Control

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.No.** | **Disease Incidence****(%)** | **Disease Severity at different days****(%)** | **Per cent decrease over Control** | **Black Scurf Disease Index****(BSDI)** |
| **45 DAP** | **60 DAP** | **75 DAP** | **90 DAP** |
| T1 | 38 | 10.5 | 19.3 | 28 | 35 | 46.15 | 11.68 |
| T2 | 45 | 13.5 | 24.8 | 36 | 45 | 30.77 | 14.85 |
| T3 | 48 | 15 | 27.5 | 40 | 50 | 23.08 | 16.63 |
| T4 | 32 | 9 | 16.5 | 24 | 30 | 53.85 | 10.2 |
| T5 | 15 | 3.6 | 6.6 | 9.6 | 12 | **81.54** | **3.53** |
| T6 | 28 | 6.6 | 12.1 | 17.6 | 22 | 66.15 | 7.44 |
| T7 | 76 | 19.5 | 35.8 | 52 | 65 | 0 | 21.49 |
| **C.V.** | **6.228** | **6.259** | **6.316** | **6.263** | **6.296** | - | **6.286** |
| **SE(m)** | **1.449** | **0.401** | **0.743** | **1.070** | **1.345** | - | **1.258** |
| **C.D.** | **4.514** | **1.250** | **2.314** | **3.334** | **4.191** | - | **4.348** |

**Table-6 : Comparative study of fungicides, bio-agents and organic amendments in managing the black scurf disease of potato under field conditions**

T1: Soil Application of FYM + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T2: Soil Application of FYM + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T3: Soil Application of Neem Cake + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T4: Soil Application of Neem Cake + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T5: Soil Application of Spent Mushroom Substrate + Seed treatment of *Trichoderma harzianum* + Foliar treatment with 2% Boric Acid ; T6: Soil Application of Spent Mushroom Substrate + Seed treatment of 2% Boric Acid + Foliar treatment with 2% Boric Acid ; T7: Control.