Faculty of Agriculture, University of Poonch Rawalakot

Jammu Kashmir Journal of Agriculture

ISSN: 2958-3756 (Online), 2958-3748 (Print)

https://jkjagri.com/index.php/journal

EFFICACY OF MORINGA EXTRACT ON THE MORPHOLOGICAL PARAMETERS OF HYDROPONICALLY GROWN TOMATOES (*LYCOPERSICON ESCULENTUM* MILL.)

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A B S T R A C T

Tomato (*Lycopersicon esculentum*) belongs to the "Solanaceae" family and is the second most extensively grown vegetable around the world after potato. This study aimed to investigate the effects of Moringa Leaf Extract (MLE) as alternative to chemical fertilizers on growth and yield of hydroponically grown tomatoes in greenhouse conditions based on plant height centimeter (cm), number of leaves, number of branches, leaf area (cm), days to first flowering after sowing, number of flower clusters per plant, number of flowers per plant, days to first fruit set after sowing, fruit set percentage (%), number of fruit/plant, average individual fruit weight gram (g), fruit size, and total yield per plant kilogram (kg). The experiment was conducted at four different concentration levels of moringa extract. The morphological parameters increased with an increase in moringa leaf extract concentration from T_0 control (only distilled water), T_1 (35%) MLE, T_2 (70%) MLE, and T_3 (100%) MLE (pure). The maximum fruit yield (29.687 kg plant^{-1}) was observed in treatment T3 (pure moringa leaf extract). From this study, it was concluded that the highest percentage of moringa leaf extract resulted in yield enhancement.

Keywords: Bio-fertilizer, Concentration, Greenhouse, Growth, Yield.

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Article history
Received: April 20th, 2024
Revised: June 2nd, 2024
Accepted: June 18th, 2024

INTRODUCTION

Agriculture is a major sector of the economy of Pakistan contributing about 18.9% to the GDP of the country and gives employment to about 42.3% of the labor force. Tomato yield (10 tons/ha) in Pakistan is lower than the global average for tomato yield (34.69 tons/ha). This shows that there is a significant gap between tomato yields in Pakistan and in the world (FAO, 2018).

Vegetables are essential for the human body to provide the required nutrients. Temu and Temu (2005) described tomatoes as highly valuable vegetables because of their nutritional content. Tomatoes belong to the Solanaceae family (Matthew, 2011). Tomato plants can grow for many years in places with moderate climates, but they are typically grown as annuals, reaching a height of 1-3 meters. They have weak, woody stems that often sprawl over other plants (Warnock, 1991). They are a key crop for home gardens, market gardeners, and truck farmers. People cultivate tomatoes all around the world because of their versatility and importance. In Pakistan, tomatoes are grown on about 60.7 thousand hectares of land and produce yields of around 570.6 thousand tons (MINNFSR, 2015).

Tomato is a plant that thrives in warm weather. It is the most consumable vegetable in the country because they're rich in ingredients that are essential for human bodies, like dietary fiber, vitamins B and C, phosphorus, iron, sugars, important amino acids, and a powerful antioxidant called lycopene. Lycopene can help lower the chances of getting certain cancers and diseases that affect human brains (Srinivasan, 2010).

Plant hormones play a vital role in increasing crop yield by influencing various stages of plant development and growth. There are some main groups of these growth controllers: auxins, gibberellins, ethylene, and cytokinins. Among these, cytokinins, such as zeatin, are particularly important for enhancing the production of food. Zeatin is the one of most collective naturally arising cytokinins found in plants. Fresh leaves from the *Moringa oleifera* plant are known to contain a high amount of zeatin. According to research, Zeatin concentrations in Moringa leaves have been shown to vary widely, from 5 micrograms (mcg) to 200 mcg per gram of leaves. Vegetables are suitable to grow better with organic amendments on sustainable basis (Alam et al., 2023a). The plant's ability to increase growth and crop yield per unit area is influenced by its zeatin content (Culver et al., 2012).

A low-cost, straightforward, and environmentally friendly breakthrough, the use of an optimal blend of organic materials available locally like moringa leaf extract inspires the growth of vegetables, including cabbage, rapeseed, and tomatoes, as well as field crops like beans and maize (Alam et al., 2024). Therefore, farmers can utilize moringa leaf concentrate as organic compost. The main objective of the study was to ascertain the effects of various moringa (*moringa oleifera*) leaf extract (MLE) concentrations and application frequency on tomato Cv. Sahil yield and growth.

MATERIALS AND METHODS

The experiment was conducted during the cropping season of 2019 at the Institute of Hydroponic Agriculture, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi. The aim of the experiment was to conclude how well *Moringa oleifera* leaf extract (MLE) worked as a natural crop growth promoter. The application method involved spraying the MLE directly on hydroponically grown tomato plants in greenhouse conditions.

Preparation of Moringa Leaf Extract (MLE)

To prepare the MLE (moringa leaf extract), it followed a method described by Sarmin (2014). First, it was weighed the moringa leaf powder and mixed with water (distilled) at a ratio of 1:10 as leaf powder to water. After that electric stirrer was used to mix this mixture for four hours, and kept in the shady at room temperature for a day (24 hours). Afterward, Whatman No. 1 paper was used to filter the mixture. The resulting liquid was the stock solution, which was 100% MLE. To create different concentrations, the stock solution was diluted as follows: the control, which has 0% MLE, was made by using only distilled water. For a 35% dilution, 35 ml of the extract mixed was with 65 ml of water. A 70% dilution was made by mixing 70 ml of the extract with 30 ml of water, and for a 100% dilution, only the original MLE was used without water.

Plant Material

In this experiment, tomato cv. Sahil was selected for assessment of moringa leaf extract.

Experimental Sites and Crop Season

The study to examine and optimize the dilution of Moringa Leaf Extract (MLE) was conducted at two locations: the Institute of Hydroponic Agriculture and the laboratory in the Department of Horticulture at PMAS Arid Agriculture University in Rawalpindi. This research was conducted during the cropping season of 2019.

Experimental Design and Treatment

The experiment was set up by using a Completely Randomized Design (CRD) with three replications having three plants per replication. Following were the treatments;

T_0 Control (Only Distilled water)
T_1 35% MLE
T_2 70% MLE
T_3 100% MLE (only MLE)

The treatments were applied 30 ml of each plant with an interval of a week after transplanting.

Morphological parameters

At the completion of the cropping season, various parameters were measured to assess the plant response to various treatments. These included plant height (centimeters), no. of branches/plant, no. of leaves/plant, area of the leaf (square centimeters), the no. of days it took for the first flowering to occur after planting, the no. of flower clusters per plant, the no. of flowers per plant, the no. of days it took for the first fruit to start growing after planting, the percentage of fruit set, the no. of fruits per plant, the average weight of individual fruits (grams), the size of the fruits, and the total yield per plant (kilograms).

RESULTS

Plant Height

The average plant height (Figure 1) of tomatoes indicates that morphological parameters were affected significantly by the concentration of moringa leaf extract (MLE). The height of the plant was significantly different among all the

treatments of MLE and control treatment and the average plant height for treatment T_o control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 174.44cm, 185.44cm, 199cm and 211cm respectively. The maximum height of the plant (211cm) was recorded in treatment T_3 moringa leaf extract (pure moringa leaf extract) followed by T_2 (70%) MLE (199cm) and T_1 (35%) MLE (185cm) whereas the minimum height of the plant (174.44 cm) was recorded in treatment T_o control (only distilled water).

Number of Branches

Figure 2 indicates the average number of branches per plant of tomatoes morphological parameters were affected significantly by spraying of MLE. The number of branches was significantly different among all the treatments of MLE and control treatment, and the number of branches for treatment T_o control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 17.88, 21, 22.55 and 27 respectively. The more no. of branches (27) was noted in treatment T_3 moringa leaf extract (pure moringa leaf extract) while the lowest no. of branches (17) was noted in treatment T_o control (only distilled water).

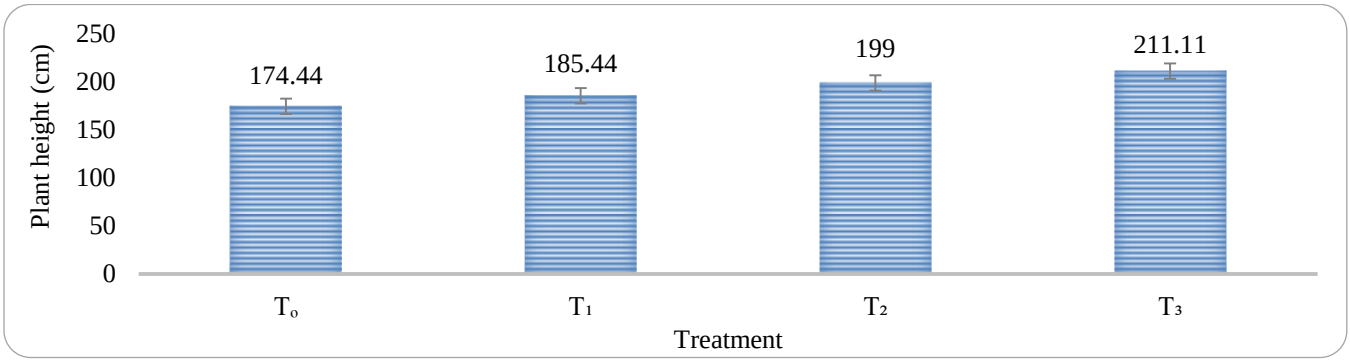

Figure 1: Effect of moringa leaf extracts foliar applications on height of tomato plant.

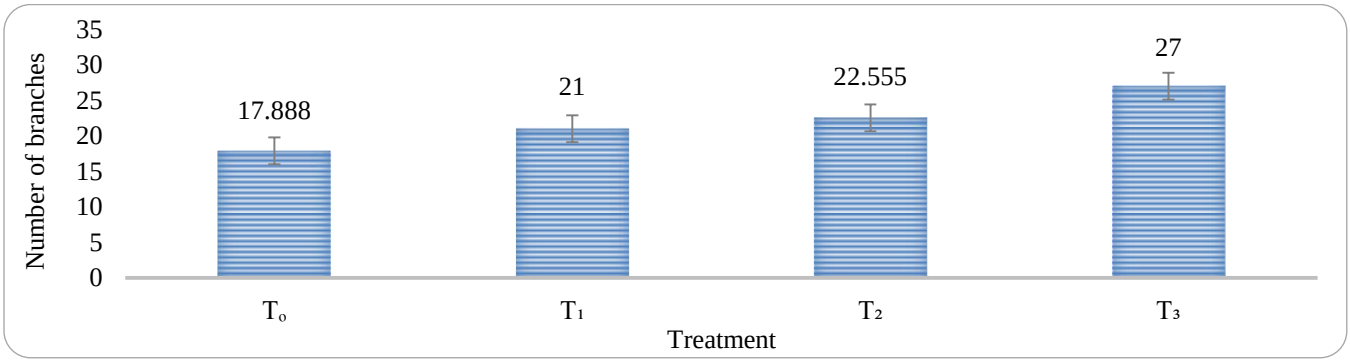

Figure 2: Effect of moringa leaf extracts foliar applications on number of branches of tomato plant.

Number of Leaves

The average no. of leaves per plant (Figure 3) of Tomatoes indicates that morphological parameters were affected significantly by the moringa leaf extract (MLE) spraying. The data regarding the leaves number were affected by various concentrations of MLE and the average number of leaves for treatment T_o control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 12, 14, 16 and 18 respectively. The no. of leaves was showed significantly different among all the treatments of MLE and control treatment. The highest no. of leaves (18) was noted in the treatment T_3 moringa leaf extract (pure moringa leaf extract) followed by T_2 (70%) MLE (16) and T_1 (35%) MLE (14), while the lowest number of leaves (12) was noted in treatment T_o control (only distilled water) respectively.

Leaf Area

The average leaf area (Figure 4) indicates that morphological parameters were affected significantly by the spraying of MLE. The data regarding the leaf area were affected by various absorptions of MLE and the

average leaf area for treatment T_0 control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 193.3, 222.11, 241 and 280 cm^2 respectively. The leaf area was significantly different among all the treatments of MLE and control treatment. The largest leaf area (280 cm^2) was recorded in treatment T_3 moringa leaf extract (pure moringa leaf extract) followed by T_2 (70%) MLE (241cm^2) and T_1 (35%) MLE (222.11cm^2) while the smallest leaf area (193.33 cm^2) was recorded in treatment T_0 control (only distilled water) respectively.

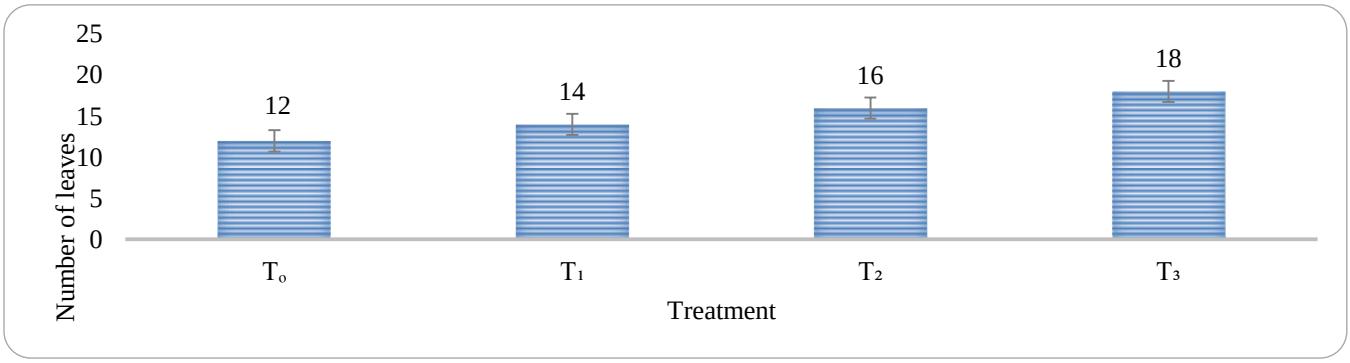

Figure 3: Effect of moringa leaf extracts foliar applications on number of leaves of tomato plant.

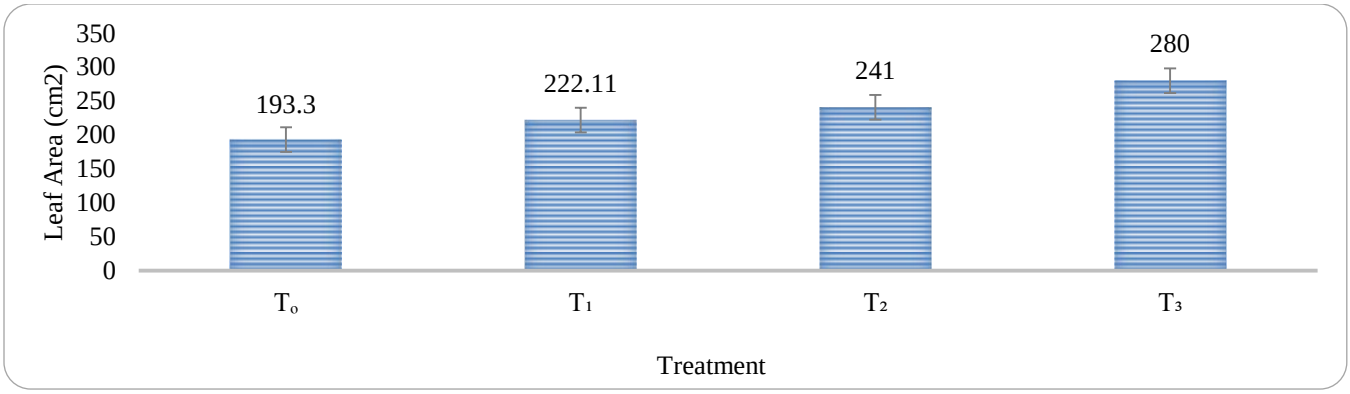

Figure 4: Effect of moringa leaf extracts foliar applications on leaf area of tomato plant.

Days to First Flowering after Sowing

The average days to first flowering after sowing (Figure 5) indicate that morphological parameters were affected significantly by the spraying of MLE. The data regarding the days to first flowering after sowing were affected by various absorptions of MLE and the average days to first flowering after sowing for treatment T_0 control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 68.44, 66.22, 63.77 and 60.55 respectively. Among all the treatments of MLE and control treatment, the days after sowing to first flowering were significantly different. The highest flowering days (68.444 days) were recorded in treatment T_0 control (only distilled water) whereas the lowest number of (60.555 days) was recorded in treatment T_3 MLE (pure moringa leaf extract).

Number of Flower Clusters per Plant

The average no. of flower clusters/plants is shown in (Figure 6) which indicates that morphological parameters were affected significantly by the spraying of Moringa leaf extract. The data about the no. of flower clusters/plants were affected by several concentrations of MLE and the average no. of flower clusters/plants for treatment T_0 control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 12.44, 14.88, 16.66 and 18.11 respectively. Among all the treatments of MLE and control treatment, the no. of flower clusters/plants was significantly different. The highest no. of flower clusters/plants (18.111) was noted in treatment T_3 Moringa leaf extract (pure moringa leaf extract) whereas the lowest no. of flower clusters/plants (12.444) was recorded in

treatment T_0 control (only distilled water) respectively.

Number of Flowers per Plant

The average no. of flowers per plants (Figure 7) indicates that morphological parameters were affected significantly by the concentration of MLE. The data regarding the flowers per plant were affected by several concentrations of MLE and the average no. of flowers/plant for treatment T_0 control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 84.33, 94.67, 105.55 and 118.89 respectively. Among all the treatments of moringa leaf extract and control treatment, the no. of flowers per plant was significantly different. The maximum no. of flowers (118.89) was noted in treatment T_3 moringa leaf extract (pure moringa leaf extract) while the minimum no. of flowers (84.33) was recorded in treatment T_0 control (only distilled water) respectively.

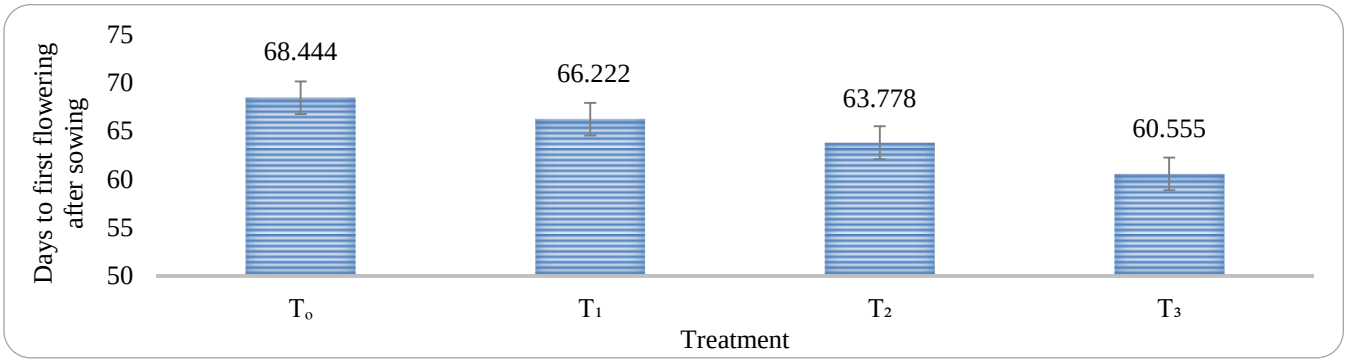

Figure 5: Effect of moringa leaf extracts foliar applications on days to first flowering after sowing of tomato plant.

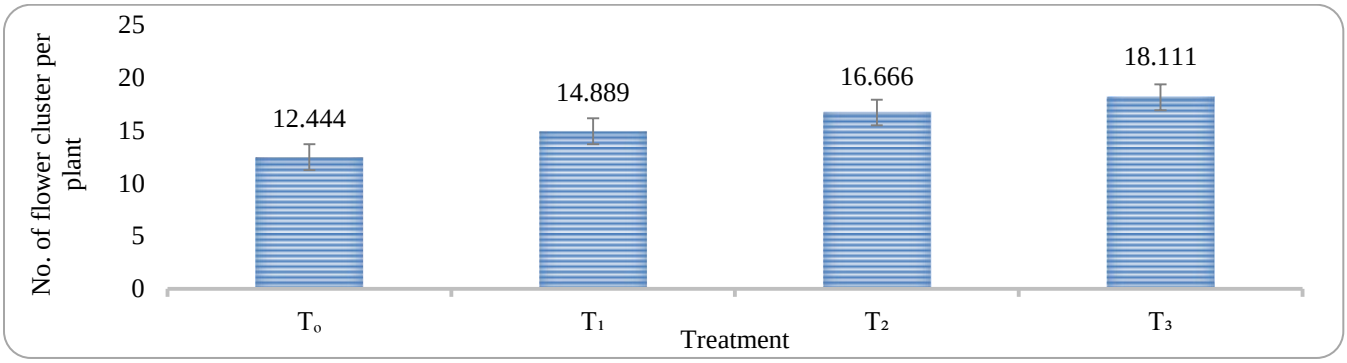

Figure 6: Effect of moringa leaf extracts foliar applications on the number of flower clusters per tomato plant.

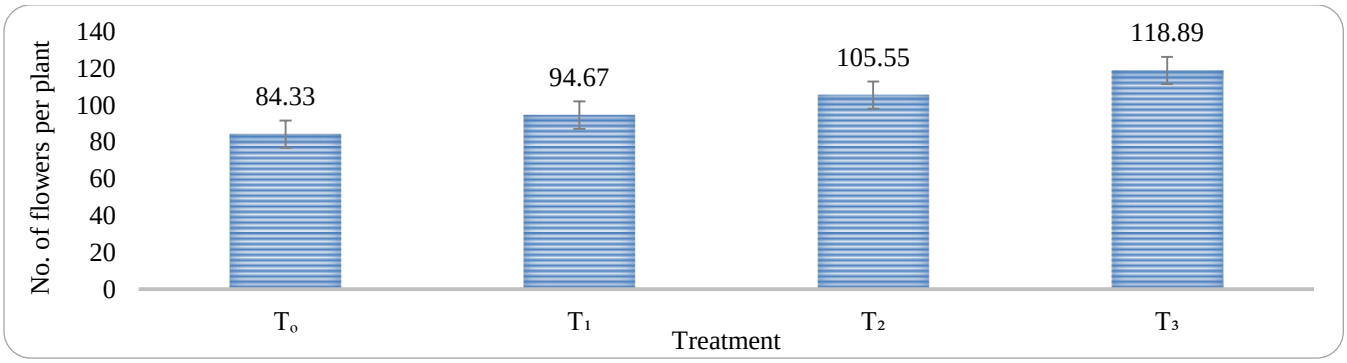

Figure 7: Effect of moringa leaf extracts foliar applications on the number of flowers per tomato plant.

Days to First Fruit Set after Sowing

The average days to the first fruit set after sowing are shown in (Figure 8) which indicates that morphological parameters were affected significantly by the spraying of MLE. The data

regarding the days to the first fruit set after sowing were affected by various absorptions of MLE. The days to the first fruit set after sowing were significantly different among all the treatments of MLE and control treatment. The maximum number of days to fruiting (108.22 days) was recorded in treatment T_o control (only distilled water) whereas the minimum number of days to fruiting (83.11) was recorded in treatment T_3 moringa leaf extract (pure moringa leaf extract).

Fruit Set Percentage (%)

The average percentage (%) of fruit set as shown in (Figure 9) indicates that morphological parameters were affected significantly by the spraying of MLE. The data regarding the fruit set percentage (%) were affected by various absorptions of MLE. The percentage of fruit set was significantly different among all the treatments of MLE and control treatment. The maximum fruit set (93.537%) was recorded in treatment T_3 moringa leaf extract (pure moringa leaf extract) whereas the minimum fruit set percentage (86.813%) was recorded in treatment T_o control (only distilled water) respectively.

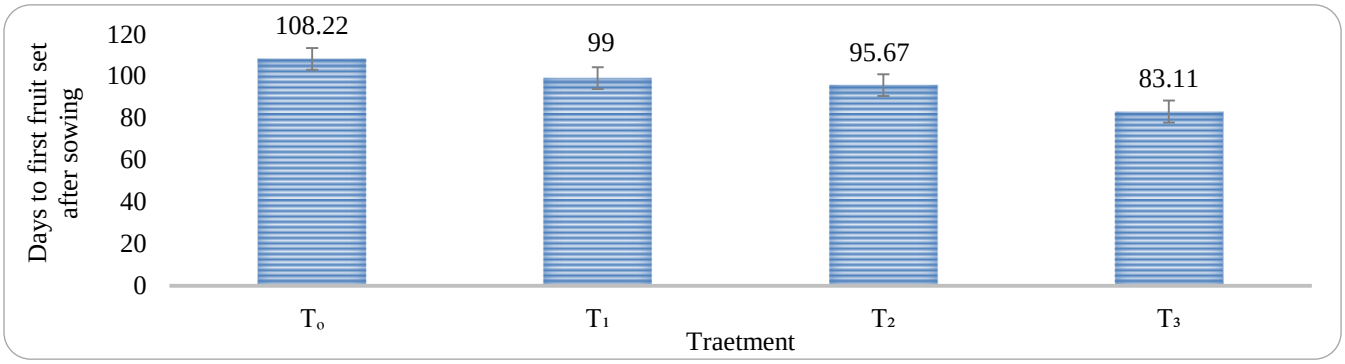

Figure 8: Effect of moringa leaf extracts foliar applications on days to first fruit set after sowing of tomato plant.

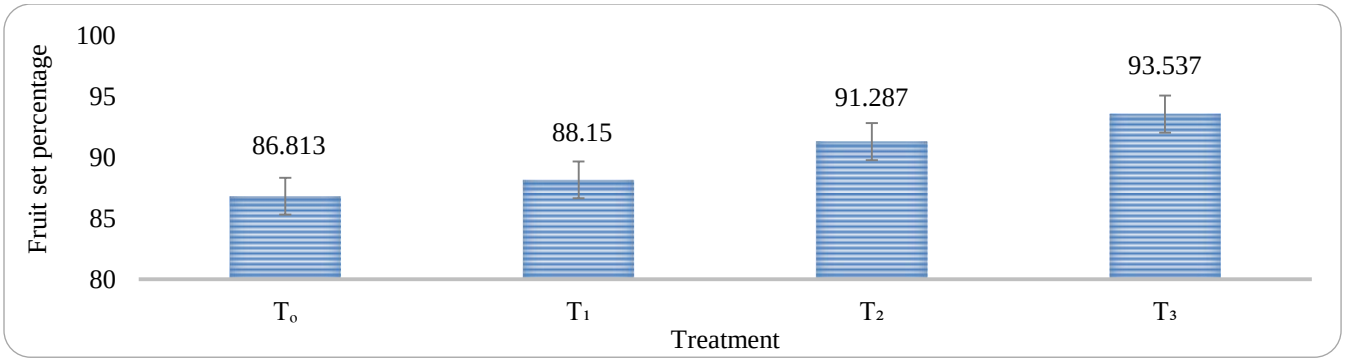

Figure 9: Effect of moringa leaf extracts foliar applications on fruit set percentage of tomato plant.

Number of Fruits per Plant

The average no. of fruits per plant is shown in (Figure 10) which indicates that morphological parameters were affected significantly by the spraying application of MLE. The data regarding the fruits at the individual plant were affected by various concentrations of MLE and the average no. of fruits per plant for treatment T_o control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was observed as 73.22, 83.44, 96.33 and 111 respectively. Among all the treatments of moringa leaf extract and control treatment, the no. of fruits at each plant was significantly different. The highest no. of fruits/plant (111) was noted in treatment T_3 moringa leaf extract (pure moringa leaf extract) whereas the lowest no. of fruits/plant (73.22) was noted in the treatment T_o control (only distilled water) respectively.

Weight of Fruit

The data regarding the average weight of individual fruit is shown in (Figure 11) which indicates that morphological parameters were affected significantly by the spraying of moringa leaf extract. The average weight of each single fruit was significantly different among all the treatments of MLE and control treatment. The maximum fruit weight (178.22g) was recorded in treatment T_3 moringa leaf extract (pure moringa leaf extract) whereas the minimum weight of

individual fruit (118.33g) was noted in treatment T_o control (only distilled water).

Size of Fruit

The average size of tomato fruit is shown in (Figure 12) which indicates that morphological parameters were affected significantly in different treatments. The data regarding the size of the fruit were affected by various concentrations of MLE. The size of the fruit was significantly different among all the treatments. The largest size of Tomato fruit (80.897mm) was recorded in treatment T_3 moringa leaf extract (pure moringa leaf extract) whereas the smallest fruit size (73.347mm) was recorded in treatment T_o control (only distilled water) respectively.

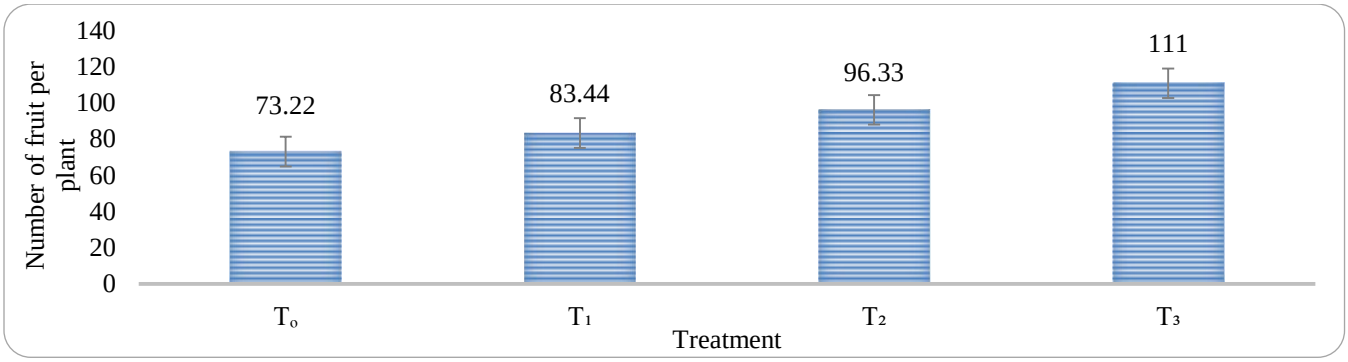

Figure 10: Effect of moringa leaf extracts foliar applications on the number of fruits per tomato plant.

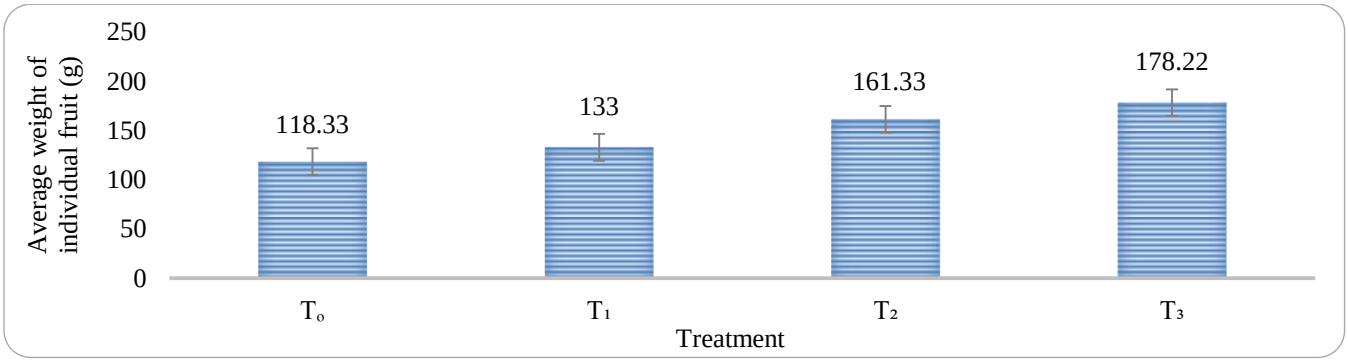

Figure 11: Effect of moringa leaf extracts foliar applications on average weight of individual fruit of tomato plant.

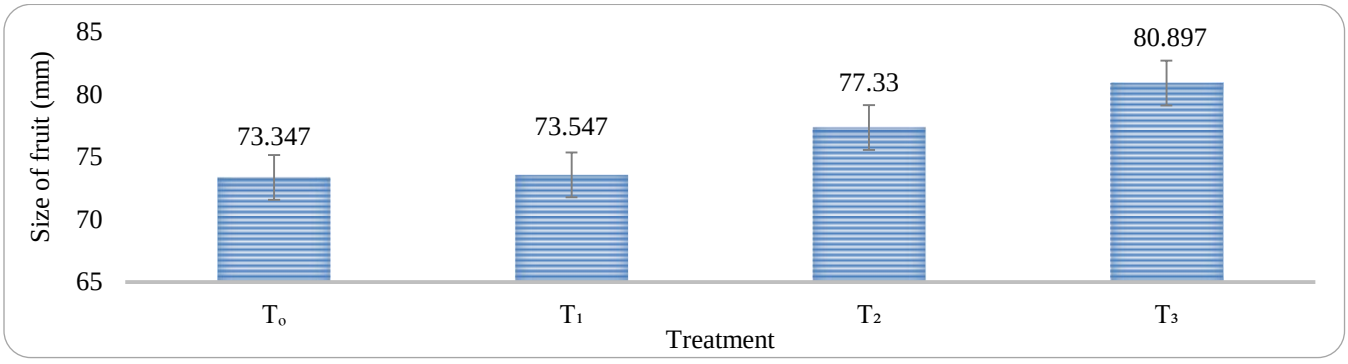

Figure 12: Effect of moringa leaf extracts foliar applications on fruit size of tomato plant.

Total Yield per Plant

The data regarding the total yield per plant is shown in (Table 13) which indicates that morphological parameters were affected significantly by the spraying of MLE and the average total yield per plant for treatment T_o control (only distilled water), treatment T_1 (35%) MLE, treatment T_2 (70%) MLE, and treatment T_3 (100%) moringa leaf extract (pure moringa leaf extract) was

observed as 23.99, 25.053, 27.003 and 29.687 kg respectively. The average yield of each plant was statistically different amongst all the other treatments of MLE and control treatment. The maximum yield of each plant (29.687 kg) was noted in treatment T_3 moringa leaf extract (pure moringa leaf extract) whereas the minimum yield of each plant (23.99kg) was noted in the treatment T_o control (only distilled water).

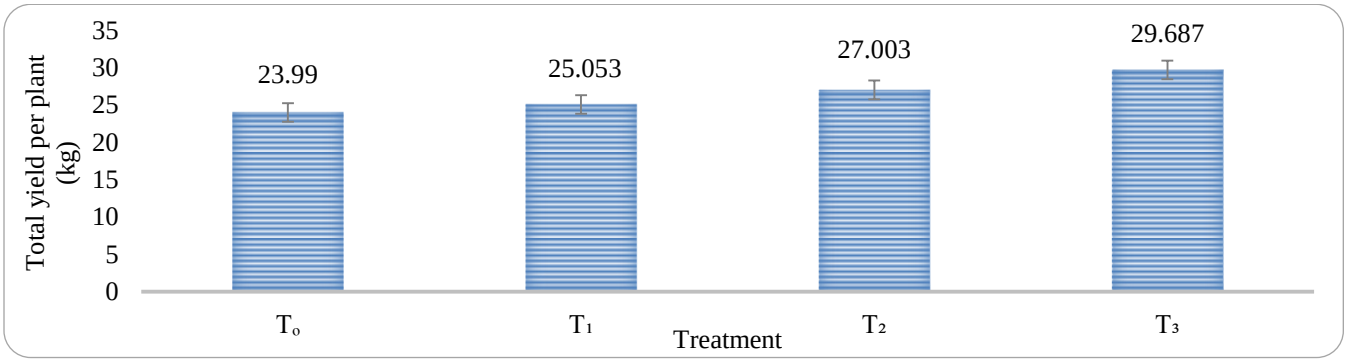

Figure 13: Effect of moringa leaf extracts foliar applications on total yield per tomato plant.

DISCUSSION

The plant height increased by increasing the concentration of moringa leaf extracts (MLE) which is with the studies of Taha et al. (2015). Taha's study showed that applying moringa leaf extract (MLE) with a 10% concentration led to an increase in the height of plants. This growth enhancement is recognized in the occurrence of natural plant hormones known as cytokinins (such as zeatin, dihydrozeatin, and isopentyl adenine) in MLE. These cytokinins have the ability to influence the movement and distribution of nutrients within the plant, promoting overall growth Emongor (2015). Another study by Culver et al. (2012) reported that the height of the crop provided the most response to the extract in comparison to the other parameters. A better response was observed in the treatment with the usage of the highest moringa extract.

The number of branches per plant was increased by increasing the concentration of moringa leaf extract (MLE) which correlates with Iqbal et al. (2014) who studied zeatin, which is a hormone of plant growth that belongs to the cytokinins group, and it plays a crucial role in the division of cell and the stretching of cells. It's also involved in moving and distributing carbohydrates to the parts of the plant that need them most for rapid growth. The rise in the number of branches aligns with the findings of previous research that suggested foliar application of (MLE) contains materials that encourage the division of cells and cell expansion. Zeatin, a growth-promoting hormone found in MLE, inspires the growing trend of lateral buds, leading to more branches. The increment in the no. of branches and the development of new shoots in tomato plants might be recognized to increase cell elongation and cell division in the side buds, which happens because cytokinins released by MLE counteract apical dominance (Davies, 2004).

The number of leaves increased as the amount of (MLE) increased which is in line with Fuglie (2000) who described that *Moringa oleifera* leaf extracts stimulate the growth of young plants, making them sturdier, promote the development of leaves, produce larger and more numerous fruits.

The leaf area of tomato plants increased by increasing the amount of moringa leaf extract (MLE) which is in line with Fuglie (2000) who described that *Moringa oleifera* leaf extracts stimulate the growth of young plants, making them sturdier, increase the size and area of leaves, promote more root development, produce larger and more numerous fruits, and, in general, enhance yields by 20 to 35%. By causing cytokinin biosynthesis, the presence of cytokinin in MLE solution as well as organic amendments promotes healthy plant growth, delays early leaf senility, and photosynthetic activity maintains a higher leaf area, which results in high leaf chlorophyll content (Alam et al., 2023b; Rady and Mohamed, 2015). They also help delay the aging of leaves and maintain a larger leaf area for efficient photosynthesis, resulting in higher chlorophyll content.

The first flowering days after sowing of tomato plant decreased as the amount of MLE increased which is in line with Nasir et al. (2016) who found that the application of MLE led to a decrease in the number of days to the flowering start by the plants. Furthermore, found that kinnow mandarins treated with MLE produced fruit earlier as the flowering of fruits was earlier. The MLE application

enhanced nutrient absorption and the supply of nutrients, which, in turn, promoted the synthesis of assimilates and led to early flowering and fruiting.

The flower clusters of tomato plants increased by increasing the amount of moringa leaf extract (MLE) which correlates with Biswas et al. (2020) who found that pure MLE produced the maximum flower clusters/plants and fruit clusters/plants. Combining MLE with distilled water produced the second-highest flower clusters/plants and fruit clusters/plants, and control-only distilled water produced the lowest flower and fruit clusters per plants.

The flower per plant of tomato increased by increasing the amount of moringa leaf extract (MLE) which is in line with Fuglie (2000) who noted that MLE contains phosphorus, which encourages root development and increases the uptake of nutrients through the roots. This ultimately led to more flower production and early fruit-bearing.

The total number of days to fruiting of tomato plants decreased by increasing the amount of moringa leaf extract (MLE) which is in line with the study of Nasir et al. (2016) who found that the concentration of MLE led to a decrease in the total number of days it took for plants to start bearing fruit. Furthermore, found that kinnow mandarins treated with MLE produced fruit earlier. The MLE application enhanced nutrient absorption and the supply of nutrients, which, in turn, promoted the synthesis of assimilates and led to early flowering and fruiting.

The percentage of fruit set of tomato plants increased by increasing the amount of moringa leaf extract (MLE) which is in line with Culver et al. (2012) who described that the percentage for fruit set increases by increasing concentration of MLE and its declining as the decreasing the concentration of MLE. In another experiment, ShM et al. (2017) found that the foliar application of moringa leaf extract at 4%, 5%, and 6% significantly enhanced the fruit set percentage when compared to untreated 0%. With spraying of 6% moringa leaf extract throughout two seasons, the maximum fruit set percentage was attained (8.39% and 8.05%, respectively). However, 0% moringa leaf extract (7.67% and 5.95%) produced the lowest fruit set percentage in both seasons.

The number of fruits at the individual plant of tomato increased by increasing the concentration MLE which is in line with Llegunas and Salas (2017) who described that there was a clear improvement in the fruits of the plant by using the pure application of MLE.

The average weight of individual fruit of tomatoes increased by increasing the concentration of MLE which correlates with the studies by Foidl et al. (2001) who reported that the spraying extract from moringa leaves on a variety of fields crops can strengthen the plants, endorse vegetative development, and increase the weight of roots, shoots, and fruits. In the field, all treatments by moringa extract increased the weight of fresh fruit and the number of stem branches (Culver et al., 2012).

The fruit size of tomato plants increased by increasing the amount of moringa leaf extract (MLE) which is in line with Llegunas and Salas (2017) who reported that using the foliar application of MLE, there's a promoted result in the size of tomato fruit and its yields.

The total yield per plant of tomatoes increased by increasing the amount of moringa leaf extract (MLE) which is in line with the finding of Culver et al. (2012) who described that the applications of lower MLE resulted in the lowering of the average yield of the crop while 100% concentrated MLE increased the yield. Plant extracts possess great potential to increase crop yield and can also be used as bio-pesticide (Alam et al., 2022). Admane et al. (2023) reported that, by promoting higher vegetative growth and nutrient application in a variety of horticultural crops, MLE applications may ultimately increase crop yield by 38%, improve nutritional value, and attract the attention of more customers.

CONCLUSION

The different concentrations of moringa leaf extract were applied to tomato plants. It included only distilled water, 35% MLE, 70% MLE, and 100% MLE. From this study, it was concluded that the highest fruit yield of hydroponically grown tomatoes was obtained with the application of 100% concentrated moringa leaf extract under a greenhouse condition. The decrease in the concentration of moringa leaf extract resulted in to fall in the total yield.

CONFLICT OF INTEREST

The authors declare that there is no conflict in the publication of this article.

AUTHOR'S CONTRIBUTION

All the authors contributed equally in the manuscript.

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