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Estimation of seaweed extract and micronutrient potential to improve net returns by enhancing yield characters in tomato using correlation analysis

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ABSTRACT

In recent days, seaweed extracts are being used as biostimulants in agriculture. Various studies define that it enhances the growth of horticultural crops, but there is still a dearth of information regarding their biostimulant effect on yield and net returns of tomatoes. Hence, this research aims to explore the efficacy of seaweed extract in conjunction with micronutrients to enhance tomato yield, ultimately maximizing the economic returns. A field experiment using a factorial randomized block design with three replications was carried out comprising two factors, factor A, i.e., 12 treatment combinations of *Ascophyllum nodosum* extract (0.2% and 0.4%), Zinc (0.2%), and Boron (0.2%) applied at 15, 30, and 45 days after transplanting as a foliar spray and factor B, i.e., two hybrid varieties of tomato *viz*., Tomato no. 575 (red) and Yellow Jubilee (yellow). As per the results obtained, the treatment T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) significantly improved the plant average weight of fruit, number of fruits/plant, equitorial and polar diameter of fruit, yield/plant, average yield/ha and harvest duration for both the studied varieties V_1 (Tomato no. 575) and V_2 (Yellow Jubilee). Moreover, it positively increased the net returns of tomato crops by enhancing marketable yield to fetch better returns. All the studied yield traits showed a significant positive correlation with the economic traits. The findings indicate significant improvements in key yield parameters, including fruit size, weight, and overall plant health. Moreover, the economic assessment underscores the financial viability of adopting these enhanced agricultural practices.

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is one of the most consumed and cultivated vegetables globally, valued for its nutritional content and culinary versatility. The economic significance of tomato cultivation underscores the importance of maximizing yields to meet the increasing demand for this crop. Factors such as climate change, soil degradation, and pest pressures pose challenges to traditional farming practices, necessitating the adoption of innovative strategies to optimize production. Tomato production organizations are seeking innovative management solutions that make extensive use of high-productivity hybrids with better nutritional value [1]. Improving yield attributing characters, such as fruit size, weight, and number per plant, can significantly impact the overall productivity of tomato crops. In the quest for sustainable agricultural practices, the utilization of organic inputs such as seaweed extracts and micronutrients has gained attention due to their ability to improve crop productivity and quality. They are essential for adequate growth and optimum yield, as plants require a proper balance of all essential nutrients [2].

Seaweed extracts, derived from marine algae are rich sources of bioactive compounds, growth regulators, and nutrients that can stimulate plant growth and development. These extracts have been proclaimed to enhance nutrient uptake, improve stress tolerance, and boost crop yields in various plant species, as it determined a 23.7% increase in tomato yield compared to control [3]. Foliar application of brown seaweed extracts increases the number of flower buds, flowers, and fruits in treated tomato plants [4]. Similarly, Kendal Root, a biostimulant containing *Ascophyllum nodosum* and plant extracts, significantly improved tomato yield traits, including fruit number, yield per plant, and yield per hectare, when applied at 5.0 l ha^{-1} [5]. The incorporation of biostimulants in crop production is a sustainable approach that boosts the productivity of crops while minimizing environmental impact [6]. Similarly, micronutrients, essential elements required in small quantities for plant growth, play vital roles in enzyme activation, photosynthesis, and overall plant metabolism. Adequate boron levels are crucial for pollen germination, fruit set, and increasing yield potential in tomatoes. Its deficiency can

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reduce the nutrient uptake, i.e., nitrogen, potassium, and calcium, impacting overall plant health and yield [7]. Zinc plays a vital role in improving flower setting, fertilization, and fruit development in crops like tomatoes, a 27.6% increase in fruit yield over control was observed with the conjoint application of Zn and B (2.0 kg ha^{-1}) [8,9].

Seaweed extracts and micronutrients hold significant implications for sustainable agriculture by offering a holistic approach to enhancing tomato production through organic means [10,11]. The combination of seaweed extracts and micronutrients can present a promising avenue for enhancing the net returns of tomato cultivation. This study highlights the potential role of seaweed extracts and micronutrients in enhancing flowering and supporting sustainable practices in horticulture. By leveraging the synergistic effects of these organic inputs, it is possible to optimize plant growth, increase nutrient assimilation, and improve yield-attributing characteristics in tomatoes. By elucidating the potential benefits of seaweed extracts and micronutrients in improving yield-attributing characteristics, this study contributes to the development of eco-friendly farming practices that promote both environmental stewardship and economic prosperity. The findings of this research can guide farmers, agronomists, and policymakers in adopting innovative strategies to optimize tomato cultivation and secure food production in a changing agricultural landscape.

2. MATERIALS AND METHODS

2.1. Experimental Area

The current study was conducted at Lovely Professional University, Punjab (India), School of Agriculture, Horticulture Research Farm. The longitude 75°23′03.02 E and latitude 31°22′31.81′N with an altitude of 252 m, which is located under the central plains of the agro climate zone of Punjab, India. The average annual rainfall is about 686 mm. The temperature range observed during the growing season was between 48°C and 6°C, respectively, and relative humidity varied between 60% to 85%.

2.2. Experimental Material

Two open-field hybrid varieties of tomato were used *viz.,* 1. Tomato no. 575: Red-colored variety with an average yield of 40–50 *t* ha^{-1}. 2. Yellow Jubilee: yellow-colored variety with an average yield of 50–60 *t* ha^{-1}. Seaweed extract of *A. nodosum* obtained from "Biovita" was used as a biostimulant. Zinc (Zn) and boron (B) were used as micronutrients in the form of zinc sulfate monohydrate (33%) and boron (20%).

2.3. Experimental Details

A factorial experiment with two factors *viz*., factor 1: 12 treatment sprays with seaweed extract (*Ascophyllum nodosum*) and micronutrients (B and Zn) in all possible combinations and factor 2: two varieties, as given in Table 1. All the treatments were replicated thrice to reduce the error. Each treatment consists of 30 plants per replication which were planted on ridges in 3 rows, i.e., 10 plants in each row. Spacing was maintained at 60 × 30 cm within rows and plants, respectively.

2.4. Treatment Applications

Treatment sprays were prepared according to the concentrations given in Table 1 using water as solvent. ANSE @ 0.2% (2 ml/l) and ANSE @ 0.4% (4 ml/l), Zn @ 0.2% (6.06 g/l), and B @ 0.2% (10 g/l). Foliar application of the prepared solutions was done thrice at the interval of 15 days, i.e., 15, 30, and 45 days after transplanting, respectively.

Table 1. Details of factor with their abbreviations and complete composition.

Factor A (Treatment spray with seaweed extract, Boron, Zinc: 12 foliar sprays)	
T_1	Control
T_2	Zn @ 0.2% (micronutrient)
T_3	B @ 0.2% (micronutrient)
T_4	ANSE @ 0.2% (seaweed extract)
T_5	ANSE @ 0.4% (seaweed extract)
T_6	Zn @ 0.2% + B @ 0.2%
T_7	Zn @ 0.2% + ANSE @ 0.2%
T_8	Zn @ 0.2% + ANSE @ 0.4%
T_9	B @ 0.2% + ANSE @ 0.2%
T_{10}	B @ 0.2% + ANSE @ 0.4%
T_{11}	Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%
T_{12}	Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%
Factor B (Varieties)	
V_1	Tomato 575
V_2	Yellow Jubilee

T: Treatment spray; V: Varieties; ANSE: *Ascophyllum nodosum* seaweed extract; Zn: Zinc; B: Boron.

2.5. Yield Attributes

The crop was transplanted in the main experimental field with a proper layout in the last fortnight of February and the first picking was taken in the second week of June till three consecutive pickings. Observation for yield parameters was taken from five randomly tagged competitive plants under each treatment and the average was noted. Yield/plant (kg) and Average fruit weight (g) was measured using a digital weighing balance and noted in grams and kgs, whereas Average Yield/ha (t) was calculated manually using yield per plant and noted in metric tonnes. Fruit diameter (cm) (equitorial and polar) was taken using a digital vernier calliper and noted in cm. The number of Fruits/plant and Locules/fruit were counted manually from the tagged plants and horizontally cut fruit after harvesting, respectively. The Harvest duration for crops under each treatment was observed by noting the number of days from the first harvest to the last harvest and mentioned in days.

2.6. Economic Attributes

The economics of crop production involves optimizing financial aspects by managing input costs and revenues to ensure profitability which depends on crop yield and market prices. The following aspects were observed in consideration to work out the economics of the crop using the methods mentioned by Akubo *et al.* [12]

Cost of cultivation (₹): The cost of cultivation for each treatment combination was calculated separately based on the price of all fixed as well as variable inputs (seed, fertilizer, labor, irrigation, and land cost) during the experimental year.

Gross return (₹): The gross returns (₹/ha) were estimated on the basis of the wholesale market price of tomato in the experimental year, which was ₹17 for V_1 (Tomato no. 575) and ₹ 23 for V_2 (Yellow jubilee).

Gross return = Yield of crop (kg) × Market price of the crop (₹/kg)

Net returns (₹): The net returns were calculated by deducting the total cost of cultivation from the gross return.

Net income (₹/ha) =Gross income (₹/ha) – Cost of cultivation (₹/ha)

Table 2. Effects of seaweed extract and micronutrient on yield attributes of the tomato.

	Polar diameter (cm)	Equitorial diameter (cm)	Number of locules /fruit	Average fruit weight (g)	Number of fruits/plant	Yield/plant (kg)	Average Yield/ha (*t*)	Harvest duration (days)
Treatment spray (*T*)								
T_1	5.59^{j}	5.19^{j}	3.57^{c}	87.88^{j}	21.88^{l}	1.67^{l}	61.92^{l}	18.97^{j}
T_2	5.85^{i}	5.40^{i}	3.74^{c}	98.24^{i}	22.88^{k}	1.84^{k}	68.51^{k}	19.58^{i}
T_3	5.91^{h}	5.54^{h}	4.59^{abc}	108.40^{h}	23.12^{j}	1.87^{j}	69.40^{j}	20.21^{h}
T_4	6.31^{d}	6.12^{d}	4.25^{bc}	139.80^{d}	27.93^{d}	2.49^{d}	92.54^{d}	23.05^{c}
T_5	6.48^{c}	6.33^{c}	4.25^{bc}	150.41^{c}	28.41^{c}	2.55^{c}	94.65^{c}	23.40^{b}
T_6	6.07^{g}	5.76^{g}	4.25^{bc}	113.59^{g}	23.75^{i}	1.96^{i}	72.78^{i}	20.99^{g}
T_7	6.08^{fg}	5.86^{f}	5.77^{a}	120.29^{f}	24.39^{h}	2.04^{h}	75.70^{h}	21.07^{fg}
T_8	6.12^{f}	5.95^{e}	4.25^{bc}	125.74^{e}	25.82^{g}	2.17^{g}	80.71^{g}	21.39^{f}
T_9	6.18^{e}	6.09^{d}	4.76^{abc}	126.12^{e}	26.66^{f}	2.30^{f}	85.47^{f}	22.13^{e}
T_{10}	6.21^{e}	6.11^{d}	4.08^{bc}	138.97^{d}	27.45^{e}	2.42^{e}	89.99^{e}	22.55^{d}
T_{11}	6.65^{b}	6.83^{b}	5.26^{ab}	167.54^{b}	29.35^{b}	2.67^{b}	99.02^{b}	23.71^{b}
T_{12}	7.13^{a}	7.01^{a}	5.43^{ab}	184.05^{a}	30.20^{a}	2.76^{a}	102.22^{a}	24.20^{a}
SEM ±	0.149	0.136	0.439	1.519	0.049	0.006	2.158	0.111
CD (p = 0.05)	0.129	0.388	1.253	4.338	0.143	0.017	6.21	0.316
Varieties (*V*)								
V_1	59.23^{b}	59.18^{b}	3.31^{b}	106.35^{b}	25.33^{b}	2.20^{b}	81.59^{b}	21.82^{b}
V_2	65.16^{a}	61.20^{a}	5.71^{a}	153.82^{a}	26.64^{a}	2.26^{a}	83.90^{a}	27.73^{a}
SEM ±	0.061	0.056	0.179	0.62	0.02	0.002	0.881	0.045
CD (p = 0.05)	0.175	0.159	0.512	1.771	0.058	0.007	2.535	0.182
Treatment combination (T × V)								
T_1V_1	5.58^{m}	4.89^{o}	2.72^{e}	76.07^{o}	21.83^{p}	1.62t	60.32t	18.91^{i}
T_1V_2	6.04^{i}	6.00^{h}	5.78^{bc}	120.03^{h}	26.03^{i}	2.21^{k}	82.17^{k}	21.70^{f}
T_2V_1	5.60^{m}	5.23^{n}	3.40^{de}	95.52^{mn}	21.92^{p}	1.71s	63.51s	18.92^{i}
T_2V_2	6.11^{h}	6.17^{g}	4.76^{cde}	121.75^{h}	26.81^{g}	2.32^{i}	86.03^{i}	22.11^{ef}
T_3V_1	5.67^{l}	5.47^{m}	3.40^{de}	95.87^{mn}	22.32^{o}	1.78r	66.21r	19.04^{i}
T_3V_2	6.33^{g}	6.18^{g}	3.74^{cde}	130.11^{g}	26.81^{g}	2.34^{i}	86.84^{i}	22.18^{ef}
T_4V_1	5.92^{j}	5.72^{j}	3.74^{cde}	107.19^{jk}	24.95^{k}	2.03^{m}	75.44^{m}	21.07^{g}
T_4V_2	6.67^{d}	6.49^{d}	4.76^{cde}	179.07^{c}	29.18^{c}	2.63^{d}	97.52^{d}	23.68^{bc}
T_5V_1	6.01^{i}	5.93^{i}	2.72^{e}	111.57^{ij}	25.07^{k}	2.05^{m}	75.97^{m}	21.08^{g}
T_5V_2	6.92^{c}	6.71^{c}	5.78^{bc}	183.72^{c}	29.64^{b}	2.68^{c}	99.44^{c}	23.82^{abc}
T6V1	5.72^{l}	5.48^{m}	3.40^{de}	96.02^{mn}	22.47^{no}	1.81q	67.25q	20.20^{h}
T_6V_2	6.34^{g}	6.24^{f}	5.10^{cd}	131.16^{fg}	26.83^{g}	2.37^{h}	87.90^{h}	22.47^{e}
T_7V_1	5.81^{k}	5.49^{m}	2.72^{e}	92.62^{mn}	22.55^{n}	1.91^{p}	70.82^{p}	20.22^{h}
T_7V_2	6.40^{f}	6.25^{f}	8.82^{a}	132.21^{fg}	27.18^{f}	2.42^{g}	89.87^{g}	22.99^{d}
T_8V_1	5.82^{k}	5.55^{l}	3.74^{cde}	99.68^{lm}	23.44^{m}	1.93^{op}	71.55^{op}	20.23^{h}
T_8V_2	6.45^{f}	6.26^{f}	4.76^{cde}	137.53^{ef}	28.08^{e}	2.53^{f}	93.95^{f}	23.13^{d}
T_9V_1	5.83^{k}	5.56^{kl}	3.74^{cde}	103.04^{kl}	23.70^{l}	1.95^{no}	72.63^{no}	20.91^{g}
T_9V_2	6.51^{e}	6.27^{f}	5.78^{bc}	139.91^{e}	28.92^{d}	2.60^{e}	96.44^{e}	23.60^{c}
$T_{10}V_1$	5.91^{j}	5.61^{k}	3.40^{de}	103.85^{kl}	23.76^{l}	1.97^{n}	73.20^{n}	20.94^{g}
$T_{10}V_2$	6.61^{d}	6.41^{e}	4.76^{cde}	170.75^{d}	29.03^{cd}	2.62^{de}	97.18^{de}	23.63^{c}
$T_{11}V_1$	6.02^{i}	5.94^{i}	3.40^{de}	115.12^{hi}	25.61^{j}	2.14^{l}	79.25^{l}	21.21^{g}
$T_{11}V_2$	7.27^{b}	7.18^{b}	7.13^{ab}	219.17^{b}	29.79^{b}	2.74^{b}	101.61^{b}	24.13^{ab}
$T_{12}V_1$	6.05^{i}	6.02^{h}	3.40^{de}	121.28^{h}	26.50^{h}	2.27^{j}	84.10^{j}	22.09^{ef}
$T_{12}V_2$	7.58^{a}	7.29^{a}	7.46^{ab}	237.99^{a}	31.22^{a}	2.88^{a}	106.92^{a}	24.28^{a}
SEm ±	0.211	0.193	0.621	2.148	0.07	0.008	3.052	0.157
CD (p = 0.05)	0.607	0.549	1.772	6.134	0.202	0.023	8.782	0.447

The alphabetic values denote the significant grouping of means in the data, where groups sharing the same letter are not significantly different. T1-Control, T2-Zn @ 0.2%, T3-B @ 0.2%, T4-*Ascophyllum nodosum* extract @ 0.2%, T5-*Ascophyllum nodosum* extract @ 0.4%, T6-Zn @ 0.2% + B @ 0.2%, T7-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, T8-Zn @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, T9-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, T10-B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, T11-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.2%, T12-Zn @ 0.2% + B @ 0.2% + *Ascophyllum nodosum* extract @ 0.4%, V1-Tomato no. 575, V2-Yellow Jubilee.

Benefit-cost ratio (B:C): It indicates the returns the farmer will get on per rupee invested. It is the ratio of net returns to the total cost of cultivation.

$$\text{Benefit cost ratio (B:C)} = \frac{\text{Net Return (₹/ha)}}{\text{Cost of cultivation (₹/ha)}}$$

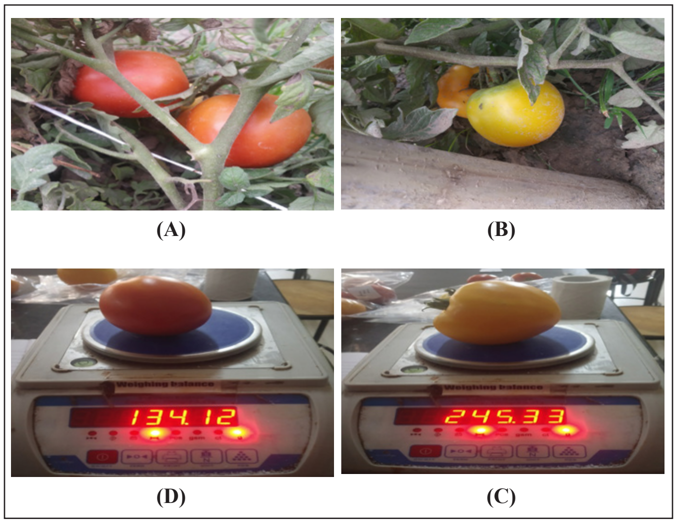

Figure 1. In field pictures of varieties Tomato no. 575 (a) and Yellow Jubilee (b); Average fruit weight (g) under treatment T_{12} for both the varieties tomato no. 575 (c) and Yellow Jubilee (d).

2.7. Statistical Analysis

The experimental data was analyzed using two-way ANOVA with R software and results were stated at a 5% level of significance (p = 0.05), after the testing normality assumptions of variance using Shapiro-Wilk normality test. Duncan's multiple range test was applied to check the significance of means. Pearson's Linear Correlation analysis was performed to find out the relation among yield and net returns.

3. RESULTS

3.1. Yield Attributes

When the yield attributing characters were evaluated, the results revealed that the applied treatment sprays consisting of *A. nodosum* extract and micronutrient had a significant positive effect on the studied varieties and their yield attributing characters in comparison to control (T_1). The impact of foliar spray of *A. nodosum* extract along with micronutrients B and Zn on yield parameters of tomato is presented in Table 2. As per the results presented in Table 2 the polar and equatorial diameter of fruit (7.13 cm and 7.014 cm) significantly increased with the application of T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) among all the applied treatments and showed an increase in polar and equatorial diameter as compared to control, respectively, similar results were observed for the average weight of fruit (184.05 g), fruits/plant (30.20), yield/plant (2.76 kg), average yield/ha (102.22 *t*) and harvest duration (24.20 days) whereas, the highest number of locules/fruit (5.77) were observed in Treatment T_7 (Zn @ 0.2% + ANSE @ 0.2%).

As for both the studied varieties, the maximum significant positive results for polar and equatorial diameter of fruit (65.16 and 61.20 cm), number

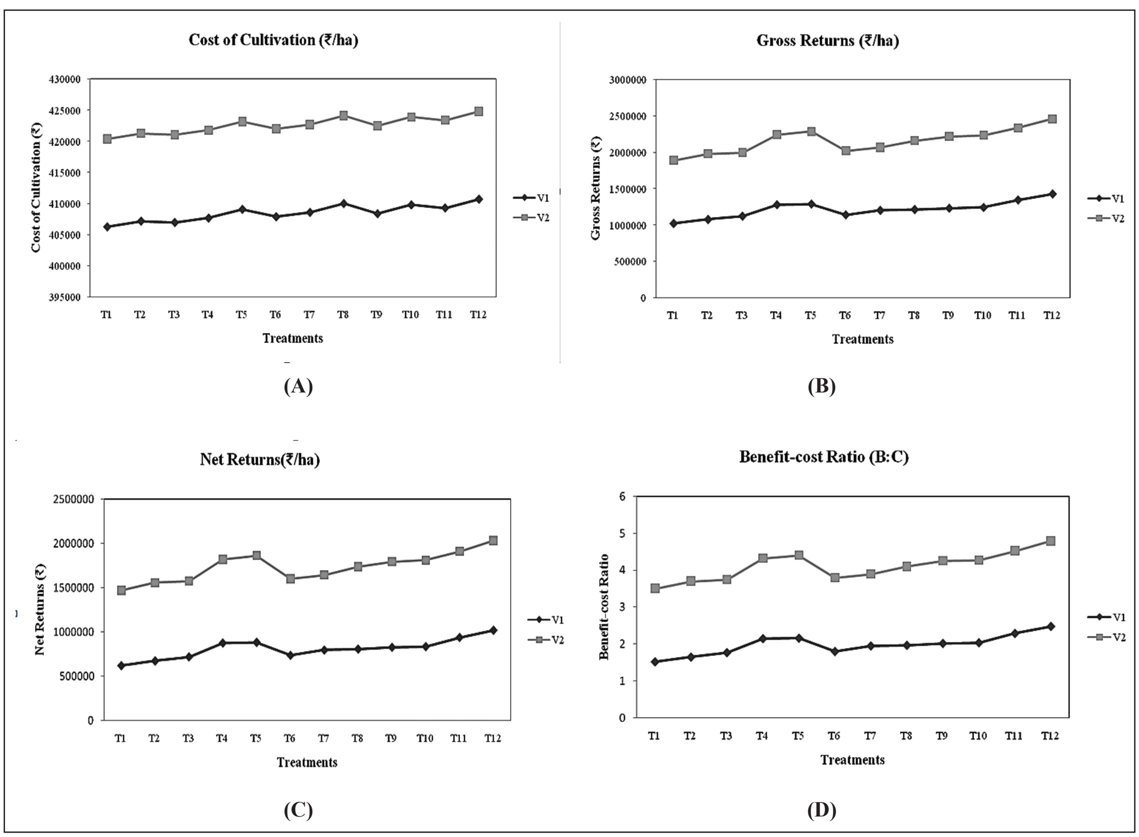

Figure 2. Results for economic characteristics of tomato crop with the application of seaweed extract and micronutrients.

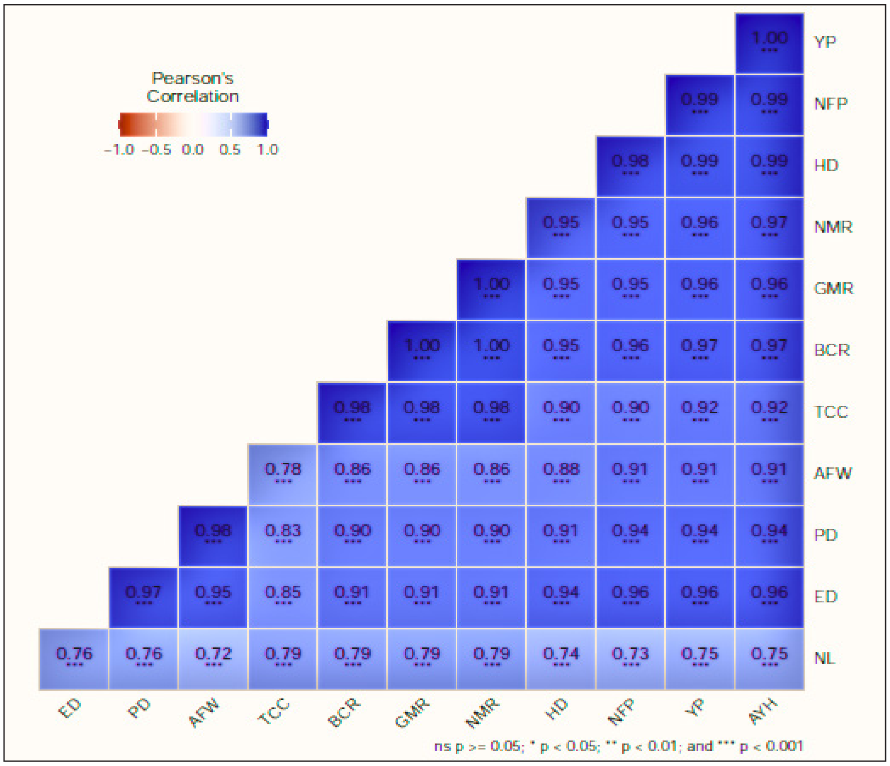

Figure 3. Pearson correlation heatmap of yield and economics of tomato plants treated with seaweed extract and micronutrients (PD: Polar Diameter; ED: Equitorial Diameter; NL: Number of locules/fruit; NFP: Number of fruits/plant; AFW: Average fruit weight; YP: Yield/plant; AYH: Average Yield/ha; HD: Harvest duration; TCC: Cost of Cultivation; GMR: Gross Return; NMR: Net Returns; BCR: Benefit Cost Ratio).

of locules/fruit (5.71), average weight of fruit (153.82 g), fruits/plant (26.64), yield/plant (2.26 kg), average yield/ha (83.90 *t*), and harvest duration (27.73 days) were observed in variety V_2 (Yellow Jubilee).

The highest positive results for all the yield attributing characters were obtained in variety V_2 when treated with foliar spray of treatment $T_{12,}$ i.e., $T_{12}V_2$ [(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)] recorded polar and equitorial diameter of fruit (7.58 and 7.29 cm), the average weight of fruit (237.99 g) (Fig. 1a and b), fruits/plant (31.22), yield/plant (2.88 kg), average yield/ha (106.92 *t*), and harvest duration (24.28 days), respectively, compared to all the studied treatment combinations. But the maximum number of locules/fruit (5.77) were observed in treatment T_7V_2 [(Zn @ 0.2% + ANSE @ 0.2%) + ((Yellow Jubilee)].

3.2. Economic Attributes

Economic attributes of the crop were also affected by the foliar spray of seaweed extract along with micronutrients, results for the same are presented in Figure 2a–d. The average wholesale selling price of tomato for V_1 is about 17 ₹/kg and for V_2 is about 23 ₹/kg. It was found that a profit of 6 ₹/kg was obtained from the variety V_2 as compared to V_1. As per the results interpreted in graphs presented in Figure 2a–d the highest gross return (24,59,160 ₹/ha) and net return (20,34,385 ₹/ha) were observed with a variety V2 (Yellow jubilee) with treatment spray T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%). It was observed that there was a 228.56% difference in terms of net profitability between the treatment combination $T_{12}V_2$ with the highest net return (20,34,385 ₹/ha) and the treatment combination T_1V_1 with the least net return (6,19,175/ha). Which resulted in the high incremental benefit-cost ratio in treatment combination $T_{12}V_2$ [(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)] (4.79) followed by treatment $T_{11}V_2$ [(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.2%) + (Yellow Jubilee)] (4.52).

3.3. Correlation Between Yield and Economics

As per the results shown in Figure 3 all the tomato yield attributes showed high significant positive Pearson's linear correlation values among each other. A maximum significant positive correlation was observed between gross return, net return, benefit cost ratio, and yield/plant (1.00). Among these yield per plant showed a better correlation with a number of fruits/plant (0.99) and Harvest duration (0.99). No variables among all the studied characters were negatively correlated with each other.

4. DISCUSSION

The findings demonstrated that seaweed extract (*A. nodosum*) in combination with micronutrients zinc and boron has a significant potential to enhance yield components, promote plant growth, and support its biostimulant actions when used in agricultural crops.

Our results were consistent with the results reported by earlier studies consisting of the application of seaweed extract [13,14]. These benefits are primarily attributable to its rich bioactive compound composition [10]. Seaweed extracts include a significant amount of hormones that boost plant growth, such as auxin, gibberellin, and cytokinin. These hormones activate the plant's metabolic pathways, resulting in increased growth, flowering, and fruit setting [11]. Another mechanism related to SWE are reduction of oxidative stress leading to increased antioxidant activity which results in increased plant yield [13].

The seaweeds particularly derived from brown seaweed contain beneficial compounds such as cytokinins, Auxins, and ABA that promote plant growth and development [15]. It comprehensively improves the plant yield metrics such as days to flowering, number of fruits per plant, fruit polar and equatorial diameter, individual fruit weight, and overall yield per hectare, which translates to higher yield and productivity [16]. This enhanced yield is primarily due to the improved growth due to the compounds present in seaweed extracts which results in improved leaf photosynthesis and overall plant health which results in more fruit production. Seaweed extracts also encourage beneficial microbial colonization in the rhizosphere which solubilizes nutrients and promotes their uptake by the plant, which boosts assimilate production and yield [17]. This improved yield is a result of increased hormone activity in plants [18]. When tomato plants were treated with *A. nodosum* extract, similar outcomes for increased fruit size and number of fruits per plant were also noted [11,16,19–21].

In addition to yield enhancement, seaweed extracts also positively influenced the physical characteristics of tomatoes, such as fruit hardness, which can reduce post-harvest losses. Furthermore, these extracts were noted to shorten the ripening time of tomatoes, allowing for better market timing and increased economic returns for growers [15]. Yao *et al*. [15] reported a 10.2% and 19.8% increase in fruit hardness as compared to control when plants were applied with 60 and 90 kg/ha of seaweed extract. It also enhances the quality by improving fruit size and sweetness commanding a higher price in the market and reducing the ripening period which allows the farmer to coincide with peak market prices resulting in maximizing economic returns. Similar findings were also observed by Hernández-Herrera *et al.* [22].

Similarly, zinc and boron are essential micronutrients that play critical roles in tomato cultivation. Zinc is vital for several physiological functions, including hormone production and enzyme activity, which are crucial for growth and development. It has been shown to improve disease resistance and overall yield. As per the results reported by Osman *et al.* [23], the application of zinc can lead to a 20% to 30% increase in the yield of various crops including tomatoes. Whereas, boron impacts tomato plants by regulating flower and fruit sets which directly influences the yield. Adequate boron levels help control flower and fruit shedding thereby contributing to higher yields [6].

Zinc and boron positively affect various yield-contributing traits in tomatoes, including flowering, fruit set, fruit weight, fruit size, and overall yield. The optimal application of these micronutrients can lead to significant improvements in both yield and fruit quality, making them essential for successful tomato cultivation. They promote early flowering, and increase the number of flower clusters, fruit sets, and individual fruit weight also known as critical factors in determining yield, which results in more number of fruits and an extended fruiting period leading to improved yield. As per the results obtained by Osman *et al.* [23], the combined application of zinc and boron has been shown to yield up to 83.50 tons per hectare, demonstrating their effectiveness in enhancing overall productivity. Similar results were also obtained by Ali *et al.* [6] and Ullah *et al.* [24].

The application of zinc and boron significantly boosts tomato yield and quality, leading to enhanced economic returns for growers. The optimal use of these micronutrients not only improves productivity but also offers a favorable benefit-cost ratio, making it a valuable practice in tomato cultivation. In a study reported by Sandilya *et al.* [25], the economic analysis of the application of zinc and boron indicated a higher benefit-cost ratio as compared to the control. the increased yield and quality lead to higher market prices further enhancing the net return. The additional investment in micronutrients increased yield and quality leading to better profit for farmers by reducing the need for more expensive fertilizers which reduced the production cost [6,26].

The combined application of seaweed extract (*A. nodosum*) with micronutrients zinc and boron has shown significant potential to enhance tomato yield and economic returns. Seaweed extract enhances plant growth, flowering, and fruit setting through its rich bioactive compound composition, including hormones such as auxin, gibberellin, and cytokinin, which boost metabolic pathways and reduce oxidative stress [27]. Zinc and boron further enhance these effects by improving physiological functions, disease resistance, and fruit set [6]. This synergistic combination not only increases overall yield, fruit size, and sweetness but also shortens ripening time, leading to better market timing and higher economic returns for growers. The combined use of these biostimulants and micronutrients thus offers a favorable benefit-cost ratio, making it a valuable practice for maximizing productivity and profitability in tomato cultivation.

5. CONCLUSION

Our findings revealed that the foliar treatment of a mixture of seaweed extract from brown seaweed *A. nodosum*, boron, and zinc boosted tomato fruit setting and production which helped in improved net returns and benefit-cost ratio, however, significant effects were observed in T_{12} (Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%). The results indicate that foliar spray of seaweed extract and micronutrients in various combinations notably enhanced the yield attributing characters such as average fruit weight, number of locules/fruit, fruits/plant, yield plant^{-1}, as well as yield ha^{-1}. Among all treatments, $T_{12}V_2$ [(Zn @ 0.2% + B @ 0.2% + ANSE @ 0.4%) + (Yellow Jubilee)] exhibited a considerable increase in all the yield attributing characters which were found significantly correlated to net returns and benefit-cost ratio, directly affecting the net returns and benefit-cost ratio. Based on these findings, it can be concluded that utilizing the combination of seaweed extract and micronutrients could be an effective strategy to increase the production of tomato crops, which can lead to better returns for the growers. However, further investigation is required to completely comprehend the pathways via which biostimulants influence tomato plants.

6. AUTHOR CONTRIBUTIONS

All authors made substantial contributions to conception and design, acquisition of data, or analysis and interpretation of data; took part in drafting the article or revising it critically for important intellectual content; agreed to submit to the current j ournal; gave final approval of the version to be published; and agree to be accountable for all aspects of the work. All the authors are eligible to be an author as per the international committee of medical journal editors (ICMJE) requirements/guidelines.

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8. CONFLICTS OF INTEREST

The authors report no financial or any other conflicts of interest in this work.

9. DATA AVAILABILITY

All the datasets generated and utilized in analysis are included in the article.

10. ETHICAL APPROVAL

This study has no involvement in experiments conducted on animal and human subjects.

11. PUBLISHER'S NOTE

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12. USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declares that they have not used artificial intelligence (AI)-tools for writing and editing of the manuscript, and no images were manipulated using AI.

REFERENCES

1. Peixoto JVM, Neto CM, Campos LF, Dourado WDS, Nogueira AP, Nascimento AD. Industrial tomato lines: morphological properties and productivity. Genet Mol Res 2017;16:1–15.
2. Ahmed N, Zhang B, Chachar Z, Li J, Xiao G, Wang Q, *et al.* Micronutrients and their effects on horticultural crop quality, productivity and sustainability. Sci Hortic 2024;323:112512.
3. Di Mola I, Ottaiano L, Cozzolino E, Marra R, Vitale S, Pironti A, *et al.* Yield and quality of processing tomato as improved by biostimulants based on *Trichoderma* sp. and *Ascophyllum nodosum* and biodegradable mulching films. Agronomy 2023;13(3):901.
4. Cristofano F, El-Nakhel C, Rouphael Y. Biostimulant substances for sustainable agriculture: origin, operating mechanisms and effects on cucurbits, leafy greens, and nightshade vegetables species. Biomolecules 2021;11:1103.
5. Haleema B, Rab A, Hussain SA. Effect of calcium, boron and zinc foliar application on growth and fruit production of tomato. Sarhad J Agric 2018;34:19–30.
6. Ali MR, Mehraj H, Jamal Uddin AFM. Effects of foliar application of zinc and boron on growth and yield of summer tomato. J Biosci Agric Res 2015;6:512–7.
7. Saha B, Saha S, Kumar J, Bairwa R. Nutritional enrichment of tomato (*Lycopersicon esculentum* L.) through Zinc (Zn) and Boron (B) Fertilization. J Plant Nutr 2023;46(9):2155–66.
8. Goñi O, Quille P, O'Connell S. *Ascophyllum nodosum* extract biostimulants and their role in enhancing tolerance to drought stress in tomato plants. Plant Physiol Biochem 2018;126:63–73.
9. El Boukhari MEM, Barakate M, Bouhia Y, Lyamlouli K. Trends in seaweed extract based biostimulants: manufacturing process and beneficial effect on soil-plant systems. Plants 2020;9:359.
10. Villa e Vila V, Rezende R, Marques PAA, Wenneck GS, Nocchi RCDF, Terassi DDS, *et al.* Seaweed extract of *Ascophyllum nodosum* applied in tomato crop as a biostimulant for improving growth, yield and soil fertility in subtropical condition. J Appl Phycol 2023;35:2531–41.
11. Ali N, Farrell A, Ramsubhag A, Jayaraman J. The effect of *Ascophyllum nodosum* extract on the growth, yield and fruit quality of tomato grown under tropical conditions. J Appl Phycol 2016;28:1353–62.
12. Akubo D, Iyaji J, Zubair A, Abdulrahman A, Obafemi RA. Anaysis of cost and returns of tomato production: empirical evidence from ankpa local government area, Kogi State. Int J Agric Technol 2024;3(1):101–12.
13. Khan W, Rayirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, *et al.* Seaweed extracts as biostimulants of plant growth and development. J Plant Growth Regul 2009;28:386–99.
14. Zodape ST, Gupta A, Bhandari S. Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum* Mill.). J Sci Ind Res 2011;70:215–9.
15. Yao Y, Wang X, Chen B, Zhang M, Ma J. Seaweed extract improved yields, leaf photosynthesis, ripening time, and net returns of tomato (*Solanum lycopersicum* Mill.). ACS Omega 2020;5(8):4242–9.
16. Hussain HI, Kasinadhuni N, Arioli T. The effect of seaweed extract on tomato plant growth, productivity and soil. J Appl Phycol 2021;2:1305–14.
17. Sani MNH, Islam MN, Uddain J, Chowdhury MSN, Subramaniam S. Synergistic effect of microbial and non-microbial biostimulants on growth, yield, and nutritional quality of organic tomato. Crop Sci 2020;60(4):2102–14.
18. Colla G, Cardarelli M, Bonini P, Rouphael Y. Foliar applications of protein hydrolysate, plant and seaweed extracts increase yield but differentially modulate fruit quality of greenhouse tomato. HortScience 2017;52(9):1214–20.
19. Ali O, Ramsubhag A, Jayaraman J. Biostimulatory activities of *Ascophyllum nodosum* extract in tomato and sweet pepper crops in a tropical environment. PLoS One 2019;14(5):e0216710.
20. Dookie M, Ali O, Ramsubhag A, Jayaraman J. Flowering gene regulation in tomato plants treated with brown seaweed extracts. Sci Hortic 2021;276:109715.
21. Renaut S, Masse J, Norrie JP, Blal B, Hijri M. A commercial seaweed extract structured microbial communities associated with tomato and pepper roots and significantly increased crop yield. Micro Biotechnol 2019;12(6):1346–58.
22. Hernández-Herrera RM, Sánchez-Hernández CV, Palmeros-Suárez PA, Ocampo-Alvarez H, Santacruz-Ruvalcaba F, Meza-Canales ID, *et al.* Seaweed extract improves growth and productivity of tomato plants under salinity stress. Agronomy 2022 Oct 13;12(10):2495.
23. Osman IM, Hussein MH, Ali MT, Mohamed SS, Kabir MA, Halder BC. Effect of boron and zinc on the growth, yield and yield contributing traits of tomato. Sch J Agric Vet Sci 2019;12(2):25–37.
24. Ullah R, Ayub G, Ilyas M, Ahmad M, Umar M, Mukhtar S, *et al.* Growth and yield of tomato (*Lycopersicon esculentum* L.) as influenced by different levels of zinc and boron as foliar application. Am-Eurasian J Agric Environ Sci 2015;15(12):2495–8.
25. Sandilya A, Prasad VM, Bahadur V, Singh D, Singh YK. Response of different level of zinc and boron on growth, flowering, yield and quality of cherry tomato (*Solanum lycopersicum* var. cerasiforme) cv.'Pusa Cherry-1'. Int J Environ Clim 2023;13(10):1889–97.
26. Deepak K, Keshav B, Praseed T, Nitesh W, Pankaj KY. Effect of foliar spray of zinc and boron on performance of tomato (*Solanum lycopersicum*) cv. Manisha under net house condition. Russ J Agric Soc-Econ Sci 2022;5:125.
27. Rajendran R, Jagmohan S, Jayaraj P, Ali O, Ramsubhag A, Jayaraman J. Effects of *Ascophyllum nodosum* extract on sweet pepper plants as an organic biostimulant in grow box home garden conditions. J Appl Phycol 2022;34(1):647–57.

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