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EFFECT OF DIFFERENT SOURCES AND LEVELS OF CALCIUM ON GROWTH AND YIELD OF TOMATO (*SOLANUM LYCOPERSICUM* L.) IN *ALFISOLS*

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ABSTRACT

A field experiment to study the effect of different sources and levels calcium on growth and yield of tomato was conducted during *Rabi* 2021 at College of Agriculture, V. C. Farm, Mandya. The experiment comprised of ten treatments replicated thrice *i.e*., soil application of gypsum (T_3 – 125 kg ha^{-1} and T_4 – 250 kg ha^{-1}), lime (T_5 -75 kg ha^{-1} and T_6 - 150 kg ha^{-1}), dolomite (T_7 – 125 kg ha^{-1} and T_8 - 250 kg ha^{-1}) and foliar application of $Ca(NO_3)_2$ (T_9 – 5 g L^{-1} and T_{10} - 7.5 g L^{-1}) which were tested against RDF + FYM (T_2) and control using RCBD design. The application of gypsum @ 250 kg ha^{-1}(T_4) has recorded highest growth parameters *i.e*., plant height (110.84 cm), number of branches (18.96 plant^{-1}) and internodal length (13.47 cm). Yield parameters such as number of clusters per plant (8.94), number of flowers per cluster (5.95), number of fruits per cluster (5.54), Dry matter yield (71.42 g per plant and 5.60 g per fruit), fruit setting rate (93.11 %), fruit weight (88.11 g), fruit diameter (4.74 cm), number of fruits per plant (44.79 fruits per plant), fruit yield (3.55 kg plant^{-1} and 88.66 t ha^{-1}) was significantly higher in the treatment T_4 compared to T_2 and T_1, which clearly indicates that application of gypsum @ 250 kg ha^{-1} along with RDF is optimum for obtaining higher growth and yield of tomato.

Key words : Gypsum, lime, Dolomite, Calcium nitrate, Tomato.

Introduction

Soil health is the vital factor responsible for better growth and yield of the crop. It can be improved by application of primary, secondary and micronutrients at an ideal rate, time, form and method. Secondary nutrients are as essential as primary nutrients. Calcium is one of the secondary nutrients, which play major role in crop development and production.

Calcium is essential for the formation of cell wall and calcium pectate in the middle lamella of the cell wall which regulates the entry of only those nutrients which are nontoxic to plants. In seeds, calcium is present as calcium pectate. In root tip, calcium is very essential for the meristematic activity, provides a base for neutralisation of organic acids and other toxins produced in plants. It plays a role in mitosis (cell division) and helps to maintain the chromosome structure. It is essential co-factor or an activator of several enzymes like hydrolases. It activates phospholipase, arginine kinase, amylase and adenosine tri phosphatase (ATPase) enzymes. It favours the assimilation of nitrogen into organic constituents especially proteins.

Plant growth and yield were hampered as a result of calcium immobility. It can be addressed by utilizing a proper calcium fertilizer delivered through soil or foliar means, which helps to enhance calcium content in plants.

Tomato (*Solanum lycopersicum* L.) is an adherent of the family Solanaceae and a self-pollinated crop with chromosome number 2n = 24. It is the world's largest vegetable crop after potatoes grown all over the world for its eclectic adaptability and nutritional value. The tomato acts as an intestinal antiseptic and cures mouth cancer and sore mouth. As a recent discovery, the antioxidant lycopene which imparts a red colour to fruit possesses tremendous nutritional properties to render it a "protective food" (Chadha, 2006).

Tomatoes are grown extensively in the United States, Russia, Italy, Spain, Turkey, India and other Asian countries. It is primarily grown in the Indian states of Uttar Pradesh, Karnataka, Maharashtra, Haryana, Punjab, Bihar and West Bengal, yielding 21 metric tonnes from an area of 0.85 million hectares and a productivity of 21.00 t ha^{-1}. Karnataka produced 2.16 metric tonnes with an output of 33.66 t ha^{-1} in an area of 0.06 million hectares from the districts of Kolar, Chikkaballapur and Bangalore (Anonymous, 2021).

All seventeen important nutrients primary, secondary, and micronutrients influence tomato productivity and quality. Calcium plays a significant function in tomato cultivation among secondary nutrients. There is a need to generate information on the influence of calcium nutrition on the yield and quality of tomatoes which propel plant health, high productivity, and fruit quality. Adequate nutrient contents in the soil constitute the foundation for the good nutritional status of the plants.

Currently and exclusively, farmers are cultivating hybrid tomatoes all over the year with poor secondary nutrition management. Amongst, calcium found to be critical to tomato, in *Alfisols*. The reduction in growth and yield due to Ca deficiency has been extensively reported in these soils. Hence, considering the above facts, an attempt has been made to evaluate the effect of different sources and levels of calcium on growth and yield of tomato.

Materials and Methods

The experiment was conducted at College of Agriculture, V.C. Farm, Mandya which comes under the Region III and Agro Climatic Zone VI (Southern Dry Zone) of Karnataka, which has 12°34' North latitude and 76° 49' East longitude with an altitude of 705 meters above mean sea level. The normal rainfall of the V.C. Farm, Mandya during the crop-growing period stood at 161.64 mm. The foremost part of the rainfall was in May (92.6 mm). Normal mean monthly maximum air temperature ranged from 30.5°C to 35.4°C. Whereas, the minimum air temperature vacillated from 17.0°C to 23.3°C. Further, the mean sunshine hours varied from 6.8 to 8.7 hours from December 2021 to May 2022.

The actual rainfall received during the cropping period (29^{th} December 2021 to 25^{th} May 2022) in V. C. Farm, Mandya was 344.8 mm. The major quantity of rainfall was attained in May (282.3 mm). The mean maximum air temperature varied from 29.8°C to 35.1°C. The highest mean maximum air temperature was perceived during April (35.1°C). The mean minimum air temperature ranged from 16.2°C to 21.6°C. The lowest mean minimum temperature was recorded during January (16.2°C). The mean bright sunshine hours varied from 5.8 to 8.7 hours from January to May. Relative humidity ranged from 87 to 93 per cent and 61 to 85 per cent during morning and afternoon hours, respectively during the growing period

The soil of the experimental site was red loamy sand with neutral soil reaction (7.27), electrical conductivity

Fig. 1 : General view of experimental site.

(0.39 dSm^{-1}) and organic carbon content (4.90 g kg^{-1}) was found to be low. The available nitrogen (263.42 $kgha^{-1}$), phosphorus (32.71kg$P_2O_5$$ha^{-1}$), potassium (155.48kg K_2O ha^{-1}) was medium, exchangeable calcium and magnesium (6.47 c mol (p^+) kg^{-1} and 2.87 c mol (p^+) kg^{-1}). The investigation was carried out in Randomized Complete Block Design with eight treatments and replicated thrice. Layout of the experiment was done with gross plot and net plot size of 4 m × 3.6 m and 3.2 m × 1.8 m, respectively. A distance of 0.5 m between two plots and 0.5 m was set to differentiate the replications. The bund height of 30 cm was raised in the space available between replications and plots. The study involved applying calcium sources and FYM (25 t ha^{-1}) two weeks before transplanting and mixing systematically. Twenty-five days old tomato seedlings were planted in a 75 cm × 45 cm field, with gap filling on the seventh day to ensure the ideal plant population. Basal doses of recommended fertilizers (50% N and 100% P_2O_5 and K_2O) were applied treatment-wise to each plot, with urea, Di Ammonium Phosphate, Single Super phosphate and Muriate of potash as sources of nitrogen, phosphorous, and potassium. Remaining 50 per cent of nitrogen applied at 30 days after transplanting (DAT) in the form of urea. Irrigation was provided initially at intervals of two to three days and later, six to eight days until complete harvest. Regular weeding was followed and staking was provided two weeks after transplanting.

Five plants were randomly selected from each plot and labelled to record growth parameters at different growth stages *viz.*, 30, 60, 90 DAT and at harvest. The tomatoes were harvested when they commenced maturity, and fruit was harvested at intervals of five to six days based on ripening. The data collected from the experiment was subjected to statistical analysis, following Gomez and Gomez's (1984) guidelines. The significance of difference among means was compared by using Duncan's Multiple Range Test (DMRT).

Treatment details

$\mathbf{T_1}$- Control, $\mathbf{T_2}$- RDF, $\mathbf{T_3}$- RDF + gypsum @ 125 kg ha^{-1}, $\mathbf{T_4}$- RDF + gypsum @ 250 kg ha^{-1}, $\mathbf{T_5}$- RDF + lime @ 75 kg ha^{-1}, $\mathbf{T_6}$- RDF + lime @ 150 kg ha^{-1}, $\mathbf{T_7}$- RDF + dolomite @ 125 kg ha^{-1}, $\mathbf{T_8}$- RDF + dolomite @ 250 kg ha^{-1}, $\mathbf{T_9}$- RDF + calcium nitrate Ca $(NO_3)_2$ foliar application @ 5 g L^{-1}, $\mathbf{T_{10}}$- RDF + calcium nitrate Ca $(NO_3)_2$ foliar application @ 7.5 g L^{-1}.

Note: RDF: 250:250:250 N: P_2O_5: K_2O kg ha^{-1} was common for all treatments except control. Foliar application @ 30 DAT, 60 DAT. In T_2 treatment phosphorous was applied through SSP and DAP.

Details of experimental data collection

Five plants were randomly selected from each plot and labelled to record the growth parameters at different growth stages *viz.*, 30, 60, 90 DAT and at harvest of the crop.

Growth parameters

Plant height (cm)

The plant height (cm) of five randomly selected plants at different growth stages was recorded with the support of a meter scale from the base of the plant up to the tip.

Number of branches

The total number of primary branches of five tomato plants were randomly selected to count and averaged at flowering, fruiting, and at harvesting, and it is expressed in numbers.

Internodal length

From all five labelled plants of each treatment, the internodal length of plants was measured from the first internode to the second internode and it was expressed in terms of centimetres.

Yield parameters

Number of flowers per cluster

The total number of fully opened flowers per cluster was recorded from each identified plant in the treatments at regular intervals.

Number of clusters per plant

A total number of clusters per plant was recorded from each appended plant in the treatments at regular intervals.

Number of fruits per cluster

The number of fruits on each tagged plant was recorded during the fruit development phase. Further, the average number of fruits per cluster was calculated.

Number of fruits per plant

The numbers of fruits from the five docketed plants harvested in all the pickings were added and the average worked out.

Fruit setting rate (%)

Five unopened flower buds marked at random in each plant from surveillance in all the treatments. The number of fruits set on labelled buds recorded periodically and per cent fruit set was calculated from the given formula and expressed in percentage.

$$\text{Fruit setting rate} = \frac{\text{No. of flowers per cluster}}{\text{No. of fruits per cluster}} \times 100$$

Dry matter yield (g)

The labelled plants were uprooted after the harvest of the crop. The root portion was separated washed, air dried and kept it in oven at 65°C till the constant weight is obtained. Similarly, the dry weight of shoot portion recorded and average was computed to express as shoot and root dry matter yield (g plant^{1}). The five fruits from labelled plants at 2nd picking were washed, chopped on watch glass, oven dried at 65°C and average was computed to express fruit dry matter yield (g fruit^{1}).

Fruit weight (g)

For all the five identified plants from each treatment, the average weight of five fruits was taken and means values were expressed in grams.

Fruit diameter (cm)

In the five labelled plants in each treatment, diameters of five fruits were measured, and mean values were expressed in centimetres.

Fruit yield per plant (kg)

The total weight of fruits harvested per plant from each harvest, in the five marked plants of each treatment, and imitations were recorded. The average yield per plant was worked out and articulated in kilograms**.**

Fruit yield (t ha^{-1})

The whole weight of fruits reaped from each picking in the identified plants in each repetition was recorded till the final harvest. The total yield of fruits per hectare under different treatments is computed in tonnes per hectare.

Results and Discussion

Plant height

The tomato plant height (cm) at different growth stages influenced by different sources and levels of calcium is indicated in Table 1. The application of different sources and levels of calcium significantly inclined the plant height at 30 and 60 DAT. The taller plant height of 53.34 and 101.12 cm, respectively observed in the treatment T_4 (RDF + gypsum @ 250 kg ha^{-1}) and was statistically on par with treatment T_8 receiving 250 kg ha^{-1} of dolomite with RDF (48.57 and 94.71 cm, respectively) although, they are significantly superior over rest of the treatments. Further, lower plant height was registered in control (T_1 -39.31 and 72.17 cm, respectively).

The result indicated that plant height @ 90 DAT and at harvest varied significantly due to the application of different sources of calcium at different rates along with RDF. Higher plant height, recorded in treatment T_4 (106.91 and 110.84 cm, respectively) followed by treatment T_{10} receiving the foliar application of calcium nitrate [Ca $(NO_3)_2$] @ 7.5 g L^{-1} (102.61 and 106.84 cm, respectively) and T_8- dolomite application @ 250 kg ha^{-1} + RDF (99.35 cm and 103.50 cm, respectively). Further, significantly lower plant heights of 79.51 and 83.48 cm (at 90 DAT and at harvest, respectively) observed in T_1 (control).

The application of gypsum, calcium nitrate, and dolomite along with RDF, significantly increased tomato plant height at different growth stages. These factors improved soil physical properties, provided favourable conditions for bacterial activities, and enhanced nitrogen availability. Gypsum's sulphur has a synergistic effect with nitrogen, supplementing nitrogen content in plants. Foliar application of calcium nitrate increases nitrogen concentration in plants through leaves, while dolomite increases nitrogen content through magnesium absorption. Calcium and sulphur in gypsum may have helped in calcium translocation and uptake, enhancing chlorophyll formation, photosynthetic and metabolic activity, and nitrogen assimilation. These all factors help to increase plant height. The above findings are similar to the research of Sathya *et al*. (2010), Abdur and Haq (2012), Babak *et al*. (2013), Ali *et al*. (2004), Hamsaveni *et al*. (2003).

Internodal length

The different sources and levels of calcium application significantly influenced the internodal length of tomato at 30 and 60 DAT. Treatment receiving gypsum @ 250 kg ha^{-1} + RDF (T_4) recorded appreciably higher internodal length (5.24 and 10.70 cm, respectively), followed by T_8 due to application of dolomite @ 250 kg ha^{-1} + RDF (4.87 and 9.72 cm, respectively) although it was significantly superior over rest of the treatments. Nevertheless, shortest intermodal length observed control (T_1-3.17 and 6.58 cm, respectively). Subsequently, noticeably more internodal length at 90 DAT and at harvest was noticed in T_4 treatment (12.81 and 13.47 cm, respectively), followed by T_{10} (11.91 and 12.07 cm, respectively) and T_8 (10.85 and 11.40 cm, respectively). Yet, they are significantly higher than the remaining treatments. Non-application of fertilizer and amendment in control (T_1- 7.35 and 8.86 cm, respectively) recorded the lower length of the internode (Table 1).

Number of branches

Data pertaining to number of branches influenced by different sources and levels of calcium at 30, 60, 90 DAT and at harvest is represented in Table 1.

At 30 and 60 DAT, treatments T_6, T_3, T_7, T_5, T_{10}, T_9 and T_2 are on par with each other. However, the soil

Table 1 : Effect of different sources and levels of calcium on plant height and number of branches of tomato plant at different growth stages.

Treatments	Plant height (cm)				Internodal length (cm)				Number of branches			
	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest	30 DAT	60 DAT	90 DAT	At harvest
T_1	39.31^{a}	72.17^{a}	79.51^{a}	83.48^{a}	3.17^{a}	6.58^{a}	7.35^{a}	8.86^{a}	5.21^{a}	7.09^{a}	8.85^{a}	10.84^{a}
T_2	44.36^{ab}	80.21^{ab}	83.84^{a}	87.84^{a}	3.51^{ab}	7.93^{ab}	8.36^{ab}	9.18^{ab}	7.23^{b}	10.48^{b}	12.22^{bc}	13.21^{ab}
T_3	46.28^{ab}	88.71^{bc}	89.95^{abc}	92.71^{abc}	4.09^{bc}	9.24^{cd}	9.47^{abc}	10.05^{abc}	7.73^{b}	11.27^{b}	12.82^{bcd}	14.80^{abc}
T_4	53.34^{c}	101.12^{d}	106.91^{d}	110.84^{d}	5.24^{d}	10.70^{e}	12.81^{d}	13.47^{d}	10.54^{c}	15.82^{c}	17.57^{f}	18.96^{d}
T_5	44.21^{ab}	82.15^{ab}	85.83^{ab}	89.83^{ab}	3.64^{ab}	7.61^{bc}	8.68^{ab}	9.50^{ab}	7.32^{ab}	10.20^{b}	11.49^{b}	13.48^{bc}
T_6	46.97^{ab}	90.38^{bc}	92.82^{abc}	94.38^{abc}	4.26^{bc}	9.11^{cd}	9.84^{abc}	10.29^{abc}	7.92^{b}	11.93^{b}	13.22^{bcd}	15.21^{abc}
T_7	45.54^{ab}	84.56^{bc}	87.18^{ab}	91.18^{ab}	3.89^{ab}	8.49^{bcd}	9.36^{abc}	9.78^{abc}	7.48^{b}	10.85^{b}	12.53^{bcd}	14.51^{ab}
T_8	48.57^{bc}	94.71^{cd}	99.35^{bcd}	103.50^{bcd}	4.87^{cd}	9.72^{de}	10.85^{bcd}	11.40^{bcd}	9.55^{c}	14.50^{c}	15.04^{def}	17.02^{bcd}
T_9	43.22^{ab}	86.57^{bc}	92.65^{abc}	96.72^{abc}	3.46^{ab}	8.63^{bcd}	9.96^{abc}	10.41^{abc}	7.05^{b}	10.89^{b}	14.28^{cde}	16.20^{abc}
T_{10}	43.99^{ab}	88.67^{bc}	102.61^{cd}	106.84^{cd}	3.48^{ab}	8.79^{bcd}	11.91^{cd}	12.07^{cd}	7.07^{b}	11.22^{b}	16.36^{ef}	18.35^{cd}
S.Em±	**2.17**	**3.59**	**4.33**	**4.37**	**0.29**	**0.41**	**0.78**	**0.68**	**0.54**	**0.85**	**0.84**	**0.85**
CD @ 5%	**6.93**	**11.49**	**13.86**	**13.97**	**0.92**	**1.31**	**1.74**	**2.17**	**1.73**	**2.72**	**2.69**	**2.71**

Treatment details:

T_1- Control
T_2- RDF
T_3- RDF + gypsum @ 125 kg ha^{-1}
T_4- RDF + gypsum @ 250 kg ha^{-1}
T_5- RDF + lime @ 75kg ha^{-1}
T_6- RDF + lime @ 150 kg ha^{-1}
T_7- RDF + dolomite @ 125 kg ha^{-1}
T_8- RDF + dolomite @ 250 kg ha^{-1}
T_9- RDF + calcium nitrate $Ca(NO_3)_2$ foliar application @ 5 g L^{-1}
T_{10}- RDF + calcium nitrate $Ca(NO_3)_2$ foliar application @ 7.5 g L^{-1}

application of gypsum @ 250 kg ha^{-1} + RDF (T_4) recorded a significantly higher number of branches (10.54 and 15.82, respectively), followed by treatment T_8 receiving dolomite @ 250 kg ha^{-1} with RDF (9.55 and 14.50, respectively). On the other hand, with the advancement of tomato plant growth, T_4 (gypsum @ 250 kg ha^{-1} + RDF) registered a significantly more (17.57 and 18.96 at 90 DAT and at harvest, respectively) number of branches. However, which is superior to the rest of the treatments except T_{10} (16.36 and 18.35) and T_8 (15.04 and 17.02). Interestingly, both T_{10} and T_8 are found to be on par with T_4.

Growth parameters increased progressively with the advancement in tomato plant growth. Significantly lower growth parameters recorded the nutrient status of the soil was unable to meet the nutrient requirement of the tomato crop, resulting in stunted growth. Subsequently, the application of calcium sources recorded significantly the highest internodal length and number of branches compared to control at different growth stages of the tomato plant. The application of gypsum, foliar application of calcium nitrate and application of dolomite serves as a source of calcium, magnesium and sulphur for plant growth. As calcium is involved in photosynthesis, carbohydrate metabolism, protein synthesis, synthesis of growth-promoting substances, cell division, and cell elongation, have enhanced the internodal length and number of branches in tomato as evident in the treatment receiving gypsum @ 250 kg ha^{-1}, foliar application of calcium nitrate [$Ca(NO_3)_2$] @ 7.5 g L^{-1} and dolomite application @ 250 kg ha^{-1}. The above findings are corroborated by the research findings of Babak *et al*. (2013), Ali *et al*. (2004), Hamsaveni *et al*. (2003) and Bharathkumar *et al*. (2020).

Yield parameters

The data with respect to yield parameters *viz*., number of clusters per plant, number flowers per cluster, number of fruits per cluster and fruit setting rate are epitomized in Table 1.

Number of clusters per plant

The calcium applied at different rates with different sources showed a significant difference in the number of clusters per plant. Significantly more bunches are documented in T_4 due to the application of gypsum @ 250 kg ha^{-1} + RDF (8.94), followed by T_{10} and T_8 (8.86 and 8.69, respectively). Although, T_4, T_{10} and T_8 treatments, found to be on par with each other and superior to other treatments.

It could be due to the application of gypsum and dolomite @ 250 kg ha^{-1} along with RDF made soil favourable for the utilization of nutrients by the plants. Along with gypsum and dolomite, foliar application of calcium nitrate [Ca $(NO_3)_2$] @ 7.5 g L^{-1} also aids to develop the leaf area, which in turn may enhance the photosynthesis and metabolic activity leads to the assimilation of carbohydrates. Along with these factors balanced nutritional status of the plant increases one of the growth parameters (the number of branches). As the number of branches increases, the number of clusters per plant also increases (Mallick and Muthukrishnan, 1980 and Tamilselvi *et al.*, 2005).

Number flowers per cluster

The high number of flowers per cluster significantly chronicled in treatment T_4 (5.95) due to the enactment of RDF (NPK) + gypsum @ 250 kg ha^{-1} followed by T_{10} and T_8 (5.86 and 5.83, respectively) treatments received RDF + dolomite @ 250 kg ha^{-1} and RDF + Ca $(NO_3)_2$ foliar application @ 7.5 g L^{-1}, respectively. Further, treatments T_4, T_{10} and T_8 are significant over T_9, T_6, T_3, T_7, T_5 and T_2 (5.38, 5.33, 5.30, 5.19, 4.93 and 4.84, respectively). However, the control recorded least number of flowers per cluster (T_1- 3.24).

The application of gypsum, dolomite and foliar application of calcium nitrate [Ca $(NO_3)_2$] had a positive and significant effect on the number of flowers per cluster. Gypsum (calcium and sulphur), dolomite (calcium and magnesium) and calcium nitrate (calcium and nitrogen) increase the content as well as uptake of available nutrients from the soil. Calcium increased boron uptake due to the synergistic interaction. Treatment received gypsum @ 250 kg ha^{-1} recorded higher content and uptake of boron in plant. Boron enhances flower production and retention, pollen tube elongation and germination. Among the primary nutrients, phosphorus has a positive impulse on male functional parts (pollen production per flower, size of pollen grain, and pollen P concentration) and ancillary boosting total flower production (Lau and Stephenson, 1994 and Jennifer *et al.*, 2002).

Number of fruits per clusters

The tomato fruit number per cluster varied significantly due to calcium application source and rate. A few numbers of tomato fruits per cluster set up in treatment T_1-control (no fertilizer and amendment) (2.45). However, application of gypsum @ 250 kg ha^{-1} + RDF recorded more fruit number per cluster (T_4 - 5.54) is statistically on par with treatment (T_{10}) receiving the foliar application Ca $(NO_3)_2$) @ 7.5 g L^{-1} (5.42) and treatment T_8 (250 kg ha^{-1} of dolomite + RDF) with values of 5.35, but these are significantly superior over rest of the treatments.

The highest number of fruits per cluster was due to the application of gypsum and dolomite which influences the availability and uptake of other nutrients from the soil. The utilization of these essential nutrients by the plants seems to have provided a congenial nutritional environment for better growth of plants. The calcium might have increased multiple enzymes (phosphatase and protease) and promoted growth hormones in plant tissue, helping to absorb boron from the soil is responsible for the higher number of fruits per cluster. The supply of major nutrients such as nitrogen, phosphorus and potassium resulted in better performance in fruit formation and finally increased the number of fruits per cluster (Chaudhary *et al.*, 2012).

Fruit setting rate (%)

The data indicate that the fruit setting rate is inclined by different sources and levels of calcium application. Significantly, the uppermost fruit setting rate (%) recorded in treatment (gypsum @ 250 kg ha^{-1} + RDF) T_4 (93.11 %) numerically followed by T_{10} (92.49%) and T_8 (91.77 %) as they received RDF + foliar application Ca $(NO_3)_2$) @ 7.5 g L^{-1} and RDF + dolomite @ 125 kg ha^{-1}, respectively. Although, in the control (76.82 %) recorded less fruit setting rate.

Fruit setting rate found to increase in all calcium-applied plots as compared to control and only RDF. because promotes root development and growth of the plant as it is involved in root elongation and cell division. It also improves the uptake of other plant nutrients, especially P and B, which plays an imperative role in pollen germination, pollen growth and better retention of fruits. Thus, helps in enlarging yield attributes, (the number of flowers per cluster and the number of fruits per cluster) which novice resulted in an amplified fruit setting rate (%) in tomato, these results, corroborated with Tejashvini *et al.* (2018).

Dry matter yield (g plant^{-1})

Dry matter yield per plant varied significantly with the application of different sources and levels of calcium with RDF. Results revealed that treatment T_4 (Gypsum @ 250 kg ha^{-1} + RDF) recorded, the highest dry matter yield of 71.42 g plant^{-1}. However, it was on par with treatment receiving the foliar application of calcium nitrate (Ca $(NO_3)_2$) @ 7.5 g L^{-1} (T_{10} – 69.17 g plant^{-1}) and soil application of dolomite @ 250 kg ha^{-1} with RDF (T_8 – 68.29 g plant^{-1}). The lowest was in T_1 (45.75 g plant^{-1}),

a) T_4 – RDF + gypsum @ 250 kg ha^{-1}

b) T_1- Control

Fig. 2 : Effect of different sources and levels of calcium on tomato plant height and number of branches of at 60 DAT.

T_4 – RDF + gypsum @ 250 kg ha^{-1}.

Fig. 3 : Effect of different sources and levels of calcium on fruit size of tomato.

which received no fertilizers.

Significantly higher dry matter of fruit was recorded in T_4 (5.60 g per fruit) followed by treatment T_{10} (5.43 g per fruit) and T_8 (5.18 g per fruit). However, lowest fruit dry matter recorded in control (T_1 -1.34 g per fruit).

The results with high output might be due to releases of native soil nutrients, better microbial activities, required bulk density (calcium), appropriate soil structure, soil aeration has led to higher content and uptake of plant nutrients from the soil and absorbed nutrients helped in the cell division, cell elongation, growth hormone synthesis, carbohydrate metabolism and accumulation of photosynthates, enhanced the vegetative growth of the plant which intern increased dry matter production in fruit and plant. These results corroborated with Bishnu *et al*. (2004).

Fruit diameter (cm)

The maximum tomato fruit diameter (4.74 cm) documented due to T_4 (Gypsum @ 250 kg ha^{-1} + RDF). It was followed by treatment T_{10} (4.62 cm) and T_8 (4.57 cm) which conferred with dolomite @ 250 kg ha^{-1} + RDF, and foliar application of calcium nitrate ($Ca(NO_3)_2$) @ 7.5 g L^{-1}, respectively. Conversely, the low-sized tomato fruit diameter was superficial due to treatment T_1 (no fertilizer and amendment) with values of 2.49.

Fruit weight (g)

Data on fruit weight varied significantly due to the application of different sources of calcium at different levels. Treatment control (T_1), which is not received either fertilizer or amendment, registered 65.70 g of fruit weight. Further, the application of gypsum @ 250 kg ha^{-1} + RDF recorded the highest fruit weight (T_4 – 88.11 g) followed by treatment T_{10} due to foliar application of $Ca(NO_3)_2$ @ 7.5 g L^{-1} (87.49 g), and T_8 had soil application of dolomite @ 250 kg ha^{-1} + RDF (86.77 g).

Application gypsum @ 250 kg ha^{-1}, foliar application of calcium nitrate [Ca $(NO_3)_2$] @ 7.5 g L^{-1} and dolomite application @ 250 kg ha^{-1} along with RDF along significantly increased the fruit diameter and weight of tomato. Owing to the balanced and better mineral utilization by plants resulting in enhancement of photosynthesis, other metabolic activity and great diversion of food material to the fruits, that ultimately led to an increase in cell elongation and cell division, the intern responsible for the increase in dry matter content of fruits. Apart from nitrogen, calcium also might have helped to favours cell division, meristematic activity in apical tissue, expansion of cells, and formation of new cell walls led to enlarging the width of the fruit. Bhat *et al.* (2012) and Suganiya *et al.* (2015) reported similar works.

Table 2 : Effect of different sources and levels of calcium on yield parameters and yield of tomato.

Treatments	No. of cluster per plant	No. of flowers per cluster	No. of fruits per cluster	Fruit setting rate (%)	Dry matter yield(g per plant)	Dry matter (g per fruit)	Fruit diameter (cm)	Fruit weight (g)	No. of fruits per plant	Yield per plant (kg)	Total fruit yield (t ha^{-1})
T_1	5.20^{a}	3.24^{a}	2.45^{a}	76.82^{a}	45.75^{a}	1.34^{a}	2.49^{a}	65.70^{a}	10.69^{a}	0.70^{a}	17.56^{a}
T_2	6.42^{ab}	4.84^{b}	4.19^{b}	86.57^{ab}	59.34^{b}	3.46^{b}	3.96^{b}	79.64^{b}	29.43^{b}	2.56^{b}	64.00^{b}
T_3	6.90^{bcd}	5.30^{b}	4.79^{bcd}	90.38^{b}	63.77^{bc}	4.46^{d}	4.11^{cd}	85.38^{bc}	34.71^{cd}	2.96^{cde}	74.08^{cde}
T_4	8.94^{f}	5.95^{c}	5.54^{e}	93.11^{b}	71.42^{d}	5.60^{e}	4.74^{f}	88.11^{c}	44.79^{f}	3.55^{g}	88.66^{g}
T_5	6.02^{ab}	4.93^{b}	4.32^{bc}	87.63^{ab}	60.51^{bc}	3.98^{c}	4.00^{bc}	84.93^{bc}	30.67^{bc}	2.75^{bc}	68.83^{bc}
T_6	7.69^{cd}	5.33^{b}	4.82^{bcd}	90.43^{b}	65.94^{bc}	4.79^{d}	4.22^{ade}	85.43^{b}	36.33^{cde}	3.10^{cde}	77.58^{cde}
T_7	6.83^{bc}	5.19^{b}	4.64^{bc}	89.40^{b}	61.73^{bc}	4.33^{c}	4.09^{cd}	85.31^{bc}	33.04^{bcd}	2.82^{bcd}	72.37^{bcd}
T_8	8.69^{ef}	5.83^{bc}	5.35^{de}	91.77^{b}	68.29^{cd}	5.18^{de}	4.57^{ef}	86.77^{bc}	41.76^{f}	3.30^{efg}	82.59^{efg}
T_9	7.82^{de}	5.38^{b}	4.90^{cd}	91.08^{b}	66.38^{bc}	5.05^{de}	4.29^{de}	86.08^{bc}	37.58^{e}	3.23^{def}	80.87^{def}
T_{10}	8.86^{f}	5.86^{bc}	5.42^{de}	92.49^{b}	69.17^{cd}	5.43^{e}	4.62^{ef}	87.49^{bc}	42.28^{f}	3.44^{fg}	85.98^{fg}
S.Em ±	**0.31**	**0.14**	**0.19**	**3.87**	**1.34**	**0.14**	**0.13**	**3.40**	**1.38**	**0.10**	**2.16**
CD (5%)	**0.99**	**0.54**	**0.62**	**12.38**	**5.01**	**0.42**	**0.43**	**7.45**	**4.43**	**0.30**	**7.06**

Treatment details:

T_1 - Control
T_2 - RDF
T_3 - RDF + gypsum @ 125 kg ha^{-1}
T_4 - RDF + gypsum @ 250 kg ha^{-1}
T_5 - RDF + lime @ 75kg ha^{-1}
T_6 - RDF + lime @ 150 kg ha^{-1}
T_7 - RDF + dolomite @ 125 kg ha^{-1}
T_8 - RDF + dolomite @ 250 kg ha^{-1}
T_9 - RDF + calcium nitrate Ca $(NO_3)_2$ foliar application @ 5 g L^{-1}
T_{10} - RDF + calcium nitrate Ca $(NO_3)_2$ foliar application @ 7.5 g L^{-1}

Number of fruits per plant

A significantly higher number of fruits per plant due to T_4 (44.79) marked when the treatment received 250 kg ha^{-1} of gypsum with RDF and was statistically on par with treatment T_{10} and T_8 (42.28 and 41.76, respectively), but treatments T_4, T_{10}, and T_8 found significantly high when compared with remaining treatments. Interestingly, treatments T_3, T_5, T_6 and T_7 were found to be on par. Further, the control (T_1) registered significantly fewer tomato fruits (10.69).

Yield (kg $plant^{-1}$)

Similarly, the results on tomato yield per plant indicated that treatment T_4 (gypsum @ 250 kg ha^{-1} with RDF) recorded significantly and numerically the highest yield (3.55 kg) per plant compared to other treatments. While, control (0.70 kg $plant^{-1}$) and T_2 -RDF alone (2.56 kg $plant^{-1}$) registered less yield. However, T_{10} (3.44 kg $plant^{-1}$) and T_8 (3.30 kg $plant^{-1}$) are on par with T_4.

Total yield (t ha^{-1})

Absolute control treatment (does not receive any fertilizer or amendment during crop growth) registered (17.56 t ha^{-1}). Further, Treatments T_4 (88.66 t ha^{-1}), T_{10} (85.98 t ha^{-1}) and T_8 (82.59 t ha^{-1}) are statistically on par, as these treatments received RDF as commonly, along with gypsum @ 250 kg ha^{-1}, foliar spray of Ca $(NO_3)_2$ @ 7.5 g L^{-1}, and dolomite @ 250 kg ha^{-1}, respectively. Even though the total yield was numerically descending in the order of T_6 (77.58 t ha^{-1}), T_3

(74.08 t ha^{-1}), T_7 (72.37 t ha^{-1}), T_5 (68.83 t ha^{-1}) and T_2 (64.00 t ha^{-1}), respectively.

An increase in the yield of tomato is a manifestation of the growing condition and nutrient management. An increase in the plant fruit number and tomato fruit yield in the treatments received different sources of calcium at different levels could be attributed to improvement in growth parameters *viz*., plant height, number of branches, and inter nodal length (Table 1) and yield parameters *viz*., number of flower clusters per plant, number of flowers per cluster, number of fruits per cluster, fruit set, fruit diameter and fruit weight (Table 2). The plant fruit number and tomato yield increased in all calcium-treated plots compared to the control. High diversion of photosynthates to fruits ultimately increases the dry matter content of tomato fruits, enhancing the fruit weight (Tejashvini *et al*., 2018). Tomato fruit width increase may be due to the involvement of nitrogen and sulphur in chlorophyll formation. Apart from nitrogen and sulphur, calcium might have helped in cell division, meristematic activity in apical tissue, expansion of cells, and new cell wall formation, augmenting the fruit width and utilization of available nutrients to enlarge flowering, fruit set and yield of the crop signified the role of K in enhancing fruit yield parameters. They reported an increased number of fruits per plant and tomato fruit weight with increased K availability and assimilation. These findings are as per previous studies of McLay *et al*. (1994), Huett and Deltmann (1988), Bhatt and Srivastava (2005), Chaudhary *et al*. (2012) and Bharathkumar *et al*. (2020).

Conclusion

The present study highlighted the application of different calcium sources along with recommended dose of fertilizer and evaluating their effect on growth and yield by using tomato as test crop. Among the different sources of calcium, application of gypsum along with RDF and FYM recorded higher growth and yield parameters when compared to rest of the treatments. Moreover, foliar application of calcium nitrate @ 5g L^{1} along with RDF and FYM was next best treatment followed by soil application of dolomite @ 250 kg ha^{-1} with RDF in terms of growth and yield of tomato. However, soil application of Lime @ 150 kg ha^{-1} with RDF recorded significantly higher growth and yield of tomato as compared to treatment with only RDF and control. Thus, application of calcium sources is superior over control treatment in term of achieving higher growth and yield parameters in tomato.

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Conflict of interest

The author declares that they have no conflict of interest.

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