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RESEARCH PAPER

Sensitivity and Revenue Analysis of Fortified Vermicompost Tea and its Effect on Production Economics of Tulsi

Jancy Garg, Sabyasachi Koley and Amitava Rakshit*

Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Science, Banaras Hindu University, Varanasi, Uttar Pradesh, India

*Corresponding author: amitavar@bhu.ac.in (**ORCID ID:** 0000-0002-9406-8262)

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ABSTRACT

Vermicompost tea (VCT) is an emerging bio-stimulant that enhances plant growth, soil fertility, and economic sustainability in organic and integrated farming systems. This study evaluates the economic viability and agronomic impact of VCT application in Tulsi (*Ocimum sanctum* L.) cultivation over two consecutive years (2021–22 and 2022–23). A sensitivity analysis of VCT production revealed a profit margin of 58.4% and a break-even price of ₹ 20.8 per liter, demonstrating its cost-effectiveness. Further economic assessments showed that integrating VCT with chemical fertilizers improved yield, net returns, and benefit-cost (B:C) ratios. Treatments T3 (100% RDF + SS) and T4 (100% RDF + DS) recorded the highest leaf count and net returns, while T7 (90% RDF + DS) exhibited comparable performance, indicating that a 10% reduction in fertilizers along with dual VCT application could maintain optimal yields. The B:C ratio and return-on investment (ROI) were highest for T3 and T4, reflecting their superior profitability. Fresh leaf production generated higher economic returns than dry leaves, as additional post-harvest processing costs reduced profitability in the latter. The results highlight the synergistic benefits of microbial inoculants in improving nutrient uptake efficiency and soil health. The study supports sustainable agricultural practices, aligning with SDGs 2, 8, 12, and 13, and suggests that medicinal and aromatic plants (MAPs) can be effectively integrated into existing cropping systems for enhanced economic resilience and environmental sustainability. These findings provide a scientific foundation for scaling up VCT-based interventions in organic and low-input farming systems.

HIGHLIGHTS

- 10% fertilizer reduction + VCT sustained Tulsi yield and promoted sustainability.
- 58.4% profit margin and ₹ 20.8/L break-even price ensured economic viability.
- T3 (100% RDF + SS) and T4 (100% RDF + SS) showed the highest B:C ratio and ROI.
- Supports SDGs 2, 8, 12, and 13 for eco-friendly farming.

Keywords: Cost-effectiveness, B:C ratio, break-even point, sustainability, microbial inoculants

Medicinal plants play a crucial role in global healthcare systems, serving as primary sources of bioactive compounds for pharmaceuticals, nutraceuticals, and traditional medicine. Among them, Tulsi (*Ocimum basilicum L.*) is widely recognized for their medicinal properties, including antimicrobial, antioxidant, hepatoprotective, and immunomodulatory effects (Arya *et al*. 2024; Dhama *et al*. 2023; Kamelnia *et al*. 2023). The rising demand for herbal medicines has intensified the need for sustainable and efficient cultivation techniques that enhance both yield and phytochemical content while minimizing environmental impact. However, conventional farming practices relying on synthetic fertilizers and agrochemicals contribute to soil

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degradation, groundwater contamination, and greenhouse gas emissions, necessitating the adoption of eco-friendly alternatives (Shafiq *et al*. 2024; Sharma *et al*. 2024; Garg *et al*. 2023; Sarkar *et al*. 2020; Rakshit *et al*. 2018). The United Nations (UN) proposed 17 Sustainable Development Goals (SDGs) after critically evaluating the situation and potential threats of climate change. These goals aim at collaborative efforts towards the upliftment of social and economic standards without compromising the environment and future generations (Ermolina *et al*. 2021; Georgeson and Maslin 2018).

In recent years, compost tea has emerged as a promising organic amendment capable of improving soil health, enhancing plant growth, and boosting the production of bioactive compounds in medicinal plants. Compost tea is a liquid extract obtained from compost, enriched with beneficial microorganisms, humic substances, and essential nutrients, which contribute to nutrient availability, microbial diversity, and plant resilience against biotic and abiotic stresses (Garg and Rakshit 2024; De Corato 2020; Eudoxie and Martin 2019). Its application in medicinal plant production is particularly relevant due to its potential to stimulate secondary metabolism, which directly influences the therapeutic efficacy of plant-derived compounds (Marcelino *et al*. 2023).

The integration of compost tea into medicinal plant farming aligns with the principles of regenerative and organic agriculture by fostering soil microbial activity, improving enzymatic functions, and enhancing plant nutrient uptake (Garg and Rakshit 2024; Rakshit *et al*. 2015). The organic compounds present in compost tea help improve soil structure, increase water retention, and suppress plant pathogens, leading to more resilient agroecosystems. Beyond its scientific significance, the social and economic implications of compost tea application in medicinal plant cultivation are substantial. The global market for medicinal plants is projected to surpass USD 200 billion, driven by increasing consumer preference for organic and herbal products (WHO, 2023). Compost tea presents an opportunity for smallholder farmers by reducing dependency on costly chemical fertilizers and promoting low-cost, sustainable agricultural practices (De Corato 2021; Martin and Brathwaite 2012). Additionally, economic analyses suggest that the benefit-cost (B:C) ratio of compost tea application may surpass that of synthetic fertilizers due to lower input costs, improved soil fertility, and premium prices for organically grown medicinal plants (Kumar *et al*. 2016). These factors collectively contribute to rural economic development, climate resilience, and long-term sustainability in medicinal plant farming.

Despite its potential, limited research has been conducted on the revenue and sensitivity analysis of compost tea and its effect on production economics of medicinal and aromatic plants. Additionally, the return of investment of compost tea-based farming remains largely unexplored, which is crucial for assessing its long-term feasibility as a sustainable input. Therefore, this study aims to analyze the sensitivity of the fortified compost tea and the economic feasibility of compost tea application through a benefit-cost (B:C) ratio and return-on investment (ROI) assessment.

MATERIALS AND METHODS

Preparation of compost tea

Fortified vermicompost tea was prepared utilising the facilities of the Department of Soil Science and Agricultural Chemistry at the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (25° 18′ N and 83° 36′E), in accordance with the procedure established by Garg and Rakshit, 2024. A brewing duration of 24 hours has been established. Compost utilised for the formulation of compost tea was sourced from the Vermicompost unit situated at the Department of Plant Pathology and Mycology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, and was prepared during the period from July to October 2023.

Pot experiment details

The experiment was carried out in the Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Banaras Hindu University. It was carried out by taking 10 kg processed soil for each pot that was air dried, crushed, sieved and analysed. The treatment details were described in Table 1. The effects of compost tea and inorganic fertilizers on plant development was examined using a Completely Randomized Design (CRD) with

10 treatment combinations viz T1: Absolute control; T2: 100% recommended dose of fertilizers (100% RDF); T3: 100% RDF + *Trichoderma asperellum* (T) + *Pseudomonas fluorescens* (P) VCT Single Spray (100% RDF+SS) ; T4: 100% RDF + *Trichoderma asperellum* (T) + *Pseudomonas fluorescens* (P) VCT Double Spray ((100% RDF+DS); T5: 90% RDF; T6: 90% RDF + *Trichoderma asperellum* (T) + *Pseudomonas fluorescens* (P) VCT Single Spray (90% RDF+SS); T7: 90% RDF + *Trichoderma asperellum* (T) + *Pseudomonas fluorescens* (P) VCT Double Spray (90% RDF+DS); T8: 80% RDF; T9: 80% RDF + *Trichoderma asperellum* (T) + *Pseudomonas fluorescens* (P) VCT Single Spray (80% RDF+SS); T10: 80% RDF + *Trichoderma asperellum* (T) + *Pseudomonas fluorescens* (P) VCT Double Spray (80% RDF+DS). Each treatment was repeated three times, yielding 30 experimental pots.

Economic analysis

1. Sensitivity and revenue analysis of vermicompost tea: Sensitivity and revenue analysis has been done by following the calculation of Sharma (2019). All the calculation has been shown in the result and discussion section.

2. Cost and return analysis of Tulsi cultivation using microbially mediated compost tea and inorganic fertilizers

The pot experiment data has been converted to a per hectare basis to calculate the costs and returns of Tulsi leaves. The research employed the average daily wage rate from Banaras Hindu University Agricultural Farm to determine the labour costs related to Tulsi cultivation. The calculation of the total cultivation cost included expenses related to seedlings, ploughing, disking, and other production input costs. We have included the production cost of compost tea based on the application rates (single and double spray) for each treatment receiving the bio-stimulant. Various economic indicators, including gross return, net return, total cost of cultivation, benefit-cost ratio (B:C), and return on investment (ROI), have been computed. Revised rates (₹) effective from 10/09/2021 for CSIR-CIMAP have been utilized for the analysis of fresh and dry leaves. The market price for fresh leaves is ₹ 100 per kg, while dry leaves are valued at ₹ 150 per kg. From the leaf count obtained from each treatment with three plants per pot, we estimated a plant population of 62,500 plants per hectare. The quality of leaves has also been considered in determining the return value. The production cost was determined by evaluating the current market prices of variable inputs and outputs. Net return is determined by deducting total expenditures incurred during crop production from gross income.

Net return = Gross return – Cost of cultivation

Gross return = Market price × Total quantity of marketed product

Cost of cultivation = Total variable cost + Total fixed cost

Benefit: cost (B: C) ratio was estimated using the following formula:

B: C ratio = Gross return (₹ per ha)/ Total expenditure (₹ per ha) (Elias *et al*. 2017)

Return-on investment (ROI) = Net return (₹ per ha) / Total expenditure (₹ per ha) (Elias *et al*. 2017)

Statistical analysis

Experimental data were tested for analysis of variance (ANOVA) and mean value of all the treatments compared through Duncan's multiple range test (DMRT) ($P \leq 0.05$ significance level). Microsoft Excel was used for all the statistical analysis.

RESULTS AND DISCUSSION

Sensitivity analysis of vermicompost tea

For 1 ha of land, 250 L of VCT was applied for single spray in Tulsi plant. According to that, we have made the calculation for 250 L. The price of 1 L of compost tea was fixed as 50 rupees after the market analysis. As the VCT has been prepared in the laboratory using normal tap water, no water charge and labour charge were required for the same. If we want to prepare it on commercial basis then these costs should be added accordingly with the other costs mentioned in Table 1. The profit margin of 58.4% highlights the economic feasibility of vermicompost tea production, making it a sustainable alternative for organic farming. The break-even price was found to be ₹ 20.8 per L, meaning that as long as the market prices remain above this threshold, production remains profitable. This indicates that even with moderate price fluctuations, the venture remains economically viable. The sensitivity analysis suggests that output price fluctuations have a greater impact on profitability than input cost variations, indicating the importance of stable pricing and value-added strategies (Saptana *et al*. 2023).

Table 1: Cost of production of vermicompost tea

Sl. No.	Materials	Quantity	Price (INR)	Total costs (INR)
1	Vermicompost	50 kg	10 per kg	500
2	Plastic drum	1 No. (500 L capacity)	3000	3000
3	Muslin cloth	10 No.	50 per piece	500
4	Molasses	1 kg	100 per kg	100
5	Air pump	1 No.	1000	1000
6	Electricity	30 unit	3.33 per unit	100
Total costs				5200

1. Profitability analysis

1. Net Profit (INR) per ha = Total Revenue - Total Cost = (250 L*50) – 5200 = 7300
2. Profit Margin (%) = (Net Profit / Total Revenue) * 100 = (7300/12500) * 100 = 58.4%
3. Break-even Price (INR) = Total Cost / Output Quantity (250L) = (5250/250) = ₹ 20.8 per L

2. Sensitivity Analysis: Impact of Input Cost Changes (±10%)

1. Cost increase by 10% = Total Cost * 1.10 = 5720
2. Cost decrease by 10% = Total Cost * 0.90 = 4680

3. New profit margins under total input cost fluctuations

1. Profit margin decreases if cost increased by 10% = {(Total Revenue – Cost increase by 10%) / Q} * 100 = 54.24%
2. Profit margin increases if cost decreased by 10% = {(Total Revenue — Cost decrease by 10%) / Q} * 100 = 62.56%

4. Sensitivity Analysis: Impact of Output Price Changes (±10%)

1. If price per L increases by 10% (₹ 55/L), N

   Profit margin increases = {(New revenue @ ₹ 55/L – Total Cost) / New revenue @ ₹ 55/L} * 100 = 62.18%
2. If price per L decreases by 10% (₹ 45/L), profit margin drops to 53.78%

Number of leaves

The data concerning the average number of leaves per pot influenced by various compost tea sprays is graphically shown in Figure 1 (90 DAT). The data unequivocally indicated that T3 (100% RDF + SS) and T4 (100% RDF + DS) exhibited the maximum leaf count at 90 DAT compared to the control and were statistically comparable to one another. T2 (100% RDF) and T7 (90% RDF + DS) exhibited comparable efficacy suggesting that a 10% reduction in mineral fertiliser, along with dual applications of VCT, might be as successful as the full mineral fertiliser dosage alone. Moya *et al*. (2016) found that in tomato plants when treated with compost tea exhibited a 30–40% increase in leaf number compared to control plants.

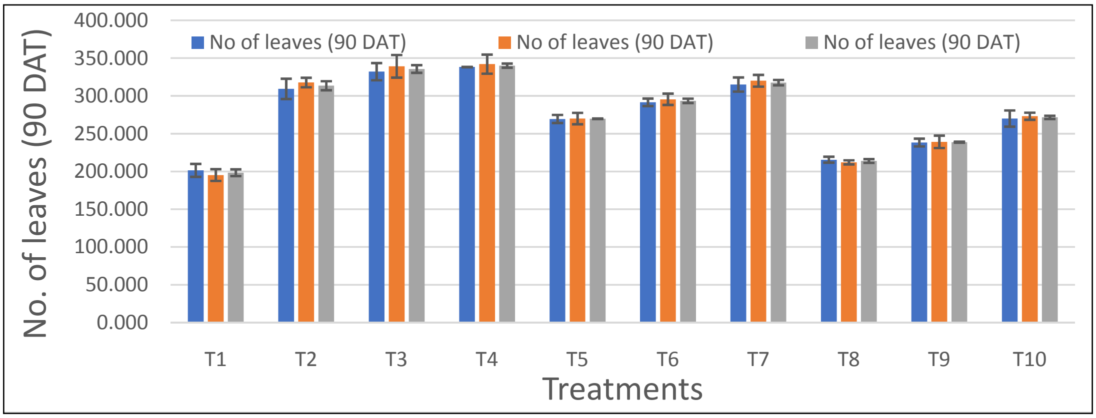

Fig. 1: Effect of microbially mediated compost tea along with chemical fertilizers on number of leaves over control (T1) after 90 DAT

Economic analysis for production of fresh leaves of Tulsi (2021–22 and 2022–23)

The economic performance of different treatments applied to Tulsi cultivation was evaluated based on key economic indicators, including total cost of cultivation, gross return, net return, benefit-cost ratio (B:C), and return on investment (ROI). The results for the years 2021–22 and 2022–23 highlight significant variations among treatments with strong implications for sustainable agricultural practices and economic resilience.

The research indicated that the cultivation expenses differed markedly between treatments, with T4 (100% RDF+DS) incurring the greatest cost. This resulted from heightened input utilization, whereas T1 (control) had the lowest expenditure. Gross returns varied, with T3 and T4 exhibiting the largest returns in the years 2021-22 and 2022-23. A dual application of VCT, in conjunction with specified fertilizers, improved leaf quantity and the quality of new foliage. Nevertheless, a singular use of VCT alone produced comparable yields. The research indicates that a 10% decrease in chemical fertiliser use, when paired with VCT, sustains equivalent revenue to complete fertiliser utilisation, improves soil health, and reduces environmental hazards.

Benefit-cost ratio and return-on-investment values help communicate the value of the research to society and key stakeholders (Asche *et al*. 2018). Analyzing benefit cost involves systematically comparing treatments' benefits with cost of cultivation of each treatment to assess the relative value of each treatment. The B:C ratio, a key indicator of economic viability, was highest for T3 in both years, indicating an increase of 8.5% in 2nd season. T4 also showed a high B:C ratio, reflecting an increase of 9.1% but statistically at par with T3 in both seasons. The lowest B:C ratio was observed in T1, indicating a decrease of 10.05% in 2nd season, highlighting its lower profitability. The higher B:C ratios in T3 and T4 can be attributed to the synergistic effects of microbial inoculants, which likely enhanced nutrient uptake efficiency and plant growth, thereby improving yield (Eudoxie and Martin, 2019). The data in Fig 3 supported the fact. Additionally, the increased market price for Tulsi leaves in the second year may have contributed to better returns. Conversely, T1 showed the lowest B:C ratio due to the absence of external nutrient supplementation, resulting in poor plant growth and lower leaf yield.

ROI, a measure of investment efficiency, further corroborated the findings. ROI value is more powerful than benefit-cost ratio because ROI value shows the net return for ₹ 100 investments. It implies the economic power of the research program in multiplying the initial investment. By comparing ROI values of different treatments, we can separate the cost-effective treatments from the ineffective one and provide the findings in monetary term to the farmers. In 2021–22, T3 had the highest ROI of 206.40%, followed by T4 (196.99%), whereas T1 had the lowest (102.99%). ROI of a similar pattern was observed in 2022–23. A comparison between 2021–22 and 2022–23 indicates overall higher economic returns in the second year. This improvement can be attributed to better market conditions, improved soil fertility, and enhanced microbial activity due to continuous application of bio-inoculants (Elias *et al.* 2017). The top-performing treatments (T3 and T4) consistently yielded higher net returns, B:C ratios, and ROI across both years, reinforcing their effectiveness in maximizing profitability.

Economic Analysis for production of dry leaves Tulsi (2021–22 and 2022–23)

The total cost of cultivation for dry leaves followed a similar trend as of fresh leaves, with T4 having the highest cost, while T1 had the lowest in both the seasons. The cost of cultivation of Tulsi for the production of dry leaves was higher than fresh leaves' production due to the cost of biomass separation, cutting, drying and cost of loading and unloading. Geyo *et al.* (2024) also found the same report and mentioned that maximum cost incurred for dry biomass production was separation of biomass. The highest B:C ratio for dry leaves was recorded in T3, indicating a 3.3% increase in the 2nd season. T4 followed closely with an increase from 2.39 to 2.43 in the subsequent year but the increase is not significant with respect to T3. ROI for T3 increased from 130.52% in 2021–22 to 149.92% in 2022–23, while T4 showed an improvement from 127.76% to 142.94%, highlighting their superior profitability. Application of no input (control) showed a significantly higher B:C ratio and ROI than

Table 2: Economic parameters for fresh leaves of Tulsi (2021-22)

Treatments	Total cost of cultivation (₹ per ha)	Gross return (₹ per ha)	Net return (₹ per ha)	B:C	ROI (%)
T1	16246[g]	32979[g]	16733[h]	2.09[e]	102.99[h]
T2	22685[de]	64456[b]	41771[b]	2.84[b]	184.13[c]
T3	24300[bc]	74456[a]	50156[a]	3.06[a]	206.40[a]
T4	25464[a]	75625[a]	50161[a]	2.96[ab]	196.99[b]
T5	22042[ef]	56147[d]	34105[d]	2.55[c]	154.72[e]
T6	23657[cd]	60741[c]	37084[c]	2.56[c]	156.75[de]
T7	24821[ab]	65650[b]	40829[b]	2.64[c]	164.49[d]
T8	21463[f]	44920[f]	23457[g]	2.09[e]	109.29[gh]
T9	23078[d]	49658[e]	26580[f]	2.15[e]	115.17[g]
T10	24242[bc]	56270[d]	32028[e]	2.32[d]	132.11[f]
CD (*p*<0.05)	994.48	2665.86	1734.15	0.132	8.066

Table 3: Economic parameters for fresh leaves of Tulsi (2022-23)

Treatments	Total cost of cultivation (₹ per ha)	Gross return (₹ per ha)	Net return (₹ per ha)	B:C	ROI (%)
T1	16265[g]	30564[g]	14299[g]	1.88[h]	87.91[j]
T2	22704[de]	66200[b]	43496[b]	2.92[b]	191.58[c]
T3	23654[bc]	78526[a]	54872[a]	3.32[a]	231.98[a]
T4	24854[a]	80325[a]	55471[a]	3.23[a]	223.19[b]
T5	22061[ef]	56124[d]	34063[d]	2.54[d]	154.40[f]
T6	23011[cd]	61484[c]	38473[c]	2.67[c]	167.19[e]
T7	24211[ab]	66515[b]	42304[b]	2.74[c]	174.73[d]
T8	21482[f]	43965[f]	22483[f]	2.04[g]	104.66[i]
T9	22432[de]	49984[e]	27552[e]	2.23[f]	122.82[h]
T10	23632[bc]	57528[d]	33896[d]	2.43[e]	143.43[g]
CD (*p*<0.05)	746.38	2373.34	1621.22	0.099	6.439

Table 4: Economic parameters for dry leaves of Tulsi (2021-22)

Treatments	Total cost of cultivation (₹ per ha)	Gross return (₹ per ha)	Net return (₹ per ha)	B:C	ROI (%)
T1	17496[h]	31484[f]	13988[f]	1.80[d]	79.95[d]
T2	23935[ef]	49339[c]	25404[b]	2.17[b]	106.14[b]
T3	25550[bc]	58898[a]	33348[a]	2.42[a]	130.52[a]
T4	26714[a]	60845[a]	34131[a]	2.39[a]	127.76[a]
T5	23292[fg]	42110[d]	18818[c]	1.91[c]	80.79[d]
T6	24907[cd]	50256[bc]	25349[b]	2.12[b]	101.77[bc]
T7	26071[ab]	52237[b]	26166[b]	2.10[b]	100.36[c]
T8	22713[g]	37690[e]	14977[e]	1.75[d]	65.94[e]
T9	24328[de]	38243[e]	13915[f]	1.65[e]	57.20[f]
T10	25492[bc]	42203[d]	16711[d]	1.74[d]	65.55[e]
CD (*p*<0.05)	856.07	2105.08	968.92	0.078	4.752

Table 5: Economic parameters for dry leaves of Tulsi (2022-23)

Treatments	Total cost of cultivation (₹ per ha)	Gross return (₹ per ha)	Net return (₹ per ha)	B:C	ROI (%)
T1	16265^{g}	30125^{h}	12565^{h}	1.72^{ef}	71.55^{g}
T2	22704de	47526^{d}	23527^{d}	1.98^{c}	98.03^{d}
T3	23654^{bc}	62352^{a}	37403^{a}	2.50^{a}	149.92^{a}
T4	24854^{a}	63526^{a}	37377^{a}	2.43^{a}	142.94^{b}
T5	22061^{ef}	41264^{e}	17908^{f}	1.77^{de}	76.67^{f}
T6	23011^{cd}	51358^{c}	27052^{c}	2.11^{b}	111.30^{c}
T7	24211^{ab}	54621^{b}	29115^{b}	2.14^{b}	114.15^{c}
T8	21482^{f}	35465^{g}	12688^{h}	1.56^{g}	55.71^{i}
T9	22432de	38496^{f}	14769^{g}	1.62^{fg}	62.25^{h}
T10	23632^{bc}	45978^{d}	21051^{e}	1.84^{d}	84.45^{e}
CD (0.05)	784.42	1955.688	1277.576	0.108	4.313

T9 (80% RDF+SS). This may be due to higher input cost in terms of fertilizers and VCT spraying but a reduction in the total number of leaves in T9. This indicates not only balanced fertilization is required but also the effect of bio-stimulant is ineffective with a reduced dose of inorganic fertilizers. Fresh leaves consistently yielded higher B:C ratios and ROI compared to dry leaves, suggesting a greater market value and demand for fresh leaves of Tulsi. Dry leaves require additional post-harvest handling, leading to lower net returns despite their market stability.

CONCLUSION

The present study demonstrates that integrating compost tea applications with chemical fertilizers significantly enhances the economic and agronomic performance of Tulsi cultivation. The economic analysis indicates that T4 (100% RDF+ DS) and T7 (90% RDF+ DS) are the most lucrative treatments for the cultivation of both fresh and dried Tulsi leaves, exhibiting the best net returns, benefit-cost ratios, and return on investment across both years. T4 (100% RDF + DS) is the most effective treatment, but T7 (90% RDF + DS) provides a robust equilibrium between sustainability and efficacy. If affordability or sustainability is a goal, T7 may be the optimal selection, however T4 may be preferable when maximum yield and growth are paramount. The incorporation of bio-inoculants with RDF markedly improved economic benefits, underscoring the significance of microbial -based interventions in sustainable agriculture. These findings closely correspond with SDGs 2, 8, 12, and 13, promoting enhanced agricultural productivity, economic resilience, responsible production, and climate-smart agriculture practices. In contrast, T1 and T9 consistently underperformed, rendering them less suitable for long-term sustainability. These insights offer a scientific framework for policymakers and farmers to improve the economic and environmental sustainability of Tulsi cultivation. Looking at the thrust of pro-diversification strategies by national agencies inclusion of medicinal and aromatic plants (MAPs) in existing cropping system can serve the purpose of ecological based agriculture drive in lower and middle Indo Gangetic Plains.

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