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Yield and fruit quality of tomato as influenced by different sources of calcium

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Abstract

A field study was conducted from December 2023 to March 2024 at the Integrated Farm of Cagayan State University – Piat Campus, Piat, Cagayan to determine the effect of various calcium sources on the growth, yield performance, fruit quality and profitability of tomato plants. Five calcium sources; Calcium Carbonate, Calcium Nitrate, Calcium Phosphate, Calcium Boron, Calcium Sulfate in combination to the recommended rate of inorganic fertilizer were evaluated as treatments following a Randomized Complete Block design replicated four times. Results of the study showed that tomato plants were affected by the supplementation of calcium at 60 days after transplanting. Moreover, calcium supplementation leads to significant increase as to the fruit quantity, weight of fruits and quality parameters such as titratable acidity, total soluble sugar and sugar-acid ratio. Particularly, this study emphasizes the effectiveness of Calcium nitrate, Calcium phosphate, and Calcium boron as beneficial forms of calcium supplementation when added to the recommended amount of inorganic fertilizer. This supplementation not only enhances fruit quality but also reduces the occurrence of blossom-end rot, leading to increased tomato yield. Specifically, the results suggest that integrating Calcium nitrate in addition to the recommended rate of inorganic fertilizer is a favorable management strategy for improving tomato plant growth, yield, and fruit quality, ultimately offering higher economic returns of 471.78 percent.

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Introduction

There are several factors that may affect the growth and yield of plants, both in quality and quantity. Some of these factors include the timing and method of irrigation and the amount and source of minerals or nutrients that are indispensable in crop production. Nutrient play a significant role in soil fertility and make it more productive for the growth of plant.

Cagayan Valley is the second top producer of tomato in the country during the second quarter of 2023 (April to June) with a total production amounting to 7.31 thousand metric tons (PSA, 2023). However, the productivity of tomatoes in the country is very low compared to other countries and farmers have been battling with the continuous dilemma on how to improve the quality of tomato fruits as to its physical attributes and chemical contents. Additionally, farmers are also struggling with blossom-end rot (BER) which persistently occurs in tomato fruits. According to Douglas (2023), BER is a physiological disorder or an abiotic disease which is usually characterized as a brown, leathery rot developing on or near the blossom end of tomato fruit.

This disease is associated with a localized deficiency of calcium at a critical stage in the development of the fruit aside from uneven watering and moisture stress. The effect of BER in tomatoes are direct fruit losses which leads to a decrease in farmers' income.

Studies shows that calcium plays a great role in improving crop fruit quality as to its size, appearance and taste. Thus, to enhance the yield and fruit quality of tomatoes, an appropriate cultural management can be done including the application of essential nutrient element such as calcium. While appropriate calcium application can enhance crop yield and contribute to addressing farmers' profitability and food security, it's just one component of a complex approach to sustainable agriculture. However, it's important to note that success in tomato farming depends on various factors such as soil quality, climate conditions, pest and disease management, and cultural management. Proper planning, management, and continuous learning are essential for maximizing productivity and increasing profitability. This study was conducted to assess the influence of application of calcium on tomato production particularly its fruit yield and quality.

Materials and methods

Procurement of Seeds

The seeds of tomato (Diamante F1) were bought in an accredited seed dealer of East West Seed Company.

Collection of Soil Sample and Analysis

A random collection of soil samples within the experimental area was done with the use of a shovel. In a newspaper, the soil samples were spread and air-dried for about 3 days. A one-kilogram soil sample was thoroughly cleaned and powderized remove foreign matters. The soil samples were then submitted for soil analysis to the Integrated Laboratory Division, Regional Soils Laboratory DA-RO2, Carig Sur, Tuguegarao City. Moreover, the NPK content of the soil were used as the basis for the fertilizer recommendation for the study. The NPK requirement for tomato was 90-120-30 kilograms per hectare.

Land Preparation

The area was cleared of stubbles, grasses, and stones to ensure proper land preparation. It was tractor-plowed and harrowed. The land was kept idle for two weeks to allow weeds to decompose and weed seeds to germinate before the final plowing. Before transplanting, the soil was extensively pulverized through final harrowing.

Seedling production

Garden soil and organic fertilizer were added to seedling trays in a 1:1 ratio. Diamante was the tomato cultivar employed in the study. One seed each cell was sowed and watered. When necessary, the seedlings received irrigation. A partial shadow was applied to the seedling trays. One week after pricking, 50 grams of urea was dissolved in four liters of water and sprayed on the seedlings. Additional watering was then performed to remove any remaining fertilizer residue from the plants' leaves. Until they were ready to be transplanted, the seedlings were kept in partial shade.

Experimental Treatments

The following treatments were utilized in this study.

T_1 – 90-120-30 kg NPK ha^{-1}

T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate (Agricultural Lime)

T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate

T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate (CalPhos)

T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron (CalBoron)

T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate (Agricultural Gypsum Powder)

Amount and Timing of Application of Treatments

The different calcium sources as treatments were purchased in an agricultural supply shop. The application of different sources of calcium was done three (3) times: (a) once at blossom stage; (b) once at 7 days after the first application; and (c) once during the early fruit stage (El-Tantawy and Mahmoud, 2016). However, the amount of the different calcium sources applied was based on the recommended dosage of the product (5ml/^{1}L or 1 teaspoon per 1 liter of water). As to the method of application, foliar spraying was utilized among treatments.

Experimental Layout and design

After the land preparation, an area of 617.5 square meters was divided into four blocks, each block measuring 4 meters by 32.5 meters with an alleyway of one meter between blocks. Each block was further subdivided into six plots, each plot measuring 5 meters by 4 meters with an alleyway of half meter between plots. The treatments were arranged following the procedure in the form of Randomized Complete Block Design (RCBD).

Making of Holes and Application of Fertilizer

Holes were dug at a distance of 70 centimeters between rows and 50 centimeters between hills, 6 centimeters deep and 10 centimeters wide. The study's fertilizer reference was the NPK rate per hectare of inorganic fertilizer determined by soil analysis. The exact amount was calculated by applying the ratio and proportion concept.

Transplanting and replanting

The seedlings were transplanted two weeks after being pricked. One seedling was transplanted per hill. To ensure full crop stand, test plants were replanted five days following transplanting.

Care and management

Cultivation was done to aerate the soil and control weeds. Hand weeding was done to control weed development, and plants were watered as needed.

Furthermore, the occurrence of insect pests and diseases was rapidly managed using chemical control.

Data Gathered

Agronomic parameters

Plant Height

The plant height of sample plants was measured at 60 days after transplanting. It was measured from the base of the plants up to the tip of the primary stem.

Number of fruits per plant.

The number fruits per plant were properly counted and recorded every harvest. All the fruits from the first priming up to the last priming per plant were summed up and divided by ten to obtain the average number of fruits per plant.

Weight of fruits per plant

The fresh fruits were weighed every priming and were recorded. After the last priming, the recorded weights of fruits were summed up and be divided by ten to obtain average fresh weight of fruits per plant.

Fruit diameter

The diameter of fruits per sample plants was measured using a caliper. The recorded size of fruits was summed up and divided by ten to obtain average fruit size per plant.

Number of damaged fruits

The number of damaged fruits were properly counted and recorded every harvest. All the fruits from the first priming up to the last priming per plant were summed up and divided by ten to obtain the average number of number of damaged fruits per plant.

Percentage of blossom-end rot (BER).

The percentage of Blossom End Rot (BER) incidence of fruits per plant was computed by dividing the number of BER fruits by the total number of fruits per plant multiplied by 100.

Computed fruit yield per plot

The computed fruit yield per plot was computed based on the average yield per sample.

Computed fruit yield per hectare

The computed fruit yield per hectare was computed based on the computed fruit yield per plot.

Cost and return analysis

The return on investment was computed using the simple economic analysis. The cost of production was based on the prevailing price of farm inputs and labor in the community. The gross income was determined based of the prevailing price of tomato per kilo. The net income is equal to the gross income minus the cost of production and the return of investment was computed by dividing the net income with the cost of production multiplied by 100.

Fruit quality.

The quality of fruits were determined by subjecting the samples to chemical analysis. Freshly harvested samples were obtained from each treatment plots and were brought to the laboratory for analysis.

Chemical analysis

The harvested fruits per sample plants was subjected to the following measurements and analysis (Umair *et al.*, 2019; Iqbal *et al.*, 2022):

Total soluble solids (TSS).

Total soluble solids (TSS) were determined through refractometry using a hand refractometer. TSS in tomatoes is mainly sugars (fructose). Two to three (2-3) drops of extract of homogenized ripe tomato sample from each treatment were placed in the prism of the apparatus. Total soluble solids (TSS) determination was performed for each sample fruit in four replications at 20°C and expressed as °Brix.

Percent Titratable Acidity (%TA). Acidity corresponds to the amount of acids in a solution. Titratable acidity (TA) is a type of measurement that deals with total acid concentration in any food. The core unit of acidity is hydrogen ions (H+) (Nielsen, 2017). In fruits, juice titration is done with an alkaline solution until reaching a pH of 8.1.

The total titratable acidity was computed using the formula:

%TA = [(Titer value x Normality x m.eq.wt. of acid)/(volume of sample)] x 100

Or simply,

%TA = [(Vol. of NaOH used x 0.1N x 0.064)/(10)] x 100

Sugar-Acid Ratio. The Total Soluble Solids and acidity ratio of tomato fruits was analyzed by dividing the TSS by % Titratable Acidity.

Statistical analysis

The data collected was analyzed using the Analysis of Variance (ANOVA) for Randomized Complete Block Design with the Statistical Tool for Agricultural Research (STAR). The treatments with significant result were compared using the Tukey's Honest Significant Difference Test (HSD).

Results and discussion

Plant Height (cm)

Inorganic fertilizer in combination to various sources of calcium contributes significantly to the proper growth and development of tomato plants. The effectivity of calcium as one of the essential elements for crop growth and development is reflected in the height of the plants at 60 days after transplanting. Plants applied with Calboron displayed the tallest with 99.31 cm, similar to those treated with Calphos (98.86 cm), Calcium Nitrate (98.29 cm) and Calcium Sulfate (96.42 cm). Plants applied with agricultural lime (T_2) measures 95.39 centimeters while the control plants exhibited the shortest plants with 82.75 centimeters. It was observed that the height of the plants increases when applied with different sources of calcium. Calcium plays a crucial role for meristematic activity and in maintaining chromosome structure during mitosis (cell division), consequently promoting plant growth (Abdur and Ihsan, 2012); Tuna *et al.*, (2007). Moreover, Calboron helps in root elongation and shoot growth and proved more effective in producing taller plants, more branches per plant and high leaf number which were in accordance with the claims of Rab and Haq (2012). Furthermore, as far as tomato plants are vulnerable and incapable of thriving in environments with high salinity may either fail to survive or exhibit stunted growth, characterized by smaller leaves and a reduced stature which are similar to the control plants. When exposed to salinity stress, augmenting the concentration of Ca^{2+} frequently mitigates the growth-inhibiting effects. Hence, the supplementation of Ca^2 (calcium boron, phosphate, nitrate, and sulfate) to the growth substrate is a remedial measure for the several stresses.

Table 1. Plant height at 60 days after transplanting (cm) as influenced by different sources of calcium.

TREATMENTS	Plant Height (cm) 60 DAT
T_1 – 90-120-30 kg NPK ha^{-1}	82.75^c
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	95.39^b
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	98.29^{ab}
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	98.86^{ab}
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	99.31^a
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	96.42^{ab}
F- RESULTS	**
C. V. (%)	1.68

Note: Means with common letter are not significant (0.01) with each other using HSD.

Number of Fruits per Plant

A significant increase in the quantity of tomato fruits was observed due to the application of calcium. Plants without calcium application yielded the lowest with only 11 fruits (T_1). Followed by the plants treated with calcium carbonate and calcium sulfate which produced 20 fruits respectively. The highest fruit count was observed in plants treated with calcium boron, calcium nitrate, and calcium phosphate yielding 27 fruits. This indicates that there was a synergistic effect of inorganic fertilizer with calcium boron, calcium nitrate, and calcium phosphate in increasing the production of fruits in tomatoes. This agrees to Haque *et al.*, (2011) who stated that calcium acts as a central regulator during plant development while boron, a component of Calboron, enhances stigma sugar levels, facilitates pollen tube development and germination, influences carbohydrate metabolism, and increases carbohydrate availability for flower and fruit formation and reducing flower abscission. Likewise, Dhiman *et al.* (2017) affirmed that phosphorus and nitrogen, as a component of Calphos and Caltrate, has a positive effect on flower initiation and formation, resulting to a higher fruit yield and net returns. Consequently, the application of boron, nitrogen and phosphorous resulted in an increase in the number of fruits per plants.

Table 2. Number of fruits per plant as influenced by different sources of calcium.

TREATMENTS	Number of Fruits
T_1 – 90-120-30 kg NPK ha^{-1}	11^c
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	20^b
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	27^a
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	27^a
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	27^a
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	20^b
F- RESULTS	**
C. V. (%)	6.67

Note: Means with common letter are not significant (0.01) with each other using HSD.

Weight of Fruits (g)

Variation existed on the weight of fruits per plant as affected by the addition of calcium as shown in Table 3. Data shows that the lightest fruits were produced by the plants without any addition of calcium with 187.25 grams. The low yield from the control plot was attributed to the higher incidence of blossom end rot and more non-marketable fruits due to distorted fruits. Followed in rank are the plants applied with Calcium sulfate with 819.50 grams and 816.25 grams for the plants added with Calcium carbonate.

When Calcium nitrate and calcium phosphate are applied to the plants, consisting of calcium and nitrogen, as well as calcium and phosphorus, it contributes to the improvement of tomato plant growth and highest number and weight of fruits per tomato plant (Conde and De Asis, 2021). On the other hand, the addition of Calcium carbonate (T_2) resulted in a 335.91% increase in fruit weight, while calcium nitrate (T_3) led to a 452.20 percent increase, calcium phosphate (T_4) to a 451.66%, Calboron (T_5) to a 454.60%, and calcium sulfate (T_6) to a 337.65% increase over the plants without calcium application.

Table 3. Weight (g) of fruits per plant as influenced by different sources of calcium.

TREATMENTS	Weight (g)
T_1 – 90-120-30 kg NPK ha^{-1}	187.25^c
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	816.25^b
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	1034.00^a
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	1033.00^a
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	1038.50^a
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	819.50^b
F- RESULTS	**
C. V. (%)	1.65

Note: Means with common letter are not significant (0.01) with each other using HSD.

This significant increase is due to the effect of calcium in minimizing fruit losses (Patanè *et al* (2018) while boron which is one of the most important micronutrients is involved in the carbohydrate metabolism, cell division and maintaining cell wall structure, flowering and fruit setting (Milagres *et al,* 2009). It also promotes the absorption of calcium and increases the content of vitamin C in the fruit by improving membrane integrity, slowing biosynthesis and reducing respiration in tomatoes resulted to heavier fruits. Tomato plant relies on both macro and micronutrients for its growth, development, and successful completion of its life cycle, especially during fruit production. It shows that the application of Calcium Nitrate, Calcium Phosphate, and Calboron has been shown to have a significant effect on the fruit yield per plant.

This increase in fruit yield is primarily attributed to the presence of calcium on the above products which helps to address calcium deficiency during periods of rapid cell expansion. These not only enhances the number of fruits produced but also promotes faster growth. Additionally, supplementing soil fertilization with calcium-rich products maximizes crop yield, as highlighted by Peyvast, *et al.* (2009).

Table 4. Fruit diameter (mm) as influenced by different sources of calcium.

TREATMENTS	Diameter (mm)
T_1 – 90-120-30 kg NPK ha^{-1}	31.75^b
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	42.75^a
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	43.00^a
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	43.25^a
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	43.25^a
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	41.25^a
F- RESULTS	**
C. V. (%)	3.73

Note: Means with common letter are not significant (0.01) with each other using HSD.

Fruit diameter (mm)

The diameter of tomato fruits was notably affected by the calcium sources. In the control plants, the fruit diameter showed variability across all treatments with an average size of 31.75 millimeters. However, plants treated with calcium exhibited significantly larger fruits, ranging from 41.25 mm to 43.25 millimeters (Table 4). Notably, irrespective of the calcium sources, the plants treated with any of the calcium sources produced the highest mean values. This observation suggests that the application of calcium contributed to increased fruit sizes. This effect can be attributed to the presence of calcium which enhances plant stress tolerance, ultimately leading to bigger and higher quality fruit production (Papadopoulos and Hao, 2003).

Table 5. Number of Damaged Fruits as Influenced by Different Sources of Calcium.

TREATMENTS	Damaged Fruits
T_1 – 90-120-30 kg NPK ha^{-1}	2
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	2
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	3
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	3
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	3
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	2
F- RESULTS	ns
C. V. (%)	23.6

Number of damaged fruits

The number of damaged fruits is presented in table 5. Data shows that there were no variations on the number of damaged fruits per plant across treatments. Plants with no application of calcium and those applied with calcium carbonate and calcium sulfate obtained the lowest number of damaged fruits with a mean value of 2. However, plants treated with calcium nitrate, calcium phosphate, and calcium boron has 3 damaged fruits. This indicates that the supplementation of calcium in tomato plants will not affect the number of damaged fruits.

Table 6. Percentage of blossom end rot on tomato fruits as influenced by different sources of calcium.

TREATMENTS	Percent BER
T_1 – Control	19.96^{a}
T_2 – RR+ Calcium Carbonate	12.12^{ab}
T_3 – RR + Calcium Nitrate	11.21^{b}
T_4 – RR + Calcium Phosphate	12.03^{ab}
T_5 – RR + Calcium Boron	11.85^{ab}
T_6 – RR + Calcium Sulfate	12.39^{ab}
F- RESULTS	*
C. V. (%)	22.44

Note: Means with common letter are not significant (0.01) with each other using HSD.

Percentage of blossom-end rot (BER)

Blossom end rot is characterized by large brown to black, dry leathery areas on the blossom end of tomato. These patches progressively grow eventually covering as much as half of the fruit's surface. This condition leads to distortion in the shape of the tomato. The highest occurrence of blossom end rot was noted in the control plants with a mean value of 19.96 percent. However, plants treated with calcium sulfate, calcium phosphate, calcium boron and calcium carbonate showed comparable levels of blossom end rot, with respective values of 12.39 percent, 12.03 percent, 11.85 percent, and 12.12 percent.

Table 7. Computed fruit yield per plot (kg) and per hectare (tons) as influenced by different sources of calcium.

TREATMENTS	Weight (kg)	Weight (tons)
T_1 – 90-120-30 kg NPK ha^{-1}	10.49^c	5.24^c
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	45.71^b	22.86^b
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	57.90^a	28.95^a
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	57.85^a	28.92^a
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	58.16^a	29.08^a
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	45.89^b	22.95^b
F- RESULTS	**	**
C. V. (%)	1.66	1.66

Note: Means with common letter are not significant (0.01) with each other using HSD.

On the other hand, the addition of calcium nitrate (T_3) recorded the lowest percentages of blossom end rot incidence, at 11.21 percent, respectively. This could be attributed to the excessive shoot growth leading to blossom end rot in developing fruit due to the competition between calcium in the soil solution and potassium, magnesium (Mg), and ammonium-nitrogen ($NH^{4-}N$) for uptake by the plant. This competition may also arise from overfertilization of potassium (K) during the early bloom and fruiting stages. Likewise, blossom end rot was reduced by application of Ca because the underlying cause of this disorder is an inadequate amount of Ca^{2+} in the blossom-end of the fruit (Saure, 2001). The findings from the research affirms with those of Fletcher *et al.* (2000), indicating that the calcium sources in the nutrient solution leads to higher calcium levels in the fruit and promotes better health, enhanced growth, increased yield, and a decrease in fruit blossom end rot.

Table 8. Percentage titratable acidity as influenced by different sources of calcium.

TREATMENTS	Titratable Acidity
T_1 – 90-120-30 kg NPK ha^{-1}	0.16^c
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	0.23^b
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	0.28^a
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	0.28^a
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	0.27^a
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	0.20^b
F- RESULTS	*
C. V. (%)	5.53

Note: Means with common letter are not significant (0.01) with each other using HSD.

Computed fruit yield per plot (kg) and per Hectare (tons)

Yield parameters were significantly influenced by calcium treatment, presented in Table 7. The highest weight of marketable fruits was 58.16 kilograms per plot or 29.08 tons per hectare (T_4) which has a 454.43% increase over the control treatment.

However, this was comparable to the Treatment 3 with 57.90 kilograms per plot or 28.95 tons per hectare (451.95 %) and Calcium Phosphate with 57.85 kilograms per plot or 28.92 tons per hectare (451.47) increase. Calcium Sulfate treated and Calcium carbonate plants yielded 45.89 kilograms per plot or 22.95 tons per hectare and 45.71 kilograms per plot or 22.86 tons per hectare (337.464% and 335.74 percent) increases while the lightest yield was the untreated control with 10.49 kilograms per plot or 5.24 tons per hectare. The increased yield observed in T_3, T_4, and T_5 may be attributed to their increased fruit production and reduced incidence of blossom end rot (BER) compared to other treatments.

Table 9. Total soluble solids as influenced by different sources of calcium.

TREATMENTS	TSS (°Brix)
T_1 – 90-120-30 kg NPK ha^{-1}	6.48[a]
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	5.10[b]
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	5.15[b]
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	5.10[b]
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	5.05[b]
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	5.08[b]
F- RESULTS	**
C. V. (%)	1.46

Note: Means with common letter are not significant (0.01) with each other using HSD.

Moreover, calcium Phosphate is proved to improve growth parameters and mitigate stress associated with climatic variability (Ramirez-Gil *et al*, 2023) and highest number and weight of fruits per tomato plant (Conde and De Asis (2021). Calcium Boron on the other hand, is responsible for cell division, carbohydrate metabolism and maintaining cell wall structure, flowering and fruit setting (Gupta and Solanki, 2013) thus, increasing tomato yield while Calcium nitrate produces better fruit and becomes resistant to pests and diseases as cited by Nolan (2023). Highlighting the benefits of calcium that positively influences tomato production by supplementing mineral content, flower cluster formation, fruit set percentage, and mitigating physiological disorders, thereby resulting in higher yields. Treated plants exhibited significantly greater yields compared to the control plants.

Table 10. Sugar-acid ratio as influenced by different sources of calcium.

TREATMENTS	Sugar-Acid Ratio
T1 – 90-120-30 kg NPK ha-1	40.56[a]
T_2 – 90-120-30 kg NPK ha^{-1}+ Calcium Carbonate	22.00[bc]
T_3 – 90-120-30 kg NPK ha^{-1} + Calcium Nitrate	18.58[c]
T_4 – 90-120-30 kg NPK ha^{-1} + Calcium Phosphate	18.42[c]
T_5 – 90-120-30 kg NPK ha^{-1} + Calcium Boron	18.89[c]
T_6 – 90-120-30 kg NPK ha^{-1} + Calcium Sulfate	24.88[b]
F- RESULTS	**
C. V. (%)	33.92

Note: Means with common letter are not significant (0.01) with each other using HSD.

Treated plants demonstrated notably higher yields in comparison to the control group. These results are supported by research from Hao and Papadopoulos (2003), indicating that calcium application not only reduces flower drop but also improves fruit retention (Fletcher *et al.,* 2000; Iqbal *et al.,* 2009.

Table 11. Cost and return analysis.

Treatment	Total Cost of Production	Gross Income	Net Income	Return on Investment (%)
T_1	73,675.25	78,645.00	4,969.75	6.75
T_2	74,335.25	342,825.00	268,489.75	361.19
T_3	75,952.25	434,280.00	358,327.75	471.78
T_4	88,525.25	433,860.00	345,334.75	390.10
T_5	86,545.25	436,170.00	349,624.75	403.98
T_6	75,127.25	344,190.00	269,062.75	358.14

Percent titratable acidity

The results showed significant differences in the titratable acidity existed with the application of various calcium sources (Table 6). The highest acidity levels were recorded in the control treatment with a mean value of 0.16. Following closely were the applications of calcium carbonate and calcium sulfate, resulting in acidity levels of 0.20% and 0.23 percent, respectively, while (0.28% and 0.27%) were observed in fruits harvested from plots treated with calcium nitrate, calcium phosphate and Calboron. Upon ripening of the tomato fruits, there was an evident increase in acidity noted possibly due to the concentration of nutrient sources which led to the retention of acid content, thereby elevating the titratable acidity. This rise in acidity during ripening from various calcium sources might cause from the absorption of organic acids as a respiration substrate, conversion of acid to sugar, metabolic translocation and transformation.

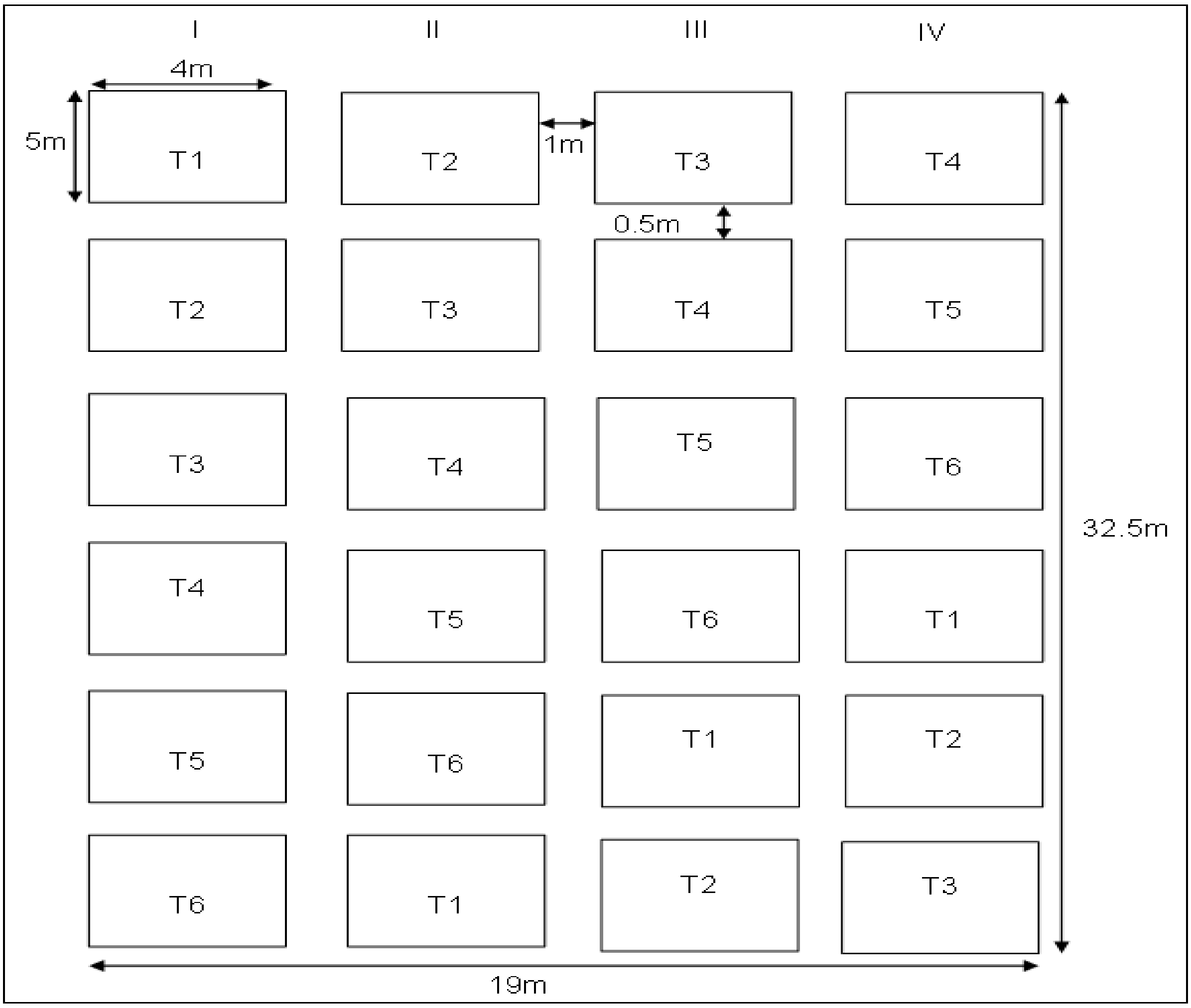

Fig. 1. Experimental layout.

The percentage of titratable acidity could be attributed to the inhibitory effect of calcium on ripening and the reduction in metabolic activity, as previously documented (Demes *et al.*, 2021).

Total Soluble Solids

The data on the fruit total soluble solids showed a significant difference as affected by the various sources of calcium. As shown in Table 7, there was no variability in the amount of total soluble solids for plants applied with various calcium sources with a mean value ranging from 5.05 °Brix to 5.13 °Brix. However, control plants exhibited a higher TSS with 6.48 °Brix compared to calcium-treated plants. A lower total soluble solids in calcium-treated plants indicates that the fruits are more acidic which might contribute to a longer ripening period. Indeed, in the fruit, calcium binds to pectin by forming the salt bridge between Ca^{2+} and the CaO group. As a result, calcium pectate is formed, which will reduce the degradation of the cell wall and the production of ethylene, therefore slowing down the fruit ripening process. Likewise, tomatoes ripened on the vine have higher levels of total soluble solids due to a higher importation of sugars from the plant to the fruit during this stage (Nunes, 2008). When the tomato turns red, total soluble solids increases to around 7% which were not at par with result of the study. Accordingly, the addition of calcium as foliar spray significantly decreased the total soluble solids of tomato fruits (Bibi *et al*, 2020, Sajid *et al*, 2019).

Sugar-acid ratio

The sugar-acid ratio of tomatoes was influenced by calcium sources, as shown in Table 8. The Control groups exhibited the highest values (40.56), indicating a higher value of sweetness in the fruit. Likewise, the addition of calcium sulfate (24.88) and calcium carbonate (22.0) in fruits have likely similar sugar-acid ratio. However, the fruits treated with calcium nitrate (18.58), calcium boron (18.89) and calcium phosphate (18.42) are similarly sweet. The results indicates that calcium treated fruits regardless of source tend to be less sweet and have higher acidity levels compared to untreated fruits which is consistent with the result in titratable acidity and total soluble solids.

The levels of sugars and organic acids in tomatoes vary according to their ripeness. As a tomato ripens, biochemical transformations occur, transitioning it from a sour, unripe state to a sweet, fragrant fruit. Throughout ripening, the sugar content rises, initially dominated by glucose in unripe tomatoes, gradually shifting towards higher levels of fructose in ripen fruits (Padmanabha *et al.,* 2016).

Cost and return analysis

The cost of production, gross income and net income to determine the return on investment of producing tomatoes using the different sources of calcium in supplementation to the recommended rate of inorganic fertilizer is reflected in Table 9. In descending order, Treatment 3 (Calcium nitrate) recorded an ROI of 471.78 percent. It was followed by Treatment 5 (calcium boron) with 403.98 percent, Treatment 4 (calcium phosphate) with 390.10 percent, Treatment 2 (calcium carbonate) with 361.19 percent, Treatment 6 (calcium sulfate) with 358.14 percent, and Treatment 1 (control) with 6.75 percent, respectively.

Conclusion

The application of different calcium sources during the flowering and early fruit stage with 5ml/1L dosage have resulted to a significant effect on the yield and fruit quality of tomato. The findings of the study showed that calcium supplementation to the recommended rate of inorganic fertilizer significantly enhances both the growth and yield of tomato plants, leading to a larger and higher fruit production. More importantly, the supplementation lessens the susceptibility to blossom end rot of the tomato fruits. The different forms of calcium such as Calcium nitrate, Calcium phosphate, and Calboron influenced the quality of the tomato fruits and increases the profitability of tomato production.

The researcher recommends that supplementing calcium to the recommended rate of inorganic fertilizer specifically in the forms of either Calcium nitrate, Calcium phosphate, or Calboron is suggested as they could significantly enhance the growth and yield of tomato plants. Foliar spraying of calcium during the flowering and early fruit stage is suggested as it reduces the susceptibility of tomato fruits to blossom-end rot, thus improving the quantity and quality of fruits. Further, calcium as supplement to inorganic fertilizer can be used by tomato farmers to increase their return on investment. Lastly, future studies should be conducted to assess the influence of application of different calcium sources on various tomato cultivars or crops.

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