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Effect of Moringa Leaf Extract on Growth and Yield of Tomato

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A B S T R A C T

This study delves into the effects of Moringa oleifera leaf extract (0%, 3%, 6%, and 9% V/V) on tomato plant growth. Employing a randomized design, the 6% concentration emerges as a key player, significantly boosting performance. Results include heightened leaf count, increased height, larger and heavier fruits, improved firmness, volume, and elevated chlorophyll content. Intriguingly, the 9% concentration indicates a potential for increased branches, suggesting enhanced fruit production. Fruit pH remains consistently unaffected across treatments. Integrating moringa leaf extract, particularly at 6% and 9%, not only enhances tomato plant productivity and fruit quality but also lays the ground work for sustainable cultivation practices. This research contributes valuable insights for optimizing growth conditions, there by offering a pathway to improving overall crop yield and agricultural sustainability.

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INTRODUCTION

Around the world, tomatoes (*Solanum lycopersicum)* are grown as a vegetable crop of economic significance, prized for its nutritional value and culinary versatility (FAO, 2023). Despite its importance, optimizing tomato plant growth and increasing yield pose persistent challenges in agriculture. The exploration of natural bio-stimulants has emerged as a promising avenue, with Moringa oleifera, commonly known as the "Miracle Tree," gaining attention for its rich bioactive compounds (Siddhuraju & Becker, 2003). This study delves into the intricate effects of Moringa leaf extract on tomato plant growth and yield, with a focus on its potential contributions to sustainable agricultural practices. The ecological friendliness of Moringa leaf extract positions it as an appealing substitute for synthetic growth regulators and fertilizers. This aligns with the escalating awareness of the environmental consequences associated with conventional agricultural inputs Adekiya *et al.* (2017). By thoroughly assessing impacts on various physiological parameters, this research aims to advance understanding of sustainable agricultural practices and offer nuanced insights into optimizing tomato cultivation. The multifaceted challenges in tomato cultivation, such as nutrient deficiencies, soil quality, environmental stressors, and disease pressure, necessitate innovative solutions. Traditional approaches involving synthetic fertilizers, pesticides, and growth regulators, while effective, raise concerns about environmental sustainability and potential health risks Kumar and Agarwal (2017). In this context, the exploration of natural bio-stimulants provides a promising avenue for sustainable agriculture Moringa oleifera leaf extract has gained recognition as a potential bio-stimulant due to its rich composition of bioactive compounds, including vitamins, minerals, antioxidants, and growth-promoting substances Silva *et al*. (2020). These compounds have demonstrated potential in enhancing plant growth, nutrient uptake, and stress tolerance across various crop species. Several studies have shown the positive effects of Moringa leaf extract on tomato plants, indicating its efficacy as a growth enhancer and yield booster Khan *et al*. (2018).

This study aims to unravel the nuanced effects of Moringa oleifera leaf extract on tomato plant growth and yield. Specifically, we will investigate the multifaceted impacts on critical growth parameters, such as height, stem diameter, and overall plant vigor. Additionally, we will evaluate the influence on both the quantity and quality of tomato yield, considering factors such as fruit weight, size, and the number of fruits per plant. By addressing these objectives, the research endeavors to contribute substantively to the current body of knowledge, offering practical insights into sustainable tomato cultivation. This includes the potential reduction of reliance on chemical inputs, the promotion of environmentally friendly practices, and the optimization of growth conditions for improved crop yield. As the global agricultural landscape faces increasing challenges, this study aspires to provide a scientific basis for incorporating natural bio-stimulants like Moringa leaf extract into mainstream agricultural practices. In doing so, we aim to facilitate the development of sustainable and environmentally friendly approaches to tomato cultivation, fostering resilience and productivity in the face of evolving agricultural demands.

LITERATURE REVIEW

Enhancing tomato yield and improving fruit quality are primary objectives for growers. Several studies have reported the positive impact of Moringa leaf extract on these aspects. Jain *et al.* (2019) demonstrated that the application of Moringa leaf extract significantly increased the number of flowers, fruit set percentage, and yield in tomato plants. The extract's nutritional composition, including high levels of vitamins, minerals, and antioxidants, may contribute to improved fruit development and quality (Anjum *et al.*, 2014). Moreover, Moringa leaf extract has been shown to enhance the biochemical attributes of tomato fruits. Ahmad *et al*. (2018) found that treated tomato plants exhibited increased levels of antioxidants, such as phenolics and flavonoids, which are associated with improved nutritional value and extended shelf life.

Understanding the underlying mechanisms of Moringa leaf extract's effects on tomato plants is crucial for optimizing its application. Several potential mechanisms have been proposed based on existing research. One mechanism involves the regulation of plant hormones. Moringa leaf extract contains natural plant growth regulators, including cytokinins, auxins, and gibberellins, which can modulate hormone levels and balance in tomato plants. These hormonal changes influence various physiological processes, such as cell division, differentiation, and flowering, leading to enhanced growth and yield (Bharathi *et al.*, 2012). Another mechanism involves the activation of plant defense responses. Moringa leaf extract has been found to induce the synthesis of defense-related compounds, such as phenolics and flavonoids, in tomato plants. These compounds play a crucial role in plant defense against pests and diseases, thereby improving plant health and productivity (Saini *et a*l., 2018; Goudarzi *et al*., 2019). Furthermore, Moringa leaf extract has been reported to enhance nutrient uptake and assimilation in tomato plants. It contains compounds that promote the activity of beneficial soil microorganisms, improving nutrient availability and uptake by the roots. The increased nutrient uptake contributes to enhanced plant growth, development, and overall productivity (Saini *et al*., 2018; Goudarzi *et al*., 2019).

Several field studies have been conducted to evaluate the effectiveness of Moringa leaf extract on tomato growth and yield. For example, Nagarajan *et al*. (2016) conducted a field experiment and observed that the application of Moringa leaf extract as a foliar spray resulted in significant improvements in plant height, leaf area, and fruit yield in tomato plants. The study also suggested that repeated applications of the extract at specific growth stages can maximize its benefits. In, terms of application methods, Moringa leaf extract can be applied as a foliar spray, root drench, or incorporated into the soil. The choice of application method depends on factors such as plant growth stage, target outcome, and crop management practices. Each method has its advantages and considerations, and further research is needed to determine the most effective application protocol for specific tomato cultivars and growing conditions.

The use of Moringa leaf extract as a plant growth enhancer offers several environmental and economic benefits. Firstly, it provides a natural and sustainable alternative to synthetic chemical fertilizers and growth regulators, reducing the environmental impact associated with their use. Moringa leaf extract is biodegradable and poses minimal risks to soil, water, and air quality. Furthermore, the cultivation of Moringa trees for leaf extract production can have additional environmental advantages. Moringa trees are known for their fast growth and ability to thrive in diverse agroclimatic conditions, making them suitable for reforestation and ecological restoration efforts. The trees also act as carbon sinks, contributing to climate change mitigation. From an economic standpoint, the use of Moringa leaf extract can reduce input costs for farmers, especially those practicing organic or sustainable agriculture. By utilizing locally available Moringa resources, farmers can enhance their crop productivity without relying heavily on expensive synthetic inputs.

METHODOLOGY

The experiment conducted at the Pakistan Agriculture Research Council, ARI Research Farm in Tarnab Peshawar in 2023 aimed to investigate the impact of foliar application of Moringa leaf extract on the growth and yield of tomato plants *(Solanum lycopersicum)*. The selected tomato variety for the experiment was Red Rock.

Experimental Design

The experimental design employed for this study was a Completely randomized design with one factor and replicated three times. The factor under investigation was the concentration of Moringa leaf extract, which included four levels: 0%, 3%, 6%, and 9% V/V. After two weeks of transplanting the tomato plants, they were sprayed with the respective concentrations of the moringa leaf extract.

Moringa Leaf Extracts (MLE) Preparation

Young leaves of Moringa were sourced from mature trees at Malakandher Farm, The University of Agriculture Peshawar. To prepare Moringa leaf extract (MLE), the collected leaves were ground with a small amount of water using a conventional juicer operating at 10,000 rpm. The resulting mixture was then strained using a cheese cloth to separate the solid material from the juice. The obtained juice was collected in a separate container, and four dilutions of MLE were prepared as follows:

M_0- Distilled water (taken as control).

M_1- 24 ml MLE mixed with 776 ml of distilled water (3% v/v).

M_2- 48 ml MLE mixed with 752 ml of distilled water (6% v/v).

M_3- 72 ml MLE mixed with 728 ml of distilled water (9% v/v).

After two weeks of transplanting the tomato plants, the respective dilutions of MLE, and distilled water, were applied as a foliar spray.

Parameter

Data were recorded on the following parameters.

Number of Leaves Plant

The procedure involved randomly selecting two plants from each treatment within each replication and counting the number of leaves on those plants. The counts obtained from the selected plants were then averaged to derive the final results.

Leaf Chlorophyll Content (SPAD)

The leaf chlorophyll content was determined using a Soil Plant Analysis Development (SPAD) meter. For each treatment and replication, two plants were randomly chosen. From each of these plants, five leaves were selected. The SPAD meter was used to measure the chlorophyll content of these leaves. Finally, the average chlorophyll content was calculated based on these measurements.

Plant Height (cm)

To measure the plant height, a careful procedure was followed. Firstly, two plants were randomly chosen from each treatment in every replication. Using a measuring tape, the height of each selected plant was measured from the soil surface up to the highest point of the plant. This encompassed the entire vertical extent of the plant, including any stems, branches, or leaves. The process was repeated for each of the chosen plants. Finally, the recorded heights were averaged within each treatment and replication to obtain the average plant height for that specific combination.

Single Fruit Weight (g)

The single fruit weight data was collected through a systematic approach. In each replication, two plants were randomly selected for measurement. Using a digital weighing balance, the weight of each individual fruit from the chosen plants was accurately recorded. This process was repeated for all selected plants. Finally, the average weight of the single fruits was calculated by taking the mean of the recorded weights.

Number of Branches Per Plant

The counting of branches was carried out to gather data on plant morphology. Randomly selected plants from each treatment within each replication were observed, and the number of branches on each plant was counted. This process was repeated for multiple plants in order to obtain a representative sample. By calculating the average number of branches across the selected plants, an overall measure of branch density or branching pattern was determined.

Number of Fruits Per Plant

Two plants are randomly selected from each treatment, and data regarding the number of fruits is recorded after five harvests. The recorded data is then used to calculate the average number of fruits for each treatment.

Fruit pH

To assess the fruit pH, the AOAC (2012) method was employed. Randomly selected tomato fruits from all treatments were subjected to pH measurement using a pH meter. Prior to conducting the measurements, the pH meter was calibrated using standard buffer solutions.The procedure involved extracting the juice from the tomato samples and immersing a digital pH meter into the juice to determine its pH value. Before taking the measurements, the pH meter was calibrated using buffer solutions with pH values of 4 and 7. To ensure accuracy, the pH meter's electrode was washed with distilled water and carefully dried using tissue paper between each measurement.

Fruit Firmness ($Kgcm^{-2}$)

To assess fruit firmness, a penetrometer was utilized. Randomly selected tomato fruits were gently held with one hand, and a small portion of the fruit's skin was peeled off. Using the other hand, the penetrometer was pressed into the exposed area using the palm and two fingers until the knob made contact with the fruit surface. This allowed for the measurement of firmness.

Fruit Volume (cm^3)

To measure fruit volume, a procedure was followed. For each treatment in each replication, two fruits were randomly selected. These fruits were then submerged in water-filled beakers, and the amount of water displaced by the submerged fruits was carefully collected. The collected water was then transferred into a graduated cylinder to measure the fruit volume. This process was repeated for all selected fruits, and the average volume was calculated by taking the mean of the recorded volumes. This method allowed for an estimation of the average volume of the fruits, providing valuable information about their size and growth.

Fruit Yield Per Plant $^{-1}$(kg)

Fruit yield per plant is recorded after each harvest per plant.

Statistical Analysis

The recorded data were subjected to analysis of variance (ANOVA); in case of significant differences, the data were further tested for least significant difference for mean comparison at 1% and 5% levels of significance through statistical software “Statistix 8.1” (Steel and Torrie, 1997).

RESULT AND DISCUSSION

Number of Leaves Per Plant

The data concerning number of leaves per plant of tomato is presented in table 1: the ANOVA in table 1.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on number of leaves of tomato. The mean concerning moringa leaf extract concentration shown in table. I reveled that maximum number of leaves per plant (192.00) was observed in treatment applied with 6% of moringa leaf extract while minimum (165.00) was recorded in controle. The results of this study demonstrate that the foliar application of moringa leaf extract zt different concentrations significantly influences the number of leaves per tomato plant. Increasing the concentration of moringa leaf extract up to 6% MLE led to a notable increase in the number of leaves per plant, suggesting a positive effect on plant growth. However, the 9% MLE concentration did not result in a significant increase in leaf count compared to the lower concentrations. The observed, increase in the number of leaves per plant can be attributed to the presence of growth-promoting regulators, such as gibberellins, found in moringa leaf extract (Solaimalai et al., 2001; Brady and MeCourt, 2003: Harris et al., 2007). These regulators stimulate photo-assimilate translocation and effective partitioning of accumulated resources, leading to enhanced early flower development, reduced abscission of flowers and fruits, and increased seed production in field crops.

The results of this study indicate that foliar application of moringa leaf extract at concentrations up to 6% MLE significantly increases the number of leaves per tomato plant. These findings highlight the potential use of moringa leaf extract as a natural and sustainable approach to promote plant growth and improve crop productivity.

Leaf Chlorophyll (SPAD)

The data concerning leaf chlorophyll (SPAD) of tomato is presented in table 2: the ANOVA in table 2.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on leaf chlorophyll (SPAD) of tomato. The mean concerning moringa leaf extract concentration shown in table I reveled that maximum number of leaf chlorophyll (43.66 SPAD) was observed in treatment applied with 9% of moringa leaf extract while minimum (38.33) was recorded in treatment applied with 3%. The findings of this study indicate that the foliar application of different concentrations of moringa leaf extract significantly affect the leaf chlorophy II (SPAD) content of tomato fruits. Stevia increased photosynthetic pigments may be attributed to the presence of Fe and Mg in moringa leaves, which may have regulated chlorophyll production by facilitating the conversion of proporphyrine to chlorophyllide (Farooq and Koul. 2020). The presence of cytokinins in MLE could explain the increased chlorophyll production in stevia plants (Yasmeen et al., 2013). MLE also helps to avoid premature leaf senescence and chlorophyll breakdown, which may help to boost chlorophyll production and improve photosynthesis (Basra and Lovatt, 2016). MLE successfully improved photosynthetic pigments and nutraceutical characteristics in a variety of other crops, including rocket (Eruca

vesicaria L.), common bean (Phaseolus vulgaris L..), and sweet basil (Ocimum basilicum L.) plants (Nambiar et al., 2005; Abdalla, 2013; Latif and Mohamed, 2016; Alkuwayti et al., 2020). Further research is necessary to explore the potential effects of different concentrations of moringa leaf extract on other physiological parameters, such as photosynthetic rate, stomatal conductance, or nutrient uptake, to gain a comprehensive understanding of the impact of moringa leaf extract on tomato plant physiology.

The results of this study suggest that the foliar application of different concentrations of moringa leaf extract did not significantly affect the leaf chlorophyll content of tomato fruits. These findings provide valuable insights into the specific physiological responses of tomato plants to moringa leaf extract and can guide future studies on optimizing the application protocols or investigating alternative plant growth regulators for enhancing tomato fruit quality and productivity.

Table 1. Number of leaves per plant of Tomato as affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	165.00 C
3%	173.00 BC
6%	192.00 A
9%	178.33 B

LSD Value 9.8887

Table 1 shows number of leaves per plant as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 1.1a. Analysis of variance for days to leaves per plant as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	1,160.25	386.75	14.02	0.0015
Error	8	220.67	27.58	0.13	
Total	11	1,380.92	125.54		

CV 2.97 %

Table 2. leaf chlorophyll (SPAD) content of tomato fruit as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	39.00 B
3%	38.33 B
6%	42.33 A
9%	43.66 A

LSD VALUE 1.6306

Table 2 shows leaf chlorophyll (SPAD) content of tomato fruit as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 2.1a. Analysis of variance for leaf chlorophyll (SPAD) content of tomato fruit as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	59.67	19.89	26.52	0.0002
Error	8	6.00	0.75	0.13	
Total	11	65.67	5.97		

CV 2.12%.

Plant Height (cm)

The data concerning plant height of tomato is presented in table 3; the ANOVA in table 3.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on plant height of tomato. The mean concerning moringa leaf extract concentration shown in table I reveled that maximum number of plant height (175.93 cm) was observed in treatment applied with 6% of moringa leaf extract while minimum (141.23 cm) was recorded in controle. The findings of this study reveal that the foliar application of moringa leaf extract at different concentrations significantly influences the plant height of tomatoes. Increasing the concentration of moringa leaf extract led to a progressive increase in plant height. The highest plant height was observed at the 6% MLE concentration (175.93 cm), followed by the 9% MLE concentration (159.50 cm), while the lowest height was recorded at the 0% concentration (141.23 cm). The significant increase in plant height can be attributed to the presence of growth- promoting regulators, such as gibberellins, found in moringa leaf extract (Solaimalai. *et al.*, 2001; Brady and McCourt, 2003; Harris *et al.*, 2007). These regulators stimulate

plant cell elongation and promote overall growth and development, resulting in taller plants.

The findings of this study indicate that the foliar application of moringa leaf extract at concentrations up to 6% MLE significantly increases the plant height of tomatoes. These results highlight the potential use of moringa leaf extract as a natural and sustainable approach to promote plant growth and development in tomato cultivation.

Single Fruit Weight (g)

The data concerning single fruit weight of tomato is presented in table 4: the ANOVA in table 4.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on single fruit weight (g) of tomato. The mean concerning moringa leaf extract concentration shown in table 1 reveled that maximum single fruit weight (95.00 g) was observed in treatment applied with 6% of moringa leaf extract while minimum (73.67 g) was recorded in control. The results indicate that the foliar application of moringa leaf extract at different concentrations had a significant effect on the single fruit weight of tomatoes. Increasing the concentration of moringa leaf extract up to 6% ML.E led to a notable increase in the weight of individual fruits. However, the 9% ML. E concentration did not result in a significant increase in fruit weight compared to the lower concentrations. These findings suggest that the application of moringa leal' extract can positively influence fruit development and potentially enhance yield in tomato plants.

The results of this study demonstrate that the foliar application of different concentrations of moringa leaf extract significantly influenced the single fruit weight of tomatoes. Increasing the concentration of the extract up to 6% MLE resulted in a significant increase in fruit weight. These findings highlight the potential use of moringa leaf extract as a natural and sustainable approach to enhance fruit development and yield in tomato cultivation.

Table 3. Plant height as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	141.23 C
3%	146.97 C
6%	175.93 A
9%	159.50 B

LSD VALUE 10.671

Table 3 shows plant height as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 3.1a. Analysis of variance for Plant height as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	2,127.63	709.21	22.08	0.0003
Error	8	256.98	32.12	0.13	
Total	11	2,384.61	216.78		

CV 3.64%.

Table 4. Single fruit weight (g) of Tomato as affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	73.67 B
3%	82.33 B
6%	95.00 A
9%	79.00 B

LSD VALUE 10.427

Table 4 shows single fruit weight as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 4.1a. Analysis of variance for Single fruit weight as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	739.67	246.56	8.04	0.0085
Error	8	245	30.67	0.13	
Total	11	985.00	89.55		

CV 6.71%

Number of Branches Per Plant

The data concerning number of branches per plant of tomato is presented in table 5: the ANOVA in table 5.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on number of branches of tomato. The mean concerning moringa leaf extract concentration shown in table 5 reveled that maximum number of branches per plant (14.66) was observed in treatment applied with 9% of moringa leaf extract while minimum (10.66) was recorded in control. The findings of this study demonstrate that the foliar application of moringa leaf extract at different concentrations significantly affects the number of branches per plant of tomato fruits. Increasing the concentration of moringa leaf extract led to a gradual increase in the number of branches per plant. The highest number of branches per plant was observed at the 9% MLE concentration (14.66 branches), followed by the 6% MLE concentration (14.00 branches), while the lowest number was recorded at the 0% MLE concentration (10.66 branches). The significant increase in the number of branches per plant can be attributed to the growth-promoting properties of moringa leaf extract. Moringa leaf extract contains various nutrients, phytohormones, and growth regulators that can stimulate branching and lateral shoot development in plants. These compounds may have influenced the plant's hormonal balance and meristem activity, resulting in increased branching. The results of this study have practical implications for tomato growers and horticulturists.

The findings of this study highlight the positive impact of the foliar application of moringa leaf extract on the number of branches per plant of tomato fruits. The results suggest that higher concentrations of moringa leaf extract, such as 9% and 6%, can lead to a significant increase in branching.

Number of Fruit Per Plant [1]

The data concerning number of fruits per plant of tomato is presented in table 6; the ANOVA in table 6.la. The ANOVA reveled that there is significant effect of moringa leaf extract on number of fruits of tomato. The mean concerning moringa leaf extract concentration shown in table 6 reveled that maximum number of fruits per plant (42) was observed in treatment applied with 6% of moringa leaf extract while minimum (33) was recorded in control. The findings of this study demonstrate that the foliar application of moringa leaf extract at different concentrations significantly affects the number of fruits per plant of tomatoes. Increasing the concentration of moringa leaf extract led to a gradual increase in the number of fruits produced per plant. The highest number of fruits per plant was observed at the 6% MLE concentration (42 fruits), followed by the 9% MLE concentration (38 fruits), while the lowest number was recorded at the 0% MLE concentration (33 fruits). The significant increase in the number of fruits per plant can be attributed to the growth-promoting regulators present in moringa leaf extract, such as gibberellins and other phytohormones (Solaimalai et al., 2001; Brady and MeCourt. 2003; Harris et al...2007). These regulators plov a crucial role in flowering induction, fruit set, and fruit development, ultimately leading to an increased number of fruits. The results of this study have practical implications for tomato growers and horticulturists.

By employing the foliar application of moringa leaf extract at appropriate concentrations, farmers can potentially enhance the productivity and yield of tomato plants by increasing the number of fruits per plant. Improvement can contribute to better economic returns and overall profitability.

The findings of this study highlight the positive impact of the foliar application of moringa leaf extract on the number of fruits per plant of tomatoes. The results suggest that higher concentrations of moringa leaf extract, particularly at 6% MLE and 9%, MLE can lead to a significant increase in fruit production. Further research is warranted to optimize the application protocols and investigate the underlying mechanisms of action for achieving even higher yields.

Table 5. Number of branches per plant of tomato fruit as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	10.66 C
3%	12.66 B
6%	14.00 A
9%	14.66 A

LSD VALUE 1.5373

Table 5. shows Number of branches per plant of tomato fruit as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table.5.1a. Analysis of variance for Number of branches per plant of tomato fruit as affected by foliar application of moringa leafc extract.

Source	DF	SS	MS	F	P
MORENGA	3	28.00	9.33	18.67	0.0006
Error	8	4.00	0.50	0.13	
Total	11	32.00	2.91		

CV 5.44%.

Table 6. Number of fruit per plant as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	**MEAN**
0%	33 D
3%	36 C
6%	42 A
9%	38 B

LSD VALUE 2.6067

Table 6 shows Number of fruit per plant as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 6.1a. Analysis of variance for Number of fruit per plant as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	123.67	41.22	21.51	0.0003
Error	8	15.33	1.92	0.13	
Total	11	139.00	12.64		

CV 3.69%.

Fruit pH

The data concerning fruit pH of tomato is presented in table 7; The ANOVA in table 7.1a. The ANOVA reveled that there is no significant effect of moringa leaf extract on fruit pH of tomato. The mean concerning moringa leaf extract concentration are shown in table 7 which revealed that highest pH (4.16) was observed in treatment applied with 6% of moringa leaf extract while minimum (1.33) was recorded in control. The findings of this study indicate that the foliar application of different concentrations of moringa leaf extract does not significantly affect the pH of tomato fruits. The pH values for all concentrations were similar, with no notable differences observed. The lack of significant differences in fruit pH suggests that the application of moringa leaf extract at various concentrations does not influence the acidity or alkalinity of tomato fruits. Other factors, such as genetics, environmental conditions, and fruit maturity, may have a greater influence on fruit pH. It is important to note that pH is a crucial parameter for determining the taste, quality, and shelf life of fruits. In the case of tomatoes, a pli range of 4.0-4.5 is generally considered desirable for optimal flavor and storage stability. The pH values obtained in this study (ranging from 4.133 to 4.166) fall within this desired range, indicating that the fruit quality is suitable for consumption and preservation.

The results of this study suggest that the foliar application of moringa leaf extract at different concentrations does not significantly affect the pH of tomato fruits. The pH values obtained fall within the desired range for tomato fruit quality. However, additional studies are needed to explore the potential effects of moringa leaf extract on other quality attributes and to assess its overall impact on tomato fruit development and post-harvest characteristics.

Fruit Firmness ($Kgem^3$)

The data concerning fruit firmness (Kgem) of tomato is presented in table 8; the ANOVA in table 8.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on fruit firmness ($Kgcm^2$) of tomato. The mean concerning moringa leaf extract concentration shown in table 8 reveled that maximum fruit firmness of tomato (3.40) was observed in treatment applied with 6% of moringa leaf extract while minimum (3.06) was recorded in control. The findings of this study demonstrate that the foliar application of different concentrations of moringa leaf extract significantly affects the firmness of tomato fruits. The highest firmness was observed in fruits treated with the 6% concentration. followed by the 9% MLE concentration, 3% MLE concentration, and 0% concentration. Moringa leaf extract contains various bioactive compounds such as phenolic compounds and flavonoids, which have been reported to have beneficial effects on fruit quality attributes, including firmness. These compounds may contribute to the strengthening of cell walls and the inhibition of enzymatic activities that lead to fruit softening. The significant differences observed among the different concentrations indicate that the application of moringa leaf extract at higher concentrations (6% and 9%) may result in firmer tomato fruits compared to lower concentrations (0% and 3%). The findings of this study indicate that the foliar application of moringa leaf extract at different concentrations significantly affects the firmness of tomato fruits. Higher concentrations of moringa leaf extract tend to result in firmer fruits. These results contribute to our understanding of the potential use of moringa leaf extract as a natural tool for enhancing fruit quality in tomato production.

Table 7. PH of fruit as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	4.133 A
3%	4.133 A
6%	4.166 A
9%	4.133 A

LSD VALUE 0.1087

Table 7 shows PH of fruit as affected by different concentration of moringa leaves extract, means.

Table .7.1a. Analysis of variance for PH of fruit as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	0.00	0.00	0.25	0.8592
Error	8	0.03	0.00	0.13	
Total	11	0.03	0.00		

CV 1.39%.

Table 4.8. Firmness of fruit as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	3.0667 C
3%	3.1667 B
6%	3.4000 A
9%	3.2000 B

LSD value 0.0769

Table 8 shows firmness of fruit as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 8.1a. Analysis of variance for Number of fruit per plant as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	0.18	0.06	35.17	0.0001
Error	8	0.01	0.00	0.13	
Total	11	0.19	0.02		

CV 1.27%.

Fruit Volume (cm^3)

The data concerning fruit volume (cm^3) of tomato is presented in table 9; the ANOVA in table 9.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on fruit volume (cm^3) of tomato. The mean concerning moringa leaf extract concentration shown in table 9 reveled that maximum fruit

volume (184.00 cm^3) was observed in treatment applied with 6% of moringa leaf extract while minimum (172.67 cm^3) was recorded in control. The findings of this study demonstrate that the foliar application of different concentrations of moringa leaf extract significantly affects the volume of tomato fruits. The highest volume was observed in fruits treated with the 6% MLE concentration. Followed by the 9% MLE concentration, 3% MLE concentration, and 0% MLE concentration. Moringa leaf extract contains bioactive compounds, such as plant growth regulators and antioxidants, which can influence various aspects of fruit development, includingsell division, expansion, and accumulation of metabolites. These compounds may contribute to the increased volume of tomato fruits by promoting cell elongation and enhancing the overall growth and development processes. The significant differences observed among the different concentrations indicate that the application of moringa leaf extract at higher concentrations (6% and 9%) may lead to larger fruit volumes compared to lower concentrations (0% and 3%), this suggests that higher concentrations of moringa leaf extract may have a greater impact on cell division and expansion, resulting in increased fruit size.

The findings of this study indicate that the foliar application of moringa leaf extract at different concentrations significantly affects the volume of tomato fruits. Higher concentrations of moringa leaf extract tend to result in larger fruit volumes. These results contribute to our understanding of the potential use of moringa leaf extract as a natural tool for enhancing fruit size and quality in tomato production.

Fruit Yield Per Plant ^{1} (kg)

The data concerning fruit yield (Kg) of tomato is presented in table 10: the ANOVA in table 10.1a. The ANOVA reveled that there is significant effect of moringa leaf extract on fruit yield (kg) of tomato. The mean concerning moringa leaf extract concentration shown in table 10 reveled that maximum yield (3.99 kg) was observed in treatment applied with 6% of moringa leaf extract while minimum (2.46 kg) was recorded in control. These results suggest that the foliar application of Moringa leaf extract, particularly at a concentration of 6%, positively influences tomato plant yield. This may be due to the bioactive compounds present in moringa leaf extract that promote plant growth and enhance fruit development. The findings from this study have practical implications for agricultural practices, as they suggest that the foliar application of Moringa leaf extract can be used as a beneficial approach to increase tomato yield. However, further research is recommended to optimize the concentration and application frequency of the extract and to understand the underlying mechanisms responsible for the observed effects.

The results of this study indicate that the foliar application of Moringa leaf extract at concentrations up to 6% significantly increases the yield of tomatoes per plant. These findings provide valuable insights for agricultural practices and can assist farmers in enhancing tomato production and achieving sustainable crop yields.

Table 9. Volume (cm^3) of tomato fruit as of Tomatoaffected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	MEAN
0%	172.67 C
3%	180.00 B
6%	184.00 A
9%	180.33 B

LSD VALUE 2.92

Table 9. shows volume (cm^3) of tomato fruit as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 9.1a. Analysis of variance for volume (cm^3) of tomato fruit as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	202.992	67.64	27.99	0.0001
Error	8	19.33	2.20	0.13	
Total	11	222.25	20.20		

CV 0.87%.

Table 4.10. Yield (kg) of tomato per plant as of Tomato affected by foliar application of moringa leaf extract.

Moringa concentration (v/v)	**MEAN**
0%	2.4620 C
3%	2.9637 BC
6%	3.9940 A
9%	3.0540 BC

LSD value 0.5286

Table 10 shows Yield (kg) of tomato fruit as affected by different concentration of moringa leaves extract, means followed by different alphabets are significantly different at P value 0.05.

Table 10.1a. Analysis of variance for yield (kg) per plant as affected by foliar application of moringa leaf extract.

Source	DF	SS	MS	F	P
MORENGA	3	3.68	1.23	15.55	0.0011
Error	8	0.63	0.08	0.13	
Total	11	4.31	0.39		

CV 9.00%.

CONCLUSIONS AND RECOMMENDATIONS

The application of moringa leaf extract at varying concentrations significantly impacted the growth and yield of tomato plants. Notably, the 6% concentration of moringa leaf extract demonstrated the most favorable outcomes across multiple parameters, including the number of leaves per plant, plant height, single fruit weight, fruit yield per plant, fruit firmness, fruit volume, and leaf chlorophyll content. The 9% concentration exhibited a higher number of branches per plant, suggesting potential for increased fruit production. No significant differences were observed among moringa leaf extract concentrations concerning fruit pH. The findings recommend the use of a 6% moringa leaf extract concentration as a foliar spray to enhance the growth and yield of tomato plants. However, further research is advised to optimize application protocols, including timing and frequency, to maximize the effectiveness of moringa leaf extract in tomato cultivation.

ADVANCED RESEARCH

Further explore moringa leaf extract's long-term impact on soil health, assess its interaction with diverse tomato varieties, and study the economic feasibility in large-scale farming. Consider limitations such as environmental variations, potential impacts on mixed cultivation, and variations in efficacy under different environmental conditions.

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