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ORIGINAL ARTICLE

Impact of Organic Fertilizers and Biostimulants on the Quality and Economic Viability of Beetroot (*Beta vulgaris* L.) Cultivation in the Low Hills of Uttarakhand

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ABSTRACT
A field experiment was conducted during 2022-23 at the Horticulture Research Block, School of Agriculture Sciences, SGRRU, Dehradun, Uttarakhand, to investigate the effect of organic fertilizers and biostimulants on the quality and economics of beetroot (Beta vulgaris L.) under the low hills of Uttarakhand. The experiment was laid out in a randomized block design with three replications and ten treatments. The treatments comprised different levels and combinations of organic fertilizers and biostimulants: T1 (Control), T2 (Farm Yard Manure @ 22t/ha), T3 (Vermicompost @ 5t/ha), T4 (Jeevamrutha @ 100%), T5 (Biostimulant @ 3%), T6 (FYM @ 22t/ha + Vermicompost @ 5t/ha), T7 (Vermicompost @ 5t/ha + Jeevamrutha @ 100%), T8 (FYM @ 22t/ha + Biostimulant @ 3%), T9 (FYM @ 11t/ha + Vermicompost @ 2.5t/ha + Jeevamrutha @ 50% + Biostimulant @ 1.5%), and T10 (FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%). The crop variety Detroit Dark Red was sown on November 18, 2022. Observations and studies on various growth and yield characters were recorded using standard measurement methods. Among all the organic treatments, T7 (Vermicompost @ 5t/ha + Jeevamrutha @ 100%) showed a significant improvement in net profit per hectare (₹649,830) compared to other treatments. T10 recorded the maximum mineral percentage (0.11%). T9 recorded the highest total soluble solids (°Brix) (9.84). T5 recorded the highest benefit-cost ratio (1:4.61). T4 recorded the maximum titratable acidity (0.30%). T2 recorded the highest total pH value (5.71). However, the maximum moisture percentage was observed under treatment T1 (84.47%).
Keywords: *Organic fertilizers, randomized, vermicompost, biostimulant, jeevamrutha*

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INTRODUCTION

The beetroot is the taproot portion of a beet plant, usually known in North America as beets, while the vegetable is referred to as beetroot in British English. It is also known as table beet, garden beet, red beet, dinner beet, or golden beet. Beetroot can be roasted or boiled. It can also be canned, either whole or cut up, and often pickled, spiced, or served in a sweet-and-sour sauce. Beetroot is one of several cultivated varieties of *Beta vulgaris* grown for their edible taproots and leaves, called beet greens. These have been classified as *B. vulgaris* subsp. *Vulgaris Conditiva* Group. Other cultivars of the same species include the sugar beet, the leaf vegetable known as chard or spinach beet, and mangelwurzel, which is a fodder crop. Three subspecies are typically recognized. The consumption of vegetables and fruits is essential to people's overall health. In recent years, the root vegetable Beta vulgaris subsp. vulgaris – otherwise known as red beetroot (herein referred to as beetroot) – has attracted much attention as a health-promoting functional food. Beetroot is rich in bioactive compounds that may provide health benefits, particularly for disorders characterized by chronic inflammation. The typical color of beetroots is caused by the best-known betacyanin, betanin, which forms a major part of the total betalanin content, up to 41% [1]. Red beetroot (Beta vulgaris L.), as a naturally occurring root vegetable and a rich source of phytochemicals and bioactive compounds, is known for its beneficial roles in the improvement of several clinical and pathological outcomes [2]. The application of organic manure increases the availability of organic elements in the soil, thereby improving the nutrient use efficiency (NUE) of crops and alleviating the harmful impact of climate change on crop production. In recent years, the scientific community has highlighted the advantages of implementing organic farming in agricultural production to ensure sustainable nutrient management for crops, food safety, and soil health [3]. FYM boosts plant metabolism by increasing nutrient uptake and, in turn, cell division and elongation. However, FYM can lose nutrients in the form of ammonia when it is constantly exposed to the scorching sun and heavy rain [4,5]. Vermicomposting is an eco-friendly fertilizer and is highly beneficial for growing plants. Vermicomposting enhances plant growth, suppresses diseases in plants, increases porosity, and boosts microbial activity in the soil [6]. Jeevamrutham is low-cost organic liquid manure used in organic farming for sustainable crop production. It is an excellent source of natural carbon and biomass, containing the macro and micro nutrients required by crops, making it the best alternative to chemical fertilizer [7]. The term "biostimulants" is defined in the 2018 Farm Bill as "a substance or microorganism that, when applied to seeds, plants, or on the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient use efficiency, tolerance to abiotic stress, or crop quality and yield." The EPA currently does not regulate biostimulants, but this is likely to change in the near future. Biostimulants are not classified as fertilizers, nor do they have direct effects on pests [8].

MATERIAL AND METHODS

The present research was carried out at the Horticulture Research Block, Department of Horticulture, School of Agricultural Sciences, Shri Guru Ram Rai University, Dehradun, Uttarakhand, during the rabi season of 2022–23. The experiment was designed as a Randomized Block Design (RBD) and replicated three times. A total of ten treatments were tested, namely: T1 (control), T2 (Farm Yard Manure @ 22t/ha), T3 (Vermicompost @ 5t/ha), T4 (Jeevamrutha @ 100%), T5 (Biostimulant @ 3%), T6 (FYM @ 22t/ha + Vermicompost @ 5t/ha), T7 (Vermicompost @ 5t/ha + Jeevamrutha @ 100%), T8 (FYM @ 22t/ha + Biostimulant @ 3%), T9 (FYM @ 11t/ha + Vermicompost @ 2.5t/ha + Jeevamrutha @ 50% + Biostimulant @ 1.5%), and T10 (FYM @ 22t/ha + Vermicompost @ 5t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%). The soil of the research field was sandy loam in texture, with a pH of 7.12, containing available nitrogen (220.04%), phosphorus (9.1 kg/ha), and potassium (18.1 kg/ha). The beetroot cultivar "Detroit Dark Red" was chosen for the research. Organic fertilizers, including Vermicompost, FYM, Jeevamrutha, and Biostimulant, were incorporated into the experimental field according to the specified treatments during the final field preparation. Seeds were sown on November 18, 2022. All cultural practices were performed at regular intervals as required by the crop throughout the research period. During the experiment, five plants were randomly selected from each replication to record various observations on growth and yield characteristics at 60, 90, and 120 days after sowing, and at the final harvest. The obtained data were statistically analyzed using standard statistical methods as suggested by Gomez and Gomez [19].

Table: 1 Treatment details

No. of Treatment	Combinations	Concentration
T_1	Control	Soil @100%
T_2	FYM	@22t/ha
T_3	Vermicompost	@5t/ha
T_4	Jeevamrutham	@100%
T_5	Biostimulant	@3%
T_6	FYM + Vermicompost	@22t/ha + @5t/ha
T_7	Vermicompost + Jeevamrutha	@5t/ha + @100%
T_8	FYM + Biostimulant	@22t/ha + @3%
T_9	FYM + Vermicompost + Jeevamrutha + Biostimulant	@11t/ha + @2.5t/ha + @50% + @1.5%
T_{10}	FYM + Vermicompost + Jeevamrutha + Biostimulant	@22t/ha + @5t/ha + @100% + @3%

RESULT AND DISCUSSION

The investigation revealed that different doses of organic fertilizers significantly influenced various quality and economic characteristics compared to the control group. As shown in Tables 1, 2, and 3, significant improvements were observed with the application of different combinations of organic fertilizers, relative to the control. The findings of this investigation are recorded and discussed thoroughly below:

Total Soluble Solids (°Brix)

The observation of Total Soluble Solids (°Brix) recorded at the final harvest is presented in Table 2 and Figure 1, showing significant differences among the treatments. At the final harvest, Total Soluble Solids (°Brix) ranged from 9.73 to 9.84. The highest Total Soluble Solids (9.84) was recorded in treatment T9, which included FYM @ 11 t/ha + Vermicompost @ 2.5 t/ha + Jeevamrutha @ 50% + Biostimulant @ 1.5%. The lowest Total Soluble Solids (9.73) was observed in treatment T1, the control (100%). Despite these differences, all treatments were statistically comparable to each other. This may be attributed to increased carbohydrate production, which enhanced the physiological and biochemical activities of the plant system. These findings are consistent with those reported by [9,10]. in beetroot studies.

Total pH

The observation of pH values recorded at the final harvest is presented in Table 2 and Figure 2, revealing significant differences among the treatments. At the final harvest, the maximum pH value (5.71) was recorded in both treatment T2 (Vermicompost @ 5 t/ha) and treatment T10 (FYM @ 22 t/ha + Vermicompost @ 5 t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%). The minimum pH value (5.66) was recorded in treatment T9 (FYM @ 11 t/ha + Vermicompost @ 2.5 t/ha + Jeevamrutha @ 50% + Biostimulant @ 1.5%). Despite these differences, all treatments were statistically comparable. This indicates that increased temperature does not significantly affect pH values. The observed pH changes may be due to the presence of acetic acid added in the form of brine during beetroot processing. Consequently, the pH value of beetroot remains relatively stable. These findings are consistent with those reported by [11,12] in beetroot studies.

Titratable acidity (%)

The observation of Titratable Acidity (%) recorded at the final harvest is presented in Table 2 and Figure 3, revealing significant differences among the treatments. At the final harvest, the titratable acidity % was non-significant across all treatments. However, the maximum titratable acidity (0.30%) was recorded in treatment T4 (Jeevamrutha @ 100%), and the minimum (0.25%) was recorded in treatment T5 (Biostimulant @ 3%). Despite these differences, all treatments were statistically comparable for titratable acidity %. This consistency may be due to higher acidic conditions, which help maintain product quality by limiting the growth of harmful bacteria, thereby enhancing preservative properties. These findings are consistent with those reported by [13] in beetroot studies.

Moisture content (%)

The observation of moisture content recorded at the final harvest is presented in Table 2 and Figure 4, revealing significant differences among the treatments. At the final harvest, the maximum moisture content (84.47%) was observed in treatment T3 (Vermicompost @ 5 t/ha). However, all treatments were statistically comparable, and there was no significant effect of organic fertilizers on moisture content. This consistency may be due to the variability of moisture content in beetroot during long-term cold storage. Fresh beetroots are prone to spoilage because of their high moisture content and require proper preservation. Drying and dehydration are effective preservation methods that ensure microbial safety of biological products. These findings are comparable to those reported by [14,15] in beetroot studies.

Mineral percentage

The observation of mineral percentage recorded at the final harvest is presented in Table 2 and Figure 5, revealing significant differences among the treatments. At the final harvest, the maximum mineral percentage (0.11%) was observed in treatment T2, which was statistically comparable to treatments T4, T5, T6, T7, T8, and T10. The minimum mineral percentage (0.01%) was recorded in treatment T1 (control). Overall, there was no significant effect of organic fertilizers on the mineral percentage. This lack of significant variation may be due to the role of minerals in synthesizing secondary metabolites, either directly as part of their structure or indirectly as cofactors or activators of enzymes. Therefore, optimizing nutrient supply is crucial for plant health, which can be achieved through appropriate and sustainable fertilization practices. These findings are comparable to those reported by [16] in beetroot studies.

Economics

Net profit and B:C ratio

The economics of all treatments are presented in Table 3, revealing significant differences among them. The net profit per hectare ranged from Rs. 2,45,930 to Rs. 6,49,830, with the maximum net profit recorded under treatment T7 (Rs. 6,49,830). The benefit-cost ratio varied from 1:1.16 to 1:4.61, depending on the treatment. The highest benefit-cost ratio (1:4.61) was achieved with treatment T5

(Biostimulant @ 3%), while the lowest (1:1.16) was observed with treatment T4 (Jeevamrutha @ 100%). The benefit-cost ratio indicates the economic viability of the cultivation process, as highlighted by [17,18].

Table 2: Effect of organic fertilizers on Total Soluble Solids (°Brix), Total pH, Titratable acidity (%), Moisture content (%), and Mineral percentage of beetroot at final harvest stage

Treatment	Total Soluble Solids (°Brix)	Total pH	Titratable acidity (%)	Moisture content (%)	Mineral (%)
T_1	9.78	5.70	0.28	84.47	0.01
T_2	9.76	5.71	0.26	83.20	0.11
T_3	9.73	5.70	0.26	82.80	0.10
T_4	9.74	5.68	0.30	82.87	0.11
T_5	9.81	5.70	0.25	84.33	0.11
T_6	9.82	5.70	0.26	82.93	0.11
T_7	9.79	5.68	0.28	83.93	0.11
T_8	9.81	5.70	0.28	82.87	0.11
T_9	9.84	5.66	0.28	83.47	0.10
T_{10}	9.83	5.71	0.27	83.40	0.11
$C.D_{(0.05\%)}$	NS	NS	NS	NS	NS
SE(m)	0.03	0.01	0.01	0.70	0.01
SE(d)	0.04	0.02	0.02	0.10	0.01
C.V.	0.58	0.43	9.21	1.47	15.12

Table 3: Effect of different organic fertilizer on net return and B:C ratio of beetroot at final harvest

Treatment	Net return (Rs ha^{-1})	B:C Ratio
T_1	269730	1:3.11
T_2	245930	1:1.63
T_3	253530	1:1.30
T_4	288030	1:1.16
T_5	403567	1:4.61
T_6	445330	1:2.51
T_7	649830	1:1.83
T_8	425767	1:2.80
T_9	547398	1:2.16
T_{10}	567467	1:1.35

T_1: Control; T_2: FYM @ 22t/ha; T_3:Vermicompost @ 5t/ha; T_4: Jeevamrutha@ 100%; T_5: Biostimulant @ 3%; T_6: FYM @ 22t/ha + VC @5t/ha; T_7: VC @ 5t/ha + JV @ 100%; T_8: FYM @ 22t/ha + BS@ 3%; T_9: FYM @ 11t/ha + VC@ 2.5t/ha + JV @50% + BS@ 1.5%; T_{10}: FYM @ 22t/ha + VC@ 5t/ha + JV @100% + BS@ 3%

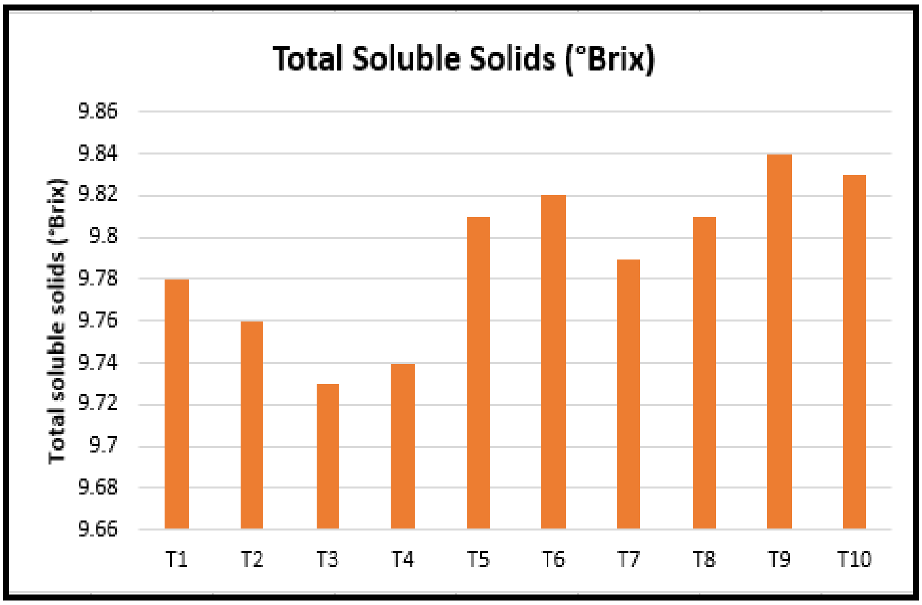

Fig.1 Total Soluble Solids (°Brix) at Final harvest as influenced by application of organic fertilizer

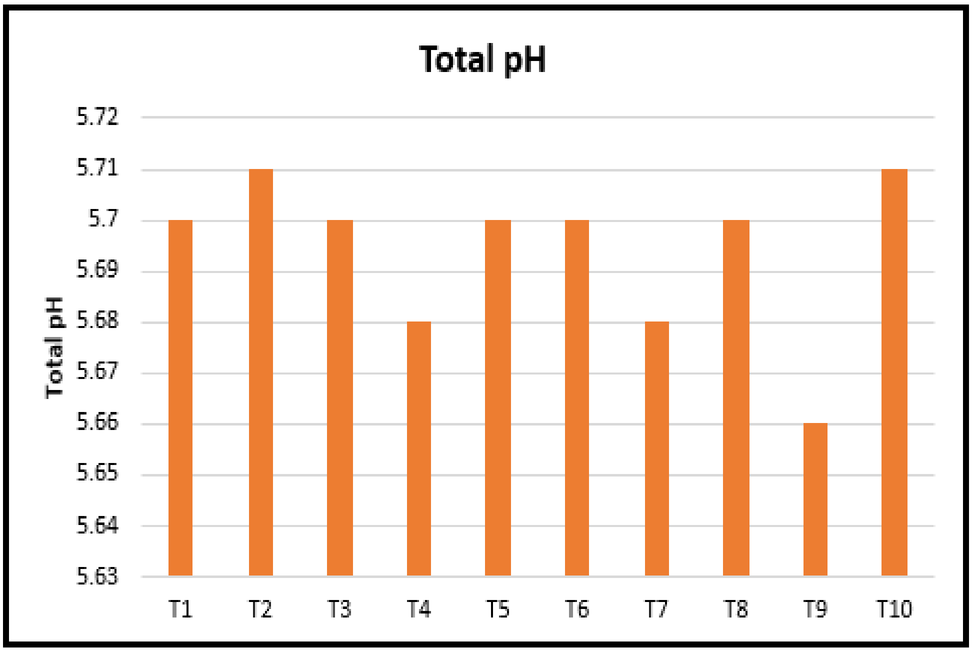

Fig.2: Total pH at Final harvest as influenced by application of organic fertilizer

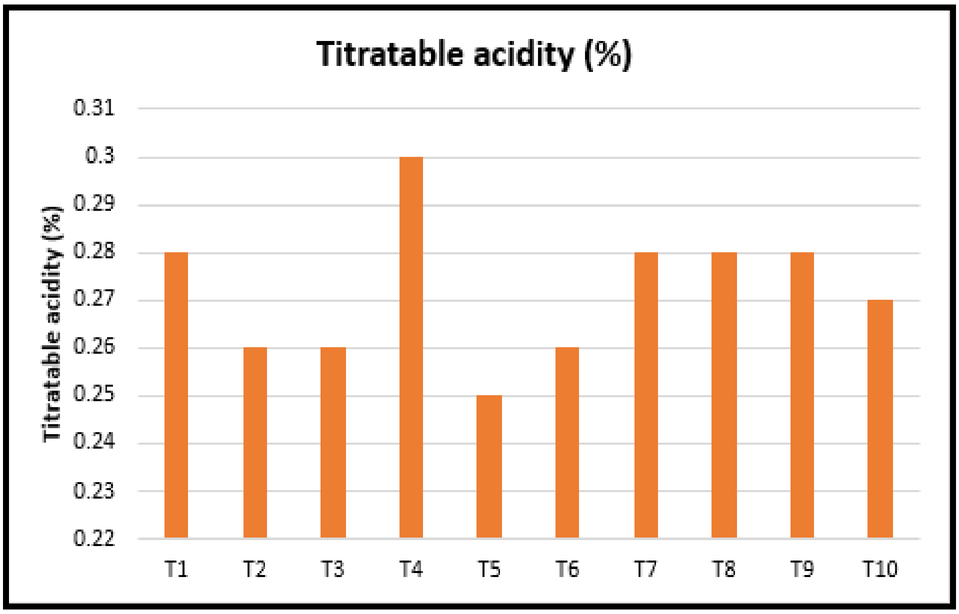

Fig.3 Titratable acidity (%) at Final harvest as influenced by application of organic fertilizer

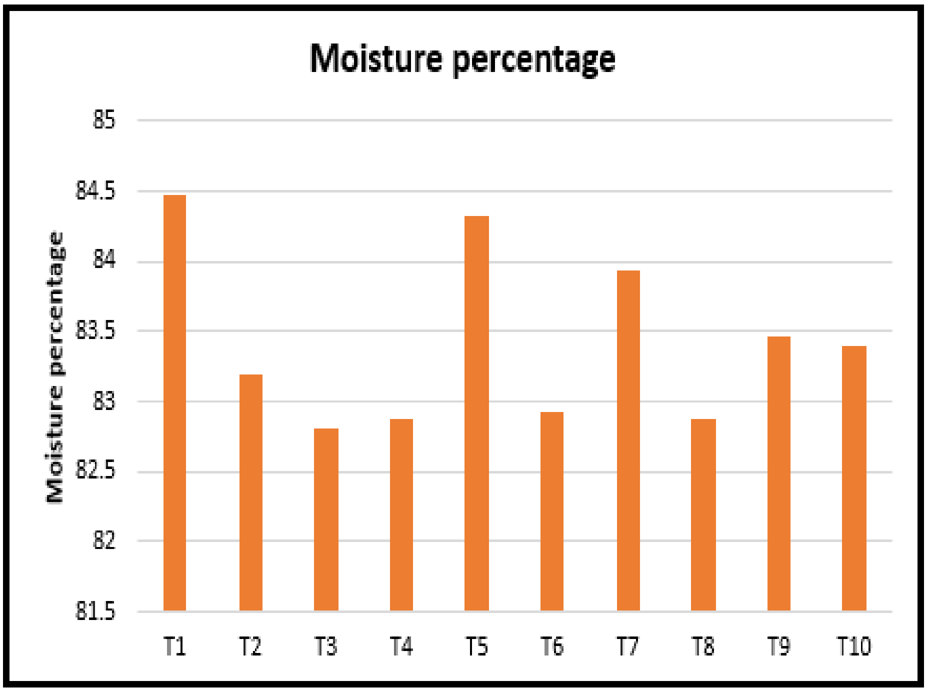

Fig.4 Moisture content at Final harvest as influenced by application of organic fertilizer

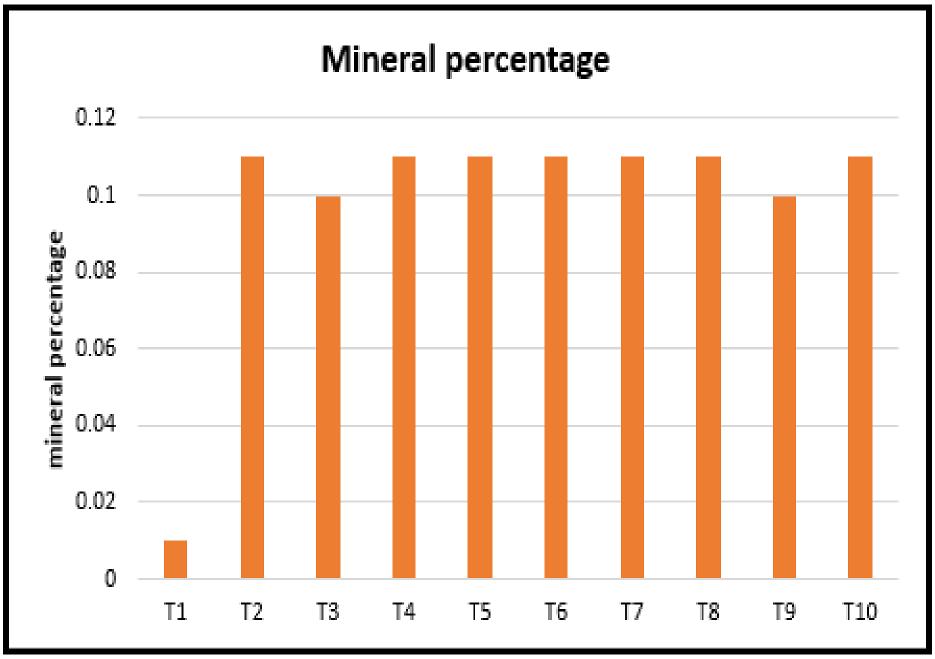

Fig.5 Mineral percentage at Final harvest as influenced by application of organic fertilizer

CONCLUSION

Based on the present investigation into the "Effect of Organic Fertilizers and Biostimulants on Quality and Economics of Beetroot (*Beta vulgaris* L.) under the low hills of Uttarakhand," several conclusions can be drawn. Treatment T7, which included Vermicompost @ 5 t/ha + Jeevamrutha @ 100%, demonstrated a significant improvement in net profit per hectare, reaching Rs. 6,49,830, compared to other treatments. Treatment T10, with FYM @ 22 t/ha + Vermicompost @ 5 t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%, recorded the highest mineral percentage at 0.11%. The highest Total Soluble Solids (°Brix) of 9.84 were observed in treatment T9, which also included FYM @ 22 t/ha + Vermicompost @ 5 t/ha + Jeevamrutha @ 100% + Biostimulant @ 3%. Treatment T5, with Biostimulant @ 3%, achieved the highest benefit-cost ratio of 1:4.61. The maximum titratable acidity of 0.30% was recorded in treatment T4 (Jeevamrutha @ 100%). Treatment T2, which used FYM @ 22 t/ha, recorded the highest total pH of 5.71.

The highest moisture percentage of 84.47% was observed in the control treatment T1. The investigation indicates that supplementing with FYM, Vermicompost, Jeevamrutha, and Biostimulants enhances soil fertility and leads to better yield performance. Thus, these treatments are recommended under the current agro-climatic conditions to achieve sustainably higher yield and quality of beetroot.

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