Journal of Natural Science Review

Vol. 3, No. 4, 2025
https://kujnsr.com
e-ISSN: 3006-7804

Effect of Sheep Manure on Growth, Yield, and Fruit Quality of Tomatoes (*Solanum lycopersicum*) in Kabul Climate Conditions

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ABSTRACT

This study was conducted to investigate the effect of Sheep manure on the growth, yield, and quality of tomatoes at the agriculture research farm of Kabul University during the spring and summer seasons of 2024. Treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications and five treatments. The tretments arrangement was (T1: Control), (T2: Sheep manure at the rate of 20 tons per hectare), (T3: Sheep manure at the rate of 25 tons per hectare), (T4: Sheep manure at the rate of 30 tons per hectare) and (T5: Sheep manure at the rate of 35 tons per hectare). The variables measured included growth parameters, such as plant height, number of leaves per plant, number of branches per plant, and leaf area per plant, as well as yield parameters, including marketable yield, non-marketable yield, and total yield. Additionally, quality parameters were assessed, including shelf life and organoleptic characteristics. The collected data were analyzed using ANOVA in STAR software version 2.0.1. Results indicated that Sheep manure used in the study had a positive effect on tomato growth, yield, and quality. The highest plant growth, yield, and best-quality fruits were recorded under the treatment containing the highest sheep manure (35 tons per hectare). According to the statistical analysis ($p<0.05$), it was comparable to the treatments containing 20, 25, and 30 tons per hectare of sheep manure. Thus, it is recommended that tomato crop growers apply at least 20 tons per hectare of sheep manure for optimal growth and yield.

ARTICLE INFO

Article history:

Received: June 12, 2025
Revised: June 22, 2025
Accepted: November 26, 2025
Published: December 31, 2025

Keywords:

Fruits quality; Growth; Sheep manure; Tomatoes; Yield

To cite this article: Faizi , Z., Salari, H., Zamany, A. Z., (2025). Impacts of humic acid on the growth, yield, and quality of tomato. *Journal of Natural Science Review, 3* (3),104-118. https://doi.org/10.62810/jnsr.v3i3.215
Link to this article: https://kujnsr.com/JNSR/article/view/215

INTRODUCTION

Tomato (*Solanum lycopersicum*) belongs to the family Solanaceae. The cultivated tomato is an annual vegetable crop farmed worldwide. Tomatoes with the chromosome number 2n=24 are herbaceous plants (Ali. thriving in both tropical and temperate climates(Sattar et al., 2024). Tomatoes are a self-pollinated crop(Mehta, 2017; Salim et al., 2020). Tomatoes are native to South America (Mehta, 2017).In Afghanistan, several varieties of tomatoes, including Pearson, Rio Grande, CXD_222, Roma, VF, etc., are grown on a commercial scale (Yousafzai, 2022).

In 2021, Afghanistan earned approximately USD 40.8 million from tomato exports, making this crop the country’s 11th most exported commodity(Khil & Pervaiz, 2024), Tomatoes provide direct employment opportunities for around 214,000 people, making them an important component of the agricultural value chain(International Labour Organization (ILO), 2015), From one jerib (about 0.2 hectares) of land, tomatoes generate an income of approximately USD 800; thus, compared to many other crops, tomatoes are far more profitable in terms of income(Bolton, 2019; International Labour Organization (ILO), 2015), Tomato is a vital vegetable crop globally known for its nutritional richness and culinary versatility(Jain et al., 2024). It is used in salads and soups (Hossain, 2021). The juice and pulp of tomatoes have antiseptic properties against intestinal infections and are a blood purifier (Waiba & Sharma, 2020). Tomato fruit is commonly consumed either raw or processed. Tomatoes are a dietary group that provides protein and vitamins; they have substantial levels of vitamin C and are the best sources of lycopene(Astija et al., 2023). However, their specific nutritional contribution in Afghanistan has not yet been studied in detail. Nevertheless, their general nutritional importance is well documented globally, and this may also apply under Afghanistan’s conditions. According to an FAO report in 2003, this crop accounted for about 16% of horticultural crops. In 2012, tomato production reached 85,000 tons across 7,940 hectares nationwide, with an average yield of 10.7 tons per hectare(Gulab et al., 2020).

Research shows that tomato cultivation following cereal crops in Kabul and surrounding districts requires high nitrogen (N) inputs. Although increased application of N did not significantly raise yields, such practices could pose environmental risks—making this an important issue from a sustainability perspective (Safi et al., 2025), Soil in Kabul Province is alkaline in nature, which directly affects the quality of tomato cultivation as well as the quantity and quality of fruit production(Gulab et al., 2020). Tomatoes require a basal application of 60 kg P_2O_5 ha-1 and 60 kg K_2O ha-1 during land preparation, and 120 kg N ha-1. Nitrogen is applied in two splits after transplant (Isah et al., 2024).

Organic fertilizers are derived from animal matter, human excrement, or vegetable matter (e.g., compost, manure). Compost is usually produced by decomposing biodegradable materials, including paper, leaves, fruit peels, leftover food, and fruit juices. These wastes include paper, leaves, fruit peelings, leftover foods, and fruit juices. Organic fertilizers make a good addition to the soil. It makes the soil ideal for planting(Assefa, 2019)

Since tomatoes are important food crops with high demand, their yields and fruit quality in Afghanistan are low. This is partly because Afghanistan's soils are low in organic matter and partly because no standardized amount of organic manure is applied in the area. Therefore, this study was conducted to determine an appropriate level of sheep manure that can improve tomato yield and fruit quality.

MATERIAL AND METHODS

The present research was carried out under open-field conditions at the agricultural research farm of Kabul University, Kabul, Afghanistan, during the spring and summer seasons of 2024. The experimental site is located at an elevation of 1,808.0 meters, with geographic coordinates of 34° 31'02.4"N and 69°08'15.7"E. The field has a flat topography and consistent soil texture. It is supplied with water through the main irrigation channel, which is connected to the farm's tube well. Kabul, situated in the central climate zone of Afghanistan, experiences hot, dry summers and cold, snowy winters, with partly cloudy conditions prevailing during the latter. Throughout the year, temperatures typically range from -4°C to 34°C, with temperatures rarely falling below -10°C or exceeding 37°C.

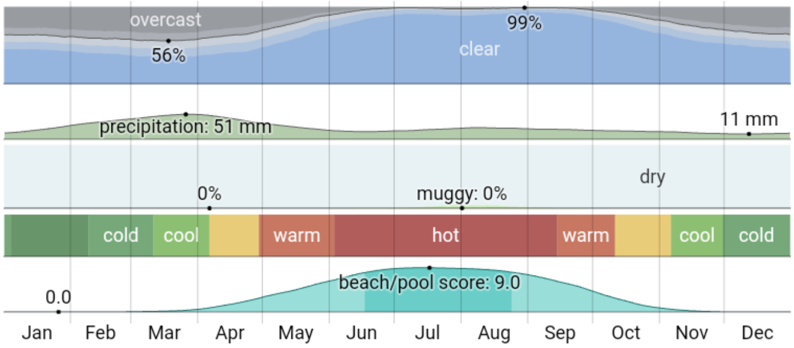

Figure 1: The weather conditions of Kabul city during 2024.

The cold season lasts 3.0 months, from mid-December to mid-March, with an average daily high temperature below 12°C. The coldest month in Kabul is January, with an average low of -4°C and a high of 7°C.

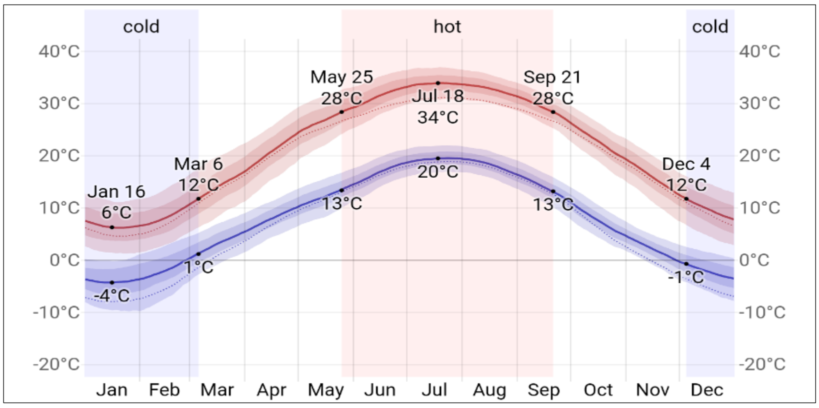

Figure 2: The average temperature of Kabul city during 2024

The total annual rainfall in 2024 was 312 mm (Kabul Climate, Weather by Month, Average Temperature (Afghanistan) - Weather Spark, 2024).

The topsoil (0–30 cm) properties of the study field were tested. The soil was silty clay in texture with the following characteristics: organic matter – 3.04%, P2O5 – 45.05 ppm, K – 319 ppm, CaCO3 – 14.8 %, EC – 0.24 ms cm-1, pH – 8.12, and cation exchange capacity – 21.4 meq 100 g-1(Sahbani et al., 2024).

The study had five treatments, and the arrangement was (T1: Control), (T2: Sheep manure at the rate of 20 tons per hectare), (T3: Sheep manure at the rate of 25 tons per hectare), (T4: Sheep manure at the rate of 30 tons per hectare) and (T5: Sheep manure at the rate of 35 tons per hectare). The treatment arrangement was based on previous studies in the same field.

The field experiment was designed using a Randomized Complete Block Design (RCBD) with three replications. The seeds of the Rio Grande variety were first sown in a greenhouse at the agricultural research farm of Kabul University. The area allocated for seedling production in the greenhouse was set at 1 m^2. The seeds were manually sown on April 6, 2024, in a scattered pattern, with a total seed quantity of 0.36 g per plot. To retain moisture, irrigation was continued regularly until the seedlings were ready for transplanting. One week after sowing, we performed pest control and removed off-type plants from the seedling bed.

Before transferring the seedlings to the main field, the field was plowed on March 30, 2024, to sterilize it using sunlight, about 1.5 months in advance, with the aim of eliminating weed seeds, disease-causing agents, and pests. It was then left to rest for a while. However, when planting the tomato seedlings, the soil was plowed with a nine-furrow plow. The study area was 135 m^2, divided into 15 plots measuring 9 m^2 each. According to the plan, irrigation channels were created with 80 cm spacing between rows and 45 cm between plants. In each plot, 24 tomato seedlings were planted, for a total of 360 across the entire field.

Sheep manure was applied to each treatment during the soil preparation phase, before transplanting the seedlings. All other agricultural practices were carried out uniformly across all treatments at their appropriate times, after 42 days. The seedlings were transferred to the main field on 19 May 2024. In the afternoon, the land was irrigated, and after midday, the seedlings were planted in the prepared irrigation channels. Weed control was performed weekly, and no herbicides were applied for weed management. In this study, soil hilling was done 30 days after transplanting. During this process, 120 kg of urea and 60 kg of diammonium phosphate (DAP) fertilizer were applied per hectare. No second hilling was conducted, but 15 days after the first hilling, an additional 60 kg of urea per hectare was applied to the field.

Overall, data were collected on three types of parameters related to tomato growth, yield, and fruit quality. For plant height, four plants were randomly selected from each plot, and their height was measured. Plant height was recorded at 40 and 80 days after transplanting the seedlings. The number of leaves per plant was counted for the selected four plants in each treatment at 40 and 80 days after transplanting. The number of brunches per plant in the selected four plants was counted in each treatment at 40 and 80 days after transplanting. Leaf area was recorded from four randomly labeled plants in each treatment at 40 and 80 days after transplanting and is presented as square centimeters per plant.

Data on tomato yield parameters were collected for marketable, non-marketable, and total yield. The data were recorded in kilograms per plant and per plot, and presented in metric tons per hectare. The number of fruits per plant was manually counted. Fruit length and diameter (polar and equatorial), the fruit width (largest equatorial diameter), length (polar diameter), and thickness (the most minor equatorial diameter) were recorded in centimeters with the help of vernier calipers.

For fruit quality parameters, various characteristics, including fruit shelf life and organoleptic attributes, were tested. For the shelf life of fruits, three fruits from each treatment were stored at room temperature (average 25°C) with an average relative humidity of 43%. The number of days during which fruits were fit for sale was counted and presented as the shelf life of fruits. The organoleptic characteristics of tomatoes, including appearance, color, flavor, texture, and overall acceptance, were recorded. The test was performed on freshly harvested fruits from each treatment by ten semi-trained evaluators.

In the data analysis, the Statistical Tool for Agricultural Research (STAR) software version 2.0.1 was used to analyze the collected data. The differences between treatments were compared using Least Significant Difference (LSD) at $p \leq 0.05$.

RESULTS AND DISCUSSIONS

In the study conducted on the effects of sheep manure on the growth, yield, and quality of tomatoes, three main parameters were generally considered: vegetative growth, yield, and quality. The results of these parameters were also compared and discussed with those of similar studies. The findings for each parameter are presented as follows.

Growth Parameters

The growth parameters evaluated in the study included four main measurements: plant height, number of branches per plant, number of leaves per plant, and leaf area. These parameters were recorded at two different time points—first at 40 days after transplanting and again at 80 days after transplanting. The results are presented as follows.

Plant Height: Statistical analysis at $P < 0.05$ revealed significant differences among treatments (Tables 2 and 3). The maximum plant height, both at 40 days (54.33 cm) and at 80 days (60.00cm), was observed in T5 (Sheep manure at the rate of 35 tons per hectare). The minimum plant height, observed at both 40 days (36.66 cm) and 80 days (50.00 cm), was in the control. The reason for larger plants under higher sheep manure treatment may be the composition of organic matter, which contains both macro- and micro-nutrients, thereby improving plant growth. Organic fertilizers provide essential nutrients like nitrogen, phosphorus, and potassium, improve the physical and chemical properties of soil, enhance microbial activity, and help retain moisture, all of which contribute to better plant growth, nutrition, and increased height (AL-Sulaimawi, 2016). In a similar study comparing the effects of organic and inorganic manure on tomato growth and yield, it was found that applying 25 tons of farmyard manure + 5 tons of vermicompost per hectare + 3% panchakavya (foliar spray) resulted in maximum plant height and internode length at various growth stages(Arivazhagan et al., 2019). Additionally, another study comparing the effects of farmyard manure and inorganic manure on tomato growth and yield found a significant increase in plant height with the application of 100% N (120 kg/ha) and 10 tons/ha of farmyard manure, resulting in plants reaching 82.8 cm in height. At the same time, control plots showed shorter plants (47.8 cm) (Isah et al., 2024).

Number of Branches Per Plant: Statistical analysis at $P < 0.05$ showed that an increased rate of sheep manure significantly affected the number of branches per plant (Tables 2 and 3). The maximum number of branches per plant (6.42) was recorded at 40 days after transplanting in T5, and T4 was on par with it. At 80 days after transplanting, the highest number of branches per plant was observed in T5 (7.17). The minimum number of branches per plant, both at 40 days after transplanting (3.47) and 80 days after transplanting (5.50), was recorded in the control treatment (T1). This is because animal manure contains essential elements, such as nitrogen, a crucial nutrient for plant growth. Sheep manure is a good source of nitrogen (N), phosphorus (P), and potassium (K), Nitrogen plays an important role in the formation of leaves, stems, and green tissues. Potassium is important for water regulation, enzymatic activity, and plant resistance. Improvement of Soil Structure It increases organic matter, enhancing soil aeration, water retention, and microbial activity. Source of Micronutrients. It also contains small amounts of calcium, magnesium, sulfur, iron, zinc, copper, and manganese, which are essential for plant physiological processes. Sustained Nutrient Release: Sheep and goat manure decomposes slowly, providing nutrients to plants over a more extended period. A similar study comparing the effects of farmyard manure and inorganic manures on tomato growth and yield showed that the combined application of 120 kg/ha nitrogen and 10 tons/ha of farmyard manure increased the number of branches per plant (Isah et al., 2024). A study found that the maximum number of branches per plant was recorded with treatment T7 (farmyard manure 33% + Poultry 33% + Vermicompost 33%) at different stages (30, 60, 90 days after transplanting), followed by treatment T6 (Vermicompost 50% + farmyard manure 50%). The study also showed that the number of branches was significantly lower in the control group (without fertilizer). This result suggests that organic manure, particularly in a mixed form, contributed to improved plant growth and increased branching. This improvement is likely due to a higher carbon-to-nitrogen ratio and enhanced plant metabolism(Mukesh et al., 2023).

Number of Leaves Per Plant: According to statistical analysis at $P < 0.05$, a significant difference was observed among treatments for the number of leaves per plant at 40 and 80 days after transplanting (Tables 2 and 3). At 40 days after transplanting, the highest leaf count per plant (57.00) was recorded in T5. Similarly, at 80 days after transplanting, the maximum number of leaves per plant (65.33) was observed in the same treatment (T5). The lowest number of leaves per plant was found at 40 days (41.58) and 80 days after transplanting (49.67) in T1 (control). This may be due to improved soil quality that enhances plant growth. The study conducted by Arivazhagan revealed that application of 25 tons of farmyard manure per hectare + 5 tons vermicompost per hectare + 3 % panchakavya (foliar spray) produced maximum leaves per plant (32.1)(Arivazhagan et al., 2019).

Leaf Area Per Plant: The farmyard manure used in the experiment significantly affected the leaf area at both 40 and 80 days after transplanting (Tables 2 and 3). Statistical analysis at $P < 0.05$ indicated that at 40 days after transplanting, the largest leaf area (81.04 cm^2) was recorded in T5, and at 80 days after transplanting, the highest value (190.12 cm^2) was also observed in T5. The lowest leaf area was observed at 40 days after transplanting (66.01 cm^2) and at 80 days after transplanting (166.62 cm^2) in T1 (control). This is because animal manure contains essential elements such as nitrogen, phosphorus, and potassium, which promote plant growth. In a study, the application of 120 kg/ha nitrogen and 10 ton/ha farmyard manure resulted in a significantly higher leaf area (301.1 cm^2) compared to the control (133.3 cm^2) (Isah et al., 2024).

Generally, Organic manures have a balanced nutritional composition that improves soil structure, water-holding capacity, and microbial activity. They release nutrients gradually, reducing the risk of nutrient leaching and ensuring crops have access to nutrients for a more extended period. For this reason, they positively affect plant growth, increasing plant height and leaf area (Kumar et al., 2023).

Table 1. *The effect of different levels of Sheep manure on the growth of tomatoes at 40 days after transplanting*

Treatments	Plant height (cm)	Number of branches per plant	Number of leaves per plant	Leaf area per plant (cm^2)
T1 (Control)	36.66^c	3.47^b	41.58^c	66.00^c
T2 (Sheep's manure @ 20 t/h)	45.91^b	5.33^a	51.66^b	74.30^b
T3 (Sheep's manure @ 25 t/h)	48.33^b	6.33^a	51.91a^b	74.60a^b
T4 (Sheep's manure @ 30 t/h)	49.91a^b	6.42^a	55.33a^b	78.70a^b
T5 (Sheep's manure @ 35 t/h)	54.30^a	6.42^a	57.00^a	81.00^a
F-test	*	*	*	*
CV%	6.53	16.64	5.38	4.77
LSD (0.05)	5.78	1.75	5.22	6.72
SD±	1.94±	0.589±	1.754±	2.26±

CV: Coefficient of Variation, Standard deviation, **LSD**: Least Significant Difference, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference.

Table 2. *The effect of different levels of Sheep manure on the growth of tomatoes at 80 days after transplanting*

Treatments	Plant height (cm)	Number of branches per plant	Number of leaves per plant	Leaf area per plant (cm^2)
T1 (Control)	50.00^b	5.50^b	49.67^b	166.62^c
T2 (Sheep's manure @ 20 t/h)	53.00^b	6.74^a	62.67^a	173.46b^c
T3 (Sheep's manure @ 25 t/h)	54.00^b	6.85^a	63.33^a	182.88a^b
T4 (Sheep's manure @ 30 t/h)	54.33a^b	7.10^a	63.67^a	183.95a^b
T5 (Sheep's manure @ 35 t/h)	60.00^a	7.17^a	65.33^a	190.12^a
F-test	*	*	*	*
CV%	5.76	6.98	5.94	3.57
LSD (0.05)	5.89	0.87	6.81	12.04
DS±	1.99±	0.294±	2.29±	4.0459±

CV: Coefficient of Variation, Standard deviation, **LSD**: Least Significant Difference, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference.

Yield Parameters

The yield parameters evaluated in the conducted study generally included the following: total yield per plant and per hectare, marketable yield per hectare, non-marketable yield per hectare, number of fruits per plant, number of large fruits per plant, and number of small fruits per plant. The results of these parameters are presented and discussed as follows.

Total yield per plant and per hectare: Statistical analysis at $P < 0.05$ showed that an increased rate of sheep manure significantly affected the yield per plant (Table 4). The highest total yield per plant (2.04 kg) was recorded in T5, which contained 35 tons of sheep manure per hectare, and was on par with T2, T3, and T4, which contained 20, 25, and 30 tons/ha of sheep manure, respectively. The lowest total yield per plant (1.36 kg) was recorded in the control. Similarly, the highest total yield per hectare (54.42 ton per hectare) was observed in T5, and it was on par with T2, T3, and T4, while the lowest (36.22 ton per hectare) was recorded in the control. This is because animal manure contains essential macro- and microelements that contribute to increased plant productivity. A similar study showed that applying 85% RCF (Ready Compost Fertilizer) and 3 tons per hectare OF (Organic Fertilizer) resulted in a higher yield. The study found that applying farmyard manure significantly increased yield per hectare. Specifically, 50.59 tons per hectare were achieved in a similar study by UK Laily(Laily et al., 2021). Another study also showed significant yield improvements, with the highest yield values obtained from the integrated application of 120 kg/ha nitrogen + 10 tons per hectare of farmyard manure(Isah et al., 2024)

Marketable yield per hectare: The farmyard manure used in the experiment significantly affected the yield of marketable fruits (Table 4). The results revealed that T5 had the highest yield per hectare (53.02 tons per hectare), being on par with T2, T3, and T4, while the lowest was recorded in the control group (33.78 tons per hectare). This indicates that using sheep manure has a notable impact on tomato marketable yield. The more the sheep manure is used, the greater the marketable yield is obtained. The integrated application of FYM and urea significantly improved tomato yield and fruit quality compared to the sole application of either FYM or urea. The treatment with 25% FYM and 75% urea achieved the highest marketable yield of 37.5 tons per hectare (Gebretsadkan, 2018). The application of organic manures significantly influenced the growth and yield parameters of tomato plants. The Cow dung @ 5 ton per hectare + Compost @ 5 ton per hectare + Poultry Manure @ 5 ton per hectare + Mustard Oil Cake @ 0.2 ton per hectare treatment produced the highest marketable yield (17.24 ton per hectare)(Farid et al., 2023)

Non-marketable yield per hectare: The statistical analysis at $P < 0.05$ showed a significant difference among treatments (Table 4). The maximum non-marketable yield per hectare (2.45 tons per hectare) was recorded in the control. In comparison, the minimum non-marketable yield per hectare was observed in T2 (1.37 ton per hectare), which was on par with T3, T4, and T5. This indicates that using sheep manure significantly reduces the non-marketable yield of tomatoes. The more the farmyard manure is used, the lower the non-marketable yield becomes. A study revealed that the cow dung @ 5 ton per hectare +

compost @ 5 ton per hectare + poultry manure @ 5 ton per hectare + mustard oil cake @ 0.2 ton per hectare treatment produced the lowest non-marketable yield(Farid, Kobir, Obaidullah, Haque, Mondal, et al., 2023).

Table 3*. The effect of different levels of Sheep manure on the yield of tomatoes*

Treatments	Yield per plant (kg)	Total yield (ton per hectare)	Marketable yield (ton per hectare)	Non-marketable yield (ton per hectare)
T1 (Control)	1.39^{b}	36.23^{b}	33.78^{b}	2.45^{a}
T2 (Sheep's manure @ 20 t/h)	1.91^{a}	50.93^{a}	49.56^{a}	1.37^{b}
T3 (Sheep's manure @ 25 t/h)	1.94^{a}	51.84^{a}	50.30^{a}	1.54^{b}
T4 (Sheep's manure @ 30 t/h)	1.99^{a}	53.15^{a}	51.70^{a}	1.45^{b}
T5 (Sheep's manure @ 35 t/h)	2.04^{a}	54.43^{a}	53.02^{a}	1.41^{b}
F-test	*	*	*	*
CV%	12.78	12.78	13.31	19.87
LSD (0.05)	0.44	11.87	11.90	0.55
SD±	0.15±	3.987±	3.612±	0.186±

CV: Coefficient of Variation, Standard deviation, **LSD**: Least Significant Difference, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference

Number of fruits per plant: According to statistical analysis ($P < 0.05$), a significant difference was observed among treatments (Table 5). The data revealed that T5 had the highest number of fruits per plant (37.51), which was on par with T2, T3, and T4, while the control group had the lowest (20.83). Animal manure contains essential elements such as nitrogen, phosphorus, potassium, and other micronutrients, which help improve soil structure and texture, crucial for promoting plant growth and increasing productivity. A similar study showed that the highest number of fruits per plant was recorded in the treatment involving the application of 30 kg of nitrogen per hectare and 6 tons of poultry manure (Olaniyi & Ajibola, 2008).

Number of large fruits per plant (100-255 g): The farmyard manure did not have a significant effect on the number of large fruits per plant.

Number of small fruits per plant (≥100 g): The farmyard manure used in the experiment significantly affected the number of small fruits per plant (≥100 g) (Table 5). The results revealed that T5 had the highest number of small fruits per plant (35.87), which was on par with T2, T3, and T4, while the control group had the lowest (21.53). A similar study was conducted on the influence of organic inputs on growth, yield, and quality of tomato (Solanum lycopersicum), in which the treatment T12 (12.5 t ha-1 FYM + 5 t ha-1 vermicompost + 3 % panchakavya) produced the maximum fruits plant-1 (20.30)(Arivazhagan et al., 2019).

***Table 4.** The effect of different levels of Sheep manure on the number of fruits per plant*

Treatments	Number of fruits/plant	Number of large fruits/plants	Number of small fruits/plants
T1 (Control)	20.83[b]	1.30	19.53[b]
T2 (Sheep's manure @ 20 t/h)	34.58[a]	1.31	33.26[a]
T3 (Sheep's manure @ 25 t/h)	35.50[a]	1.54	33.96[a]
T4 (Sheep's manure @ 30 t/h)	35.93[a]	1.61	34.32[a]
T5 (Sheep's manure @ 35 t/h)	37.50[a]	1.63	35.88[a]
F-test	*	Ns	*
CV%	17.01	-	17.64
LSD (0.05)	10.50	-	10.42
SD±	3.537±		3.5±

CV: Coefficient of Variation, Standard deviation, **LSD**: Least Significant Difference, **NS**: Not Significant, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference

Sensory Quality

The sensory quality parameters evaluated in the conducted study generally included the following: appearance, color, texture, flavor, and overall acceptance. The results of these parameters are presented and discussed as follows.

Appearance: The statistical analysis at P <0.05 showed a significant difference among treatments (Table 6). The fruit appearance at T5 was liked extremely, and it was on par with all other treatments containing sheep manure. The fruit's appearance in the control treatment was less acceptable (neither liked nor disliked). The tomatoes produced in the treatments with farmyard manure were found to be larger and more uniform in shape than the control, and hence had a more acceptable appearance. The appearance of products is the first quality attribute that motivates us to purchase (Amr & Raie, 2022).

Color: The test results indicated a significant difference among treatments (Table 6). The fruit's color in T5 was extremely liked and was on par with T2, T3, and T4. The least favorable fruit color was observed in the control group (neither liked nor disliked). In addition to the relative content of lycopene, a beneficial antioxidant, breeders have focused on increasing this factor in processed tomatoes over the past several years. Most tomato varieties are red in color due to the presence of the carotenoid (lycopene)(Amr & Raie, 2022).

Texture: Treatments had a significant difference in the fruit's texture (Table 6). The results indicated that T5 had the most favorable fruit texture (liked extremely), being on par with other treatments containing sheep manure. The control group exhibited the least favorable texture (neither liked nor disliked). They are related to the deformation, disintegration, and flow of food under a force and are measured objectively in terms of mass, time, and distance. The texture of fruits and vegetables is derived from their turgor pressure, the composition of individual plant cell walls, and the middle lamella "glue" that holds individual cells together (Amr & Raie, 2022).

Flavor: The results revealed a significant difference among treatments for fruit flavor (Table 6). T5, T4, T3, and T2 had the most preferred fruit flavor (like extremely), whereas the control group had the least favorable flavor (neither liked nor disliked). Flavor, which denotes a combination of taste and retro nasal olfaction, is a remarkably complex phenotype, influenced by many objective and subjective factors, and that involves multiple sensory systems, The characteristic sweet-sour taste of tomato and its overall flavor intensity is chemically determined by a complex blend of interplaying primary and secondary metabolites mainly comprising of sugars (glucose and fructose), acids (citrate, malate and glutamate), minerals and multiple key volatile compounds(Sinesio et al., 2021).

Overall acceptance: Statistical analysis at $P < 0.05$ indicated a significant difference among treatments (Table 6). Fruits produced in T5 had the highest overall fruit acceptability (liked extremely), while the control had the lowest overall fruit acceptability (neither liked nor disliked). A similar study investigated the effects of various organic fertilizers on the growth, yield, and fruit quality of four tomato varieties. The study concluded that the application of chicken manure and agro-fish pellets during the flowering and fruit-setting stages, combined with mixed manure before harvest, can improve the quality of tomato fruits and positively influence overall fruit quality(Ali et al., 2022; Kalbani et al., 2016).

Table 5. *The effect of different levels of Sheep manure on the sensory quality of tomato fruits at room temperature (based on a 5-point hedonic rating scale)*

Treatments	Appearance	Color	Texture	Flavor	Overall acceptable
T1 (Control)	3.60^{b}	3.08^{b}	3.35^{b}	3.53^{b}	3.60^{c}
T2 (Sheep's manure @ 20 t/h)	4.20^{a}	4.30^{a}	4.50^{a}	4.50^{a}	4.40a^{b}
T3 (Sheep's manure @ 25 t/h)	4.40^{a}	4.26^{a}	4.40^{a}	4.30^{a}	4.30^{b}
T4 (Sheep's manure @ 30 t/h)	4.50^{a}	4.20^{a}	4.10^{a}	4.50^{a}	4.40a^{b}
T5 (Sheep's manure @ 35 t/h)	4.70^{a}	4.50^{a}	4.45^{a}	4.45^{a}	4.85^{a}
F-test	*	*	*	*	*
CV%	14.42	14.34	13.18	13.82	11.77
LSD (0.05)	0.56	0.52	0.49	0.53	0.46
SD±	0.39±	0.369±	0.347±	0.37±	0.32±

CV: Coefficient of Variation, Standard deviation, **LSD**: Least Significant Difference, **NS**: Not Significant, *: 5% Significance, based on LSD (5%) means with the same letters indicate no significant difference.

CONCLUSION

The results of this study demonstrate that the application of sheep manure has significant positive effects on tomato vegetative growth, fruit yield, and fruit quality. Increasing the amount of manure application led to notable improvements in plant height, leaf number, branch number, and leaf area. In terms of productivity, manure-treated plants achieved higher yields per plant and per hectare, with a greater proportion of marketable fruits and better fruit morphology (length and diameter). Additionally, fruit quality attributes such as appearance, color, texture, and taste were significantly enhanced through manure application. Considering the limitations of advanced laboratory facilities, we were not able to analyze the lycopene and antioxidant contents of tomato fruits, which are suggested for future research.

Overall, sheep manure is an effective organic amendment for improving tomato production, both quantitatively and qualitatively. According to the statistical analysis at ($p \leq 0.05$), it was on par with the treatments containing 20, 25, and 30 tons per hectare of sheep manure. Therefore, from an economic perspective, we recommend applying 20 t/ha in tomato cultivation to improve growth, increase yields, and sustainably achieve superior fruit quality.

AUTHORS CONTRIBUTIONS

- Hamid Salari conceptualized and supervised the study.
- Zabihullah Faizi conducted the field study and collected the raw data.
- Hamid Salari, Zabihullah Fiazi, and Ahmad Jawid Zamany equally processed and analyzed the data.
- Hamid Salari, Zabihullah Fiazi, and Ahmad Jawid Zamani wrote the manuscript with input from all authors.
- All authors reviewed and approved the final version.

ACKNOWLEDGEMENTS

The authors thank the Department of Horticulture, Faculty of Agriculture, Kabul University, for their technical support.

FUNDING INFORMATION

No funding is available for the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflict of interest.

DATA AVAILABILITY STATEMENT

Data are available upon request from the corresponding author, subject to approval of the relevant ethics committee.

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