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Impact of Biochar on Evaluating the Growth and Yield Performance of 'Ansal' Tomato Variety

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The effectiveness of biochar on the growth and yield of the Ansal tomato variety was evaluated across various growth stages and quality parameters. This study was conducted to assess the impact of biochar on flowering time, fruit set, ripening, and harvest, as well as on plant height, leaf number, stem diameter, leaf area index (LAI), and dry matter accumulation. The results indicate that biochar application significantly reduced the time to flowering and fruit set, with the shortest duration observed in treatment T_2. The highest theoretical yield was recorded in T_2, reaching 77.69 tonnes per hectare, a 12.9% increase compared to the control. Actual yield also showed significant improvement, with T2 achieving 58.26 tonnes per hectare, a 12.84% increase over the control.

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Moreover, biochar treatments resulted in higher Brix values and vitamin C content, with T2 exhibiting the highest Brix value of 5.03% and a vitamin C content of 14.53 mg per 100 grams. Although fruit shape and flesh thickness did not show significant differences across treatments, the biochar treatments effectively enhanced the overall quality and yield of the Ansal tomato variety. These findings support the use of biochar as a beneficial soil amendment for improving tomato production

Keywords: Biochar; tomato growth; tomato yield; ansal variety; soil amendment.

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is a widely cultivated crop known for its economic and nutritional importance [1]. Improving tomato yield and quality is a primary goal for growers, and various agronomic practices are employed to achieve this objective. Biochar, a form of charcoal produced from organic materials through pyrolysis, has gained attention for its potential to enhance soil fertility and plant growth. Previous studies have demonstrated that biochar can improve soil properties, increase water and nutrient availability, and positively influence plant growth and productivity.

This study focuses on evaluating the effectiveness of biochar on the growth and yield of the Ansal tomato variety, a variety known for its high yield potential and fruit quality. The research aims to determine how biochar application affects key growth stages, plant development, and fruit quality indicators. Specifically, the study investigates the impact of biochar on the time from planting to flowering, fruit set, and ripening, as well as on plant height, leaf development, stem diameter, leaf area index (LAI), and dry matter accumulation. Additionally, the quality of the fruit is assessed based on Brix value, vitamin C content, total acidity, total sugars, and nitrate levels.

Understanding the effects of biochar on these parameters will provide insights into its potential as a soil amendment for enhancing tomato production. The findings from this study will contribute to the development of more effective cultivation practices and support the sustainable use of biochar in agriculture.

2. MATERIALS AND METHODS

2.1 Materials

- The Ansal tomato variety was bred by scientists from the Seminis Group and produced in India, exclusively imported and distributed in Vietnam by Mahyco Vietnam Co., Ltd. This outstanding variety combines multiple advantages and is well-suited for various cultivation regions in Northern Vietnam.
- Biochar: The biochar was derived from rice husk and produced through pyrolysis at 300°C for 2 hours. It was applied as a 100% basal dressing one week before sowing.

2.2 Methods

Experimental setup:

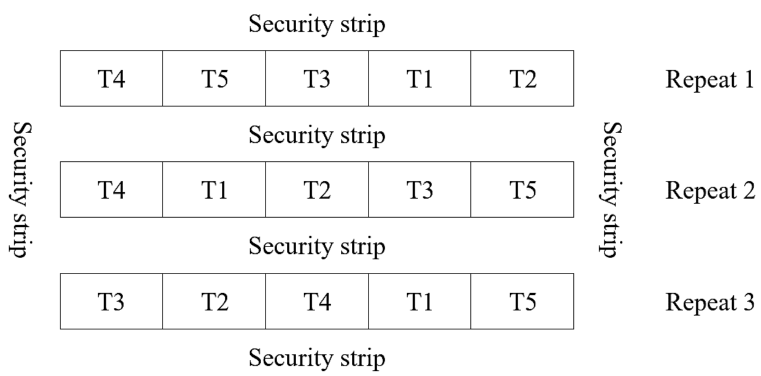

Fig. 1. Experimental design diagram

Treatments:

The experiment consisted of five treatments:

T1 (Control): 0 tons of biochar/ha + 150 kg/ha N + 100 kg/ha P_2O_5 + 150 kg/ha K_2O
T2: 3 tons of biochar/ha + 150 kg/ha N + 100 kg/ha P_2O_5 + 150 kg/ha K_2O
T3: 2.5 tons of biochar/ha + 150 kg/ha N + 100 kg/ha P_2O_5 + 150 kg/ha K_2O
T4: 2 tons of biochar/ha + 150 kg/ha N + 100 kg/ha P_2O_5 + 150 kg/ha K_2O
T5: 1.5 tons of biochar/ha + 150 kg/ha N + 100 kg/ha P_2O_5 + 150 kg/ha K_2O

Observations recorded:

The experiment was arranged in a randomized complete block (RCB) design. Each treatment was replicated three times, with each replicate consisting of one plot, and each plot measuring 5 m². The seeds were sown on September 20, 2022, and the seedlings were transplanted on October 4, 2022. Harvesting took place in January 2023.

The procedures for planting, care, and monitoring of the growth and development indicators of the tomato plants were strictly followed according to the guidelines established in QCVN 01-63:2011/BNNPTNT, issued by the Ministry of Agriculture and Rural Development of Vietnam.

2.3 Statistical Analysis

Data were statistically processed using the IRRISTAT 5.0 and Excel 2011 programs. The analysis included the examination of experimental error (CV%) and the evaluation of the least significant difference (LSD) at a 5% significance level to determine the smallest meaningful differences between the experimental treatments.

3. RESULTS AND DISCUSSION

The life cycle of tomato plants is divided into distinct stages: vegetative growth, flowering, fruit set, and fruit ripening. To complete a full life cycle, each plant must go through these growth and development stages, with their duration influenced by the genetic characteristics of the variety [2]. Additionally, environmental conditions and technical practices significantly impact the growth duration of the plants [3,4]. Besides genetic factors, temperature, humidity, light, season, and care practices are also important. Among these, the application of organic fertilizers or biochar derived from agricultural by-products is a crucial factor that can significantly affect the duration of the tomato plant's growth stages [5,6]. The results are presented in Table 1.

The time from planting to flowering ranged from 37.53 to 44.73 days. Treatments T2, T3, and T5 all exhibited shorter flowering times, ranging from 2 to 7 days earlier compared to the control (44.73 days). This difference is statistically significant at the 95% confidence level. Among these treatments, T2 had the shortest time to flowering at 37.53 days, followed by T3 and T5, which had times of 39.53 days and 40.80 days, respectively. Treatment T4 had a flowering time of 43.47 days, which did not differ significantly from the control at the 95% confidence level.

The time from planting to fruit set varied from 46.33 to 53.47 days. Treatments T2, T3, and T4 showed shorter times to fruit set compared to the control, with these differences being statistically significant at the 95% confidence level. Among these, T2 had the shortest time to fruit set at 46.33 days compared to the control (53.47 days). Treatment T5 had a fruit set time of 50.90 days, which did not differ significantly from the control at the 95% confidence level.

The time from planting to fruit ripening ranged from 80.97 to 85.87 days. At this stage, treatments T3, T4, and T5 did not show significant differences from the control at the 95% confidence level. However, T2 had the shortest time to fruit ripening at 80.97 days, which was significantly different from the control (85.87 days) at the 95% confidence level.

The time from planting to harvest completion ranged from 140.23 to 146.20 days. At this stage, all treatments showed significant differences from the control at the 95% confidence level. Specifically, T2 had the longest time to harvest completion at 146.20 days, while the control had the shortest time at 140.23 days, with this difference being significant at the 95% confidence level.

Table 1. Effect of biochar on the duration of growth stages in the Ansal tomato variety

Treatment	Time from planting to flowering (day)	Time from planting to fruit set (day)	Time from planting to fruit ripening (day)	Time from planting to harvest completion (day)
T1	44.73^{a}	53.47^{a}	85.87^{a}	140.23^{b}
T2	37.53^{c}	46.33^{c}	80.97^{b}	146.20^{a}
T3	39.53^{b}	50.33^{b}	83.23^{a}	144.20^{a}
T4	43.47^{a}	50.53^{b}	84.27^{a}	143.17^{a}
T5	40.80^{b}	50.90^{a}	83.97^{a}	143.26^{a}
$LSD_{0.05}$	1.90	2.83	3.24	3.04
CV(%)	2.5	3.0	3.1	3.3

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

The height of the tomato plants continuously increased over the observation period following planting. However, the rate of increase varied among the treatments throughout the observation days. The research results are presented in Table 2.

10 Days after planting: The height of tomato plants in the biochar treatments was greater than in the control by 0.77 cm to 1.38 cm. However, this difference was not statistically significant, as the plants had just completed the recovery phase. From day 20 to day 80 after planting: The height of the tomato plants in the biochar treatments increased rapidly. At the end of the growth period: The experimental treatments achieved the greatest heights. Among them, T2 reached the tallest height at 158.87 cm, which is 15.7 cm higher than the control (143.17 cm). The final heights for T3, T4, and T5 were 155.50 cm, 147.58 cm, and 153.98 cm, respectively.

The results indicate that variations in biochar content significantly affect plant height compared to the control, with a 95% confidence level. After 20 days, the heights of the biochar treatments ranged from 28.79 cm to 30.87 cm, growing faster than the control treatment (26.69 cm).

In tomato plants, as with all crops, the leaf canopy plays a crucial role in synthesizing organic compounds that facilitate growth and development and is a key factor in determining eventual yield [6]. The leaf area index (LAI), which is influenced by the number of leaves, is closely related to the plant's photosynthesis process and is vital for yield formation [4]. Plants with a larger leaf area and high photosynthetic rates typically have better growth and yield potential [7]. Strong leaf development indicates the plant is preparing to accumulate nutrients to support fruit production [8].

Monitoring leaf growth dynamics allows us to understand the various stages of leaf development in tomatoes, which informs optimal care practices, including fertilization and pruning [9]. This ensures the plant maintains a healthy canopy with minimal pest and disease issues, leading to better photosynthesis and higher yields [10]. The results are presented in Table 3.

At 10 days after planting, the number of leaves was relatively low. However, after transitioning past the recovery phase, the number of leaves increased rapidly across all treatments between 25 and 45 days after planting. By 85 days after planting, all treatments had higher leaf counts compared to the control (9.53 leaves), with T2 having the highest leaf count at 20.33 leaves. This indicates that the use of biochar positively impacts the number of leaves on tomato plants, thereby enhancing photosynthetic capacity and dry matter accumulation.

The data in Table 4 shows that the stem diameter of tomato plants varies across different growth stages. The impact of biochar on stem diameter growth manifests differently depending on the growth stage.

From 25 to 45 days after planting: The stem diameter ranged from 0.53 cm to 0.56 cm, with no statistically significant differences between treatments at the 95% confidence level. During this period, the tomato plants were rooting and recovering, so the stem diameter did not show marked differences. From 65 to 85 Days after planting: The stem diameter increased more rapidly compared to the previous stage, ranging from 0.92 cm to 0.97 cm, as the plants concentrated on nutrient absorption and robust stem and leaf development.

Final stem diameter: The final stem diameter across treatments ranged from 2.44 cm to 2.67

cm. All biochar treatments resulted in a larger stem diameter compared to the control, with differences ranging from 0.10 cm to 0.23 cm at the 95% confidence level. Specifically, T2 had the largest diameter at 2.67 cm, compared to the control (2.44 cm), followed by T3 and T4 with diameters of 2.64 cm and 2.54 cm, respectively.

Leaf Area (LA) and Leaf Area Index (LAI) are fundamental indicators for assessing the photosynthetic capacity of the plant population [11]. Within certain limits, an increase in LAI enhances photosynthesis, thereby improving yield [12]. The research results for LAI are presented in Table 5.

From Table 5, we observe that: The LAI values for all treatments increased gradually and peaked during the first fruit harvest period. By the peak harvest time, the LAI increased slightly and then decreased. The LAI for biochar treatments was consistently higher than that for the control and was statistically significant at the 95% confidence level. Specifically.

Pre-Flowering stage: The leaf area index (LAI) varied among the experimental treatments, ranging from 0.29 to 0.47 m^2 of leaf area per m^2 of soil. The highest LAI was observed in T2 at 0.47 m^2 of leaf area per m^2 of soil, while the lowest was in the control at 0.29 m^2.

Peak flowering stage: During this period, the LAI of the tomato plants increased significantly. The LAI values for the experimental treatments differed from the control at the 95% confidence level, ranging from 2.19 to 2.52 m^2 of leaf area per m^2 of soil. T2 had the highest LAI at 2.52 m^2 of leaf area per m^2 of soil.

First fruit harvest stage: The LAI reached its maximum, ranging from 2.79 to 3.68 m^2 of leaf area per m^2 of soil. T2 had the highest LAI at 3.68 m^2 of leaf area per m^2 of soil, which was significantly different from the control (3.03 m^2) at the 95% confidence level.

Peak fruit harvest stage: During this period, the LAI began to decrease, ranging from 2.32 to 3.20 m^2 of leaf area per m^2 of soil. The highest LAI was 3.20 m^2 of leaf area per m^2 of soil, while the lowest was in the control at 2.32 m^2.

Overall, at all growth stages of the Ansal tomato variety, T2 exhibited the highest LAI. This suggests that biochar enhances water and nutrient uptake and other physiological functions of tomato plants, particularly improving photosynthesis and leading to higher accumulation of biomass, which contributes to increased yield.

Dry matter refers to the organic substances produced through the nutrient uptake and photosynthesis of tomato plants [13]. The ability of tomato plants to accumulate dry matter and the transport of organic compounds from vegetative to reproductive organs are fundamental for yield formation [14]. Thus, higher dry matter accumulation indicates greater yield potential. Dry matter accumulation depends on the agronomic characteristics of the variety and the influence of environmental conditions, with nutrition playing a crucial role [15]. At different growth stages, dry matter accumulation varies, with each stage contributing to increased crop yield [16]. The dry matter accumulation of the Ansal tomato variety is presented in Table 6.

Pre-Flowering stage: The dry matter weight for treatments with biochar ranged from 1.01 g/plant to 1.76 g/plant, which is significantly higher compared to the control at the 95% confidence level. Among these, T2 had the highest dry matter weight at 12.37 g/plant.

Peak flowering stage: During this period, as the leaf area and number of leaves increase significantly, the dry matter weight also rises sharply. The control had the lowest dry matter accumulation, reaching only 55.47 g/plant. The dry matter accumulation for treatments with biochar ranged from 55.39 g/plant to 58.83 g/plant, all of which were higher than the control at the 95% confidence level.

Ripening stage: At this stage, most of the dry matter is accumulated in the fruit, resulting in relatively high dry matter weights. There were significant differences between biochar treatments at the 95% confidence level. T2 had the highest accumulation at 119.23 g/plant, while T5 had the lowest at 115.7 g/plant.

Yield is a critical parameter for assessing the effectiveness of cultivation techniques within the same variety [2]. The technique that results in higher yield is considered superior and predicts better economic returns [3]. The yield results for the Ansal tomato variety across different treatments are presented in Table 7.

Theoretical yield reflects the potential yield of the crop and is closely related to the yield components [17]. According to Table 7.

Table 2. Effect of biochar on the growth dynamics of plant height in the Ansal tomato variety

Treatment	10 DAP (cm)	20 DAP (cm)	30 DAP (cm)	40 DAP (cm)	50 DAP (cm)	60 DAP (cm)	70 DAP (cm)	80 DAP (cm)	90 DAP (cm)	100 DAP (cm)	Final plant height (cm)
T1	17.05a	26.67b	37.81c	48.57d	62.52b	78.17b	90.84b	103.13c	118.13c	130.29c	143.17d
T2	17.18a	30.85a	44.81a	57.04a	68.75a	84.71a	97.99a	118.96a	133.14a	146.65a	158.87a
T3	18.43a	29.33a	42.48b	54.81b	67.42a	82.37a	96.05a	111.26b	131.13a	142.73b	155.50a
T4	17.82a	28.97b	40.82b	52.21c	64.43b	78.72b	92.66b	105.08c	120.25c	132.48c	147.58c
T5	18.14a	29.72a	42.70b	54.68b	66.87a	81.93a	95.57a	111.76b	128.17b	140.62b	153.98b
$LSD_{0.05}$	1.93	1.59	2.12	2.45	2.41	4.62	2.61	2.89	2.83	3.57	4.17
CV(%)	5.7	3.9	3.7	2.5	3	3	3.5	3.4	3.2	3.4	3.5

Note: - Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

- DAP (Days after planting)

Table 3. Effect of biochar on the number of leaves in the Ansal tomato variety

Treatment	Number of leaves 10 days after planting	Number of leaves 25 days after planting	Number of leaves 45 days after planting	Number of leaves 65 days after planting	Number of leaves 85 days after planting
T1	5.60^{a}	9.00^{b}	14.27^{a}	18.47^{a}	19.53^{b}
T2	6.00^{a}	9.60^{a}	15.20^{b}	19.33^{a}	20.33^{a}
T3	5.67^{a}	9.07^{b}	15.33^{b}	19.27^{a}	20.27^{a}
T4	5.67^{a}	9.00^{b}	15.00^{b}	19.07^{a}	20.07^{a}
T5	5.47^{b}	8.93^{b}	14.67^{b}	18.80^{a}	19.87^{a}
$LSD_{0.05}$	0.50	0.49	0.79	0.59	0.77
CV(%)	4.7	2.9	2.8	1.7	2.0

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

Table 4. Effect of biochar on the growth dynamics of stem diameter in the Ansal tomato variety

Treatment	Stem diameter 10 days after planting (cm)	Stem diameter 25 days after planting (cm)	Stem diameter 45 days after planting (cm)	Stem diameter 65 days after planting (cm)	Stem diameter 85 days after planting (cm)
T1	0,55[a]	0,94[a]	1,86[b]	2,18[b]	2,44[b]
T2	0,56[a]	0,94[a]	1,94[a]	2,39[a]	2,67[a]
T3	0,56[a]	0,92[a]	1,89[b]	2,23[a]	2,64[a]
T4	0,53[a]	0,97[a]	1,92[a]	2,28[a]	2,54[a]
T5	0,56[a]	0,97[a]	1,91[a]	2,22[a]	2,59[a]
$LSD_{0.05}$	0,03	0,12	0,08	0,27	0,2
CV(%)	3,0	6,9	2,5	6,5	4,1

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

Table 5. Effect of biochar on the Leaf Area Index (LAI) of the Ansal tomato variety

Treatment	Pre-Flowering stage (m^2 of Leaf Area / m^2 of Soil)	Peak flowering stage (m^2 of Leaf Area / m^2 of Soil)	First fruit harvest stage (m^2 of Leaf Area / m^2 of Soil)	Peak fruit harvest stage (m^2 of Leaf Area / m^2 of Soil)
T1	0,29[c]	2,19[b]	2,79[b]	2,32[d]
T2	0,47[a]	2,52[a]	3,68[a]	3,20[a]
T3	0,42[b]	2,45[a]	3,61[a]	2,95[b]
T4	0,37[b]	2,42[a]	3,41[a]	2,69[c]
T5	0,43[a]	2,40[a]	3,30[a]	2,62[c]
$LSD_{0.05}$	0,05	0,14	0,39	0,17
CV(%)	6,5	3,1	6,1	3,3

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

Table 6. Effect of biochar on dry matter accumulation in the Ansal tomato variety

Treatment	Pre-Flowering stage (g/plant)	Peak flowering stage (g/plant)	Peak fruit harvest stage (g/plant)
T1	10.61b	55.47b	117.60a
T2	12.37a	58.77a	119.23a
T3	11.91a	58.83a	118.51a
T4	12.89a	57.39a	116.17b
T5	11.62a	55.77b	115.70b
$LSD_{0.05}$	1.36	2.37	2.41
CV(%)	6	2.2	2.1

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

Table 7. Effect of biochar on theoretical and actual yield of the Ansal tomato variety

Treatment	Theoretical yield (tonnes/ha)	Compared to control (%)	Actual yield (tonnes/ha)	Compared to control (%)
T1	68.80c	100	51.63c	100
T2	77.69a	112.9	58.26a	112.8
T3	76.63a	111.4	57.26a	110.9
T4	72.91b	105.9	55.07a	106.7
T5	70.86b	102.9	53.35b	103.3
$LSD_{0.05}$	4.31		2.96	
CV(%)	3.1		2.9	

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

Table 8. Effect of biochar on various morphological characteristics of the Ansal tomato variety

Treatment	Fruit Height (H) (cm)	Fruit Diameter (D) (cm)	Fruit Shape Index (I = H/D)	Fruit Flesh Thickness (cm)
T1	5.42a	5.98b	0.91 (<1)	0.75 b
T2	5.74 a	6.34 a	0.91 (<1)	0.89 a
T3	5.71 a	6.20 a	0.92 (<1)	0.85 a
T4	5.57 a	6.09 a	0.91(<1)	0.81a
T5	5.62 a	6.19 a	0.91(<1)	0.84 a
$LSD_{0.05}$	0.45	0.42		0.12
CV(%)	3.5	3		2.2

Note: Values with the same letter within a column indicate no significant difference, while values with different letters within the same column indicate significant differences at a 95% confidence level.

Table 9. Analysis results of selected quality parameters for Ansal tomato fruit

Parameter	Units of measurement %	T1	T2	T3	T4	T5
Brix	%	4.13	5.03	4.87	4.63	4.75
Vitamin C content	mg/100g	12.33	14.20	14.53	13.27	13.9
Total acidity	%	0.26	0.28	0.27	0.27	0.27
Total sugar content	fresh weight percentage (%)	3.38	4.62	4.21	4.14	3.45
Nitrate content	mg/kg	113	137	133	129	120

The highest theoretical yield was observed in T2, reaching 77.69 tonnes/ha, representing a 12.9% increase compared to the control. T3 followed with a yield of 76.63 tonnes/ha, which is a 11.4% increase compared to the control. The control had the lowest theoretical yield at 68.80 tonnes/ha. These differences are statistically significant at the 95% confidence level.

Actual yield ranged from 51.63 tonnes/ha to 58.26 tonnes/ha. All treatments showed higher yields compared to the control, with statistical significance at the 95% confidence level. The highest actual yield was in T2, reaching 58.26 tonnes/ha, an increase of 12.84% over the control. The control had the lowest yield at 51.63 tonnes/ha. Next, T3 yielded 57.26 tonnes/ha (an increase of 10.9% over the control), T4 yielded 55.07 tonnes/ha (an increase of 6.7% over the control), and T5 yielded 53.35 tonnes/ha (an increase of 3.3% over the control).

Fruit morphology and quality are crucial indicators that determine the commercial value of tomatoes [18]. The morphological characteristics and structure of the fruit are influenced by both the genetic traits of the variety and environmental conditions [19]. High commercial value fruit must exhibit key attributes such as fruit shape and flesh thickness. The results are shown in Table 8.

Fruit shape is a critical quality parameter with significant implications for consumers. It helps assess the firmness of the fruit. According to the results presented in Table 8, the height of the tomato fruit ranges from 5.42 cm to 5.74 cm, with no statistically significant differences between treatments at the 95% confidence level. The fruit shape index (I) for all treatments is less than 1, indicating that the Ansal tomato variety is generally round in shape. Since this is a genetic characteristic of the variety, the use of biochar does not significantly affect the fruit shape index.

Fruit flesh thickness is particularly important for processing, as varieties with greater flesh thickness generally have better storage and transportability. It also indicates the firmness of the fruit. The results, shown in Table 8, reveal that the flesh thickness for different biochar treatments ranges from 0.52 to 0.57 cm, with no statistically significant differences observed. Overall, the application of biochar does not have a significant impact on the fruit flesh thickness.

To validate the quality of Ansal tomato fruit when using biochar, I conducted an analysis of several fruit quality parameters: Brix value, vitamin C content, total acidity, total sugar content, and NO_3^- content compared to the control treatment. The results of the analysis are presented in Table 9.

Brix value is a biochemical indicator that assesses the content of soluble substances in fruit, with sugars comprising about 90% and the remaining being soluble organic compounds. The Brix value is highest when the fruit is fully ripe. Although Brix is a genetic trait, it is significantly influenced by environmental conditions (such as light intensity and photoperiod) and cultivation practices (such as fertilization and irrigation).

According to the results shown in the Table 9, Brix values in the various treatments ranged from 4.13% to 5.03%. Treatments using biochar exhibited Brix values higher by 0.5% to 0.9% compared to the control, with T2 achieving the highest Brix value of 5.03%.

Vitamin C content in the treatments ranged from 12.33 mg/100g to 14.53 mg/100g. T3 had the highest vitamin C content at 14.53 mg/100g, followed by 14.20 mg/100g, while the control had the lowest at 12.33 mg/100g. Therefore, using biochar as a basal fertilizer can increase the vitamin C content in tomatoes compared to conventional inorganic fertilizers.

Total acidity across treatments was low, ranging from 0.28% to 0.282% of total substances. Total sugars ranged from 3.38% to 4.62% fresh weight, with the highest being 4.62% and the lowest being the control at 3.38%.

Nitrate content in tomatoes from treatments using biochar was higher compared to the control. Overall, nitrate levels in the treatments ranged from 113 mg/kg to 147 mg/kg. Nitrate residues (NO3-) in all treatments were below the FAO and WHO threshold and within the permissible limits for tomatoes (300 mg/kg fresh weight).

4. CONCLUSION

The findings of this study demonstrate that the application of biochar, particularly in the T2 treatment, significantly improved the growth performance and yield of the Ansal tomato variety. Notably, T2 consistently exhibited superior performance across various growth parameters, including reduced time to flowering, fruit set, and ripening, compared to the control and other treatments. In addition, T2 resulted in taller plants, a greater number of leaves, and larger stem diameters, leading to enhanced photosynthetic activity, dry matter accumulation, and increased yields.

Both theoretical and actual yields were significantly higher in the T2 treatment, with actual yield showing a 12.84% increase over the control. Other treatments, such as T3 and T5, also displayed yield improvements, though to a lesser degree. Furthermore, biochar application resulted in higher Brix values, increased vitamin C content, and elevated total sugar levels, while maintaining nitrate concentrations below the permissible limits set by FAO and WHO. Importantly, key fruit quality attributes, such as shape and flesh thickness, were not significantly affected by biochar application, indicating the stability of the variety's genetic characteristics.
In conclusion, the results suggest that biochar is an effective soil amendment for enhancing both the growth and quality of tomato plants. Its use led to significant improvements in yield and fruit quality, supporting its potential role in sustainable agriculture. Further research is recommended to optimize biochar application rates and methods to maximize its benefits in tomato production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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 writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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