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Optimizing calcium nutrition through diverse sources and levels for enhancing fruit quality of tomato (*Solanum lycopersicum* L.) grown in Alfisols

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Abstract

A field experiment was conducted during Rabi 2021-22 at the College of Agriculture, V.C. Farm, Mandya, to study the influence of calcium sources and application levels on quality tomato (*Solanum lycopersicum* L.) grown in Alfisols. The experiment consisted of ten treatments arranged in a Randomized Complete Block Design (RCBD) with three replications. The treatments included 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(NO₃)₂ (T_9 -5 g L⁻¹ and T_{10} -7.5 g L⁻¹). These treatments were compared with RDF + FYM (T_2) and an untreated control (T_1). Results from the study revealed that soil application of gypsum at 250 kg ha⁻¹ (T_4) recorded the highest ascorbic acid content (96.84 mg/100 g), lycopene content (7.31 mg/100 g) and total soluble solids (5.10 °brix) and lowest values recorded in control treatment viz., ascorbic acid content (61.72 mg/100 g), lycopene content (4.91 mg/100 g) and total soluble solids (3.02 °brix). Physiological disorder i.e., blossom end rot (BER) and late blight disease was recorded lowest in T_4 treatment (gypsum at 250 kg ha⁻¹) and highest in T_1 (control).

Keywords: Ascorbic acid, lycopene, blossom end rot, gypsum, dolomite, lime

Introduction

Soil health is a fundamental determinant of crop productivity, influencing nutrient availability, plant growth, and yield. Balanced fertilization involving primary, secondary, and micronutrients is essential for sustaining soil fertility and ensuring optimal crop performance. Although primary nutrients receive major attention in crop nutrition, secondary nutrients such as calcium are equally important for maintaining plant structural stability, physiological processes, and fruit quality.

Calcium plays a critical role in plant growth and development. It is a structural component of cell walls, forming calcium pectate in the middle lamella, which strengthens cell adhesion and regulates selective nutrient uptake (Marschner, 1996) [15]. Calcium is essential for meristematic activity, particularly in root tips, and contributes to mitotic cell division by maintaining chromosome integrity. It also acts as a cofactor and activator for several enzymes, including hydrolases, phospholipase, amylase, arginine kinase, and adenosine triphosphatase (ATPase). Furthermore, calcium enhances nitrogen assimilation into proteins and aids in detoxifying organic acids and other harmful metabolites within plant tissues (Sharma, 1995) [21].

Despite its importance, calcium is relatively immobile in plants, making developing tissues and fruits particularly vulnerable to deficiency. In tomato, inadequate calcium supply leads to physiological disorders such as blossom-end rot, reduced fruit firmness, poor shelf life, diminished market quality and disease incidence (Erdal *et al.*, 2004; Lanauskas and Kvikliene, 2006) [9, 14]. Appropriate calcium management through soil amendments or foliar application can improve calcium availability, thereby enhancing fruit quality and plant health.

Tomato (*Solanum lycopersicum* L.), a member of the family Solanaceae, is one of the most widely cultivated vegetable crops worldwide due to its adaptability and high nutritional value.

The fruit is an important source of vitamins, minerals, and antioxidants, particularly lycopene, which contributes to its recognized health benefits. In India, tomato is extensively cultivated across diverse agro-climatic regions, including Karnataka, Maharashtra, Uttar Pradesh, and Punjab, where it serves as a major vegetable crop (Anonymous, 2021) [2].

Alfisols, which are prevalent in many tomato-growing regions, are often characterized by low base saturation and calcium deficiency due to leaching losses and limited nutrient reserves (Demsew and Beamlaku 2020) [7]. Such deficiencies can adversely affect the quality. With the increasing adoption of hybrid tomato cultivation and intensive cropping systems, secondary nutrient management has become increasingly important. Calcium deficiency in *Alfisols* has been widely associated with reduced productivity and inferior fruit quality.

Therefore, a systematic evaluation of different calcium sources and application levels is essential to optimize calcium nutrition in tomato. The present study was undertaken to assess the influence of calcium fertilization on fruit quality, physiological disorder and disease incidence in tomato crop cultivated in *Alfisols*.

Materials and Methods

The field experiment was carried out at the College of Agriculture, V.C. Farm, Mandya, located in Region III and Agro-Climatic Zone VI (Southern Dry Zone) of Karnataka. The site lies at 12°34' N latitude and 76°49' E longitude, with an elevation of 705 m above mean sea level. During the crop-growing period, the total rainfall recorded at V.C. Farm, Mandya was 161.64 mm, with the highest precipitation received in May (92.6 mm). The normal mean monthly maximum temperature ranged from 30.5 °C to 35.4 °C, while the minimum temperature varied between 17.0 °C and 23.3 °C. In addition, the average daily sunshine hours during the period from December 2021 to May 2022 ranged from 6.8 to 8.7 hours.

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% P₂O₅ and K₂O) 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.

Treatment details

T₁-Control, T₂-RDF, T₃-RDF + gypsum @ 125 kg ha⁻¹, T₄-RDF + gypsum @ 250 kg ha⁻¹, T₅-RDF + lime @ 75 kg ha⁻¹, T₆-RDF + lime @ 150 kg ha⁻¹, T₇-RDF + dolomite @ 125 kg ha⁻¹, T₈-RDF + dolomite @ 250 kg ha⁻¹, T₉-RDF + calcium nitrate Ca (NO₃)₂ foliar application @ 5 g L⁻¹, T₁₀-RDF + calcium nitrate Ca (NO₃)₂ foliar application @ 7.5 g L⁻¹. Note: RDF: 250:250:250 N:P₂O₅:K₂O kg ha⁻¹ was common for all treatments except control. Foliar application @ 30 DAT, 60 DAT. In T₂ treatment phosphorous was applied through SSP and DAP.

Quality parameters

Ascorbic acid content (mg 100 g⁻¹)

The ascorbic acid content was estimated titrimetrically using 2, 6 Dichlorophenol indophenol dye as per modified procedure of A.O.A.C., 1999 [3].

Five grams of fresh fruit juice was taken and diluted to a known volume with four per cent oxalic acid. This was filtered through muslin cloth to get a clear juice. Further, five ml of aliquot titrated against 2, 6-Dichlorophenol indophenol dye. The result expressed as mg of ascorbic acid per 100 g of fruit juice (Srivastava and Singh, 1993) [23].

$$\text{Ascorbic acid (mg 100 g}^{-1}\text{)} = \frac{\text{Titre value} \times \text{Dye factor} \times \text{Volume made up}}{\text{Volume of filtrate taken} \times \text{Wt. or volume of sample taken}} \times 100$$

Lycopene content (mg 100 g⁻¹)

The lycopene content of tomato fruit was analyzed by using the procedure outlined by Ranganna (1986) [19].

One gram of blended fruit sample taken into a mortar and pulp was extracted repeatedly with acetone until the residue turned colorless. The acetone extract was transferred to a separating funnel containing 10 to 15 mL of petroleum ether and mixed gently. Carotenoid pigments were taken into the petroleum ether layer by diluting the acetone with water. The petroleum ether-containing pigment was transferred to a 25 mL volumetric flask and diluted to mark with petroleum ether. Further, one ml of aliquot was diluted to 10 mL again with petroleum ether, and absorbance or OD was read in a spectrophotometer at 530 nm. Lycopene content (mg 100 g⁻¹) in fruit calculated by using the formula

$$\text{Lycopene content (mg 100 g}^{-1}\text{)} = \frac{3.1206 \times \text{OD of sample} \times \text{Volume made up} \times \text{Dilution}}{\text{Weight of sample} \times 1000} \times 100$$

Total soluble solids (o Brix)

Total soluble solids (TSS) of tomato measured as stated by Dong *et al.* (2001) [8]. One to two drops of the tomato juice extract were prepared and placed on the prism of the digital refractometer, and TSS was measured in ° Brix

Percentage of fruits affected with blossom end rot

The number of fruits infested by blossom end rot was recorded from the five marked plants in each treatment.

$$\text{BER Incidence (\%)} = \frac{\text{Number of fruits showing BER per plant}}{\text{Total number of fruits per plant}} \times 100$$

Disease infection percentage

Table 1: The disease infection percentage of late blight disease was recorded by using

Disease percent (%)	Severity symptom for whole plant assay
0	No visible symptoms apparent
0.01-10	A few minute lesions to about 10% of the total leaf area is blighted and usually confined to the 2 bottom leaves
10.01-25	Leaves on about 25% of the total plant area are infected
25.01-40	Leaves on about 50% of the total plant area are infected
40.01-60	Leaves on about 75% of the total plant area are infected
>60.01	Leaves on whole plant are blighted and plant is dead

Statistical analysis

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984). Statistical analysis conceded by taking the average of five plants from each plot. The level of significance used in “F” was $P = 0.05$. Critical difference (CD) values were calculated for the $P = 0.05$ whenever the “F” test was found significant. The significance of difference among means was compared by using Duncan’s Multiple Range Test (DMRT).

Results and Discussion

Ascorbic acid content

The data revealed that treatment T_4 (gypsum @ 250 kg ha⁻¹ with RDF) recorded higher ascorbic acid content of 96.84 mg 100 g⁻¹ followed by T_{10} (foliar application of calcium nitrate (Ca (NO₃)₂) @ 7.5 g L⁻¹) and T_8 (dolomite @ 250 kg ha⁻¹ with RDF) with the values of 91.85 and 90.48 mg 100 g⁻¹ (all three treatments are statistically at on par) which are significant over rest of the treatments. Further, T_1 (control) registered less ascorbic acid content (61.72 mg 100 g⁻¹). Nevertheless, treatments T_9 (85.34 mg 100 g⁻¹), T_6 (83.22 mg 100 g⁻¹), and T_3 (80.47 mg 100 g⁻¹) are on par with

other, similarly leftover treatments T_7 (77.35 mg 100 g⁻¹), T_5 (75.54 mg 100 g⁻¹) and T_2 (73.28 mg 100 g⁻¹) are on par among themselves.

Lycopene content

Significantly highest lycopene content was recorded in the treatment receiving gypsum @ 250 kg ha⁻¹ along with RDF (T_4 -7.31 mg 100 g⁻¹) followed by treatment T_{10} (6.88 mg 100 lowest lycopene content. Interestingly rest of the treatments were on par with T_1 (control).

Total soluble solids

The soil application of gypsum @ 250 kg ha⁻¹ + RDF (T_4) significantly recorded the highest total soluble solids (5.10 °brix) followed by treatments (except control all received RDF) T_9 (foliar spray of 5 g L⁻¹ Ca (NO₃)₂), T_6 (lime @ 150 kg ha⁻¹), T_3 (gypsum @ 125 kg ha⁻¹), T_7 (dolomite @ 125 kg ha⁻¹), T_5 (lime @ 75 kg ha⁻¹) and T_2 (gypsum @ 125 kg ha⁻¹) with the values of 4.37, 4.23, 4.17, 4.02, 3.96 and 3.90 °brix, respectively). However, treatment T_{10} (4.76 °brix) and T_8 (4.44 °brix) were on par with T_4 (5.10 °brix). Further, the control (T_1) treatment registered the lowest TSS content (3.02 °brix).

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

Treatments	Quality parameters		
	Ascorbic acid content (mg/100 g)	Lycopene content (mg/100 g)	TSS (°brix)
T_1 : Control	61.72 ^a	4.91 ^a	3.02 ^a
T_2 :RDF	73.28 ^b	5.60 ^a	3.90 ^a
T_3 : RDF + gypsum @ 125 kg ha ⁻¹	80.47 ^{bc}	5.94 ^{ab}	4.17 ^{ab}
T_4 : RDF + gypsum @ 250 kg ha ⁻¹	96.84 ^e	7.31 ^c	5.10 ^c
T_5 : RDF + lime @ 75 kg ha ⁻¹	75.54 ^{bc}	5.78 ^{ab}	3.96 ^a
T_6 : RDF + lime @ 150 kg ha ⁻¹	83.22 ^{bcd}	6.15 ^{ab}	4.23 ^{ab}
T_7 : RDF + dolomite @ 125 kg ha ⁻¹	77.35 ^{bc}	5.91 ^{ab}	4.02 ^a
T_8 : RDF + dolomite @ 250 kg ha ⁻¹	90.48 ^{de}	6.74 ^{bc}	4.44 ^{abc}
T_9 : RDF + calcium nitrate Ca (NO ₃) ₂ foliar application @ 5 g L ⁻¹	85.34 ^{cd}	6.23 ^{ab}	4.37 ^{ab}
T_{10} : RDF + calcium nitrate Ca (NO ₃) ₂ foliar application @ 7.5 g L ⁻¹	91.85 ^{de}	6.88 ^{bc}	4.76 ^{bc}
S.Em±	3.57	0.34	0.22
CD @ 5%	11.43	1.08	0.72

Physiological disorder

Blossom end rot (%)

Significantly, the minimum percentage of blossom end rot (4.42%) was recorded in T_4 treatment (gypsum @ 250 kg ha⁻¹ + RDF) followed by treatment T_{10} (4.73%) applied with RDF + foliar Ca (NO₃)₂ @ 7.50 g L⁻¹ and T_8 (RDF + dolomite at 250 kg ha⁻¹) with BER of 4.93 per cent. Further, control treatment registered a maximum BER of 9.90 per cent. However, the physiological disorder of tomato (BER) found its incidence in the descending order of treatments T_4 (4.42%) < T_{10} (4.73%) < T_8 (4.93%) < T_9 (5.19%) < T_6 (5.36%) < T_3 (5.45%) < T_7 (5.61%) < T_5 (5.82%) < T_2 (6.04%) < T_1 (9.90%) (Fig. 1).

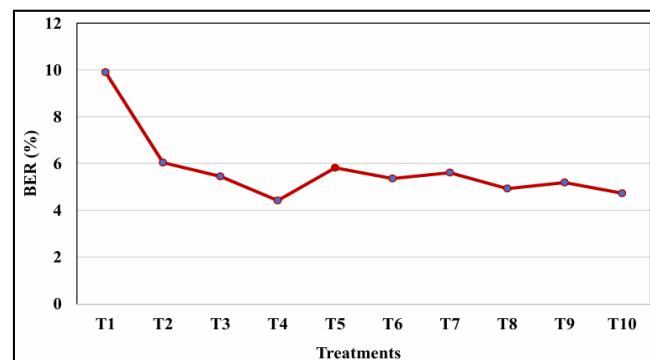


Fig 1: Calcium sources application on blossom end rot of tomato.



Plate 1: Calcium sources application on tomato blossom end rot

Late blight diseases of tomato

The different rates with different sources of calcium application to tomato significantly reduced the late blight disease infection at 30, 45, and 60 DAT indicated in fig. 2.

The lower disease infection percentage of 0.00, 10, and 23.33 per cent, respectively, were observed in treatment T₄ (gypsum @ 250 kg ha⁻¹ + RDF) followed by T₈ (dolomite @ 250 kg ha⁻¹ + RDF) with infection percent of 0, 11.67 and 25 per cent, respectively. Significantly high infection, was

recorded in control T₁ (10, 26.67 and 46.53%, respectively) compared to other treatments. Further, the late blight disease infection in tomato plant increased with the advancement of the crop growing period (from 30 to 60 DAT). The increase in disease infection was very prominent in control (from 10.00 to 46.53%, respectively), followed by T₇ (from 0.00 to 38.33%, respectively), T₆ (from 0.00 to 35%, respectively), and T₂ (from 6.67 to 40%).

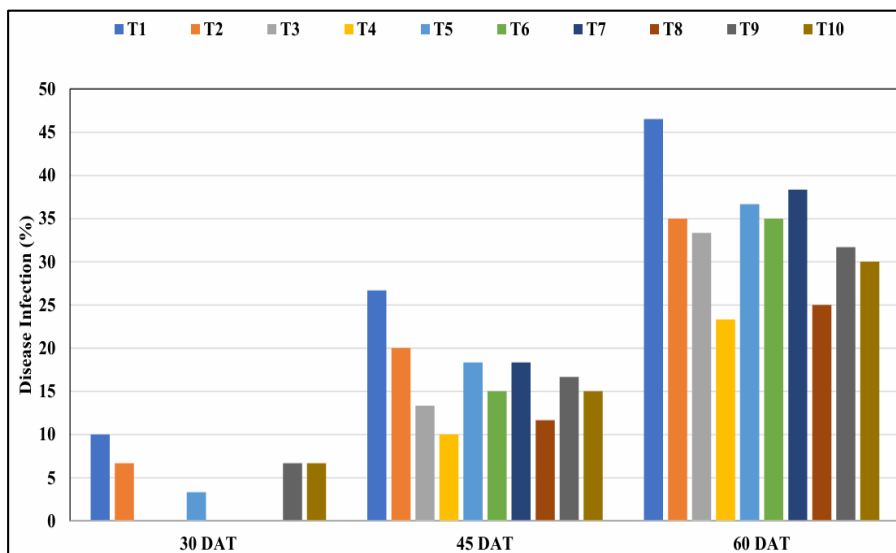


Fig 2: Calcium sources application on late blight diseases at different growth stages of tomato

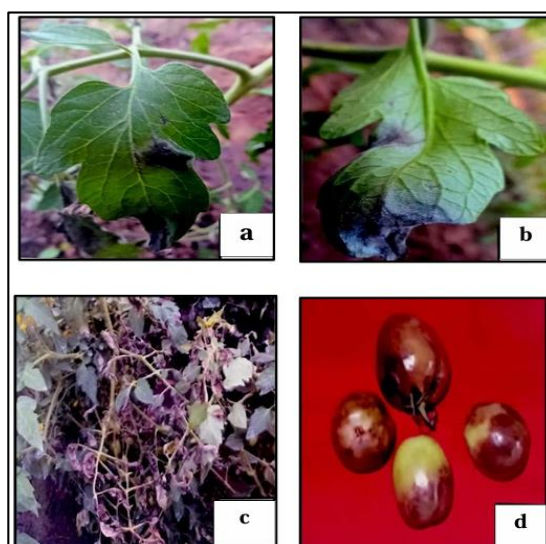


Plate 2: Effect of different sources and levels of calcium on late blight disease of tomato

Discussion

The present study revealed that supplementation of calcium through different sources significantly enhanced fruit quality attributes and reduced the incidence of major physiological and pathological disorders in tomato. Among all the treatments evaluated, application of gypsum @ 250 kg ha⁻¹ along with recommended dose of fertilizers (RDF) (T₄) proved most effective and consistently recorded superior performance in terms of ascorbic acid content, lycopene concentration, total soluble solids, reduced blossom end rot incidence and lower late blight severity. This was closely followed by foliar application of calcium nitrate @ 7.5 g L⁻¹ (T₁₀) and dolomite @ 250 kg ha⁻¹ with RDF (T₈). The overall trend clearly indicates the pivotal role of calcium nutrition in improving fruit quality and maintaining plant health in tomato.

The enhancement in ascorbic acid content under calcium-applied treatments may be associated with the protective effect of calcium on cellular membranes and its role in minimizing oxidative degradation of vitamin C during fruit development and ripening. Calcium is known to preserve membrane stability, delay senescence and maintain metabolic balance, thereby favouring retention of antioxidant compounds in fruits. In addition, the combined application of RDF with calcium sources may have promoted nitrogen uptake and protein synthesis, which are essential for enzymatic processes involved in ascorbic acid biosynthesis. The highest values recorded under gypsum application may further be due to its gradual solubility and sustained supply of calcium in the root zone. Similar observations were reported by Tejashvini (2017) [24].

Lycopene, the principal carotenoid responsible for red colour development in tomato fruits, was also significantly increased under calcium treatments. Improved lycopene synthesis under gypsum, dolomite and calcium nitrate application may be attributed to enhanced nutrient uptake, better ripening metabolism and activation of enzymes associated with carotenoid biosynthesis. Calcium also helps in maintaining cellular integrity during ripening, thereby supporting uninterrupted pigment accumulation. Moreover, sulphur supplied through gypsum and magnesium through dolomite may have contributed to chlorophyll synthesis and photosynthate production, indirectly favouring carotenoid formation. These findings are in agreement with Hareram *et al.* (2017) [11].

The increase in total soluble solids under calcium fertilization indicates improved carbohydrate metabolism and greater accumulation of soluble sugars in fruits. Calcium is known to regulate membrane permeability and facilitate efficient translocation of assimilates from source leaves to developing fruits. Consequently, fruits from calcium-treated plants recorded higher °Brix values than the control. In the case of gypsum-treated plots, improved soil physical properties and enhanced root proliferation may also have supported better nutrient absorption and photosynthetic efficiency. Magnesium supplied through dolomite, being a structural component of chlorophyll, might have additionally enhanced sugar synthesis. Similar findings were earlier documented by Kazemi (2014) [13] and Tejashvini (2017) [24].

A marked reduction in blossom end rot incidence due to calcium application further confirms the essential role of calcium in fruit tissue development. Blossom end rot is mainly caused by inadequate calcium supply to rapidly

enlarging fruit tissues, leading to membrane disintegration, cellular leakage and tissue necrosis at the distal end of fruits. Adequate calcium availability through gypsum, dolomite and foliar calcium nitrate may have ensured proper calcium transport to developing fruits, thereby preventing physiological breakdown. The minimum BER incidence under gypsum treatment suggests continuous calcium availability throughout fruit growth. Similar results were reported by Hao and Papadopoulos (2003) [10], Smit and Combrink (2005) [22] and Bharathkumar *et al.* (2020) [5].

The lower incidence of late blight disease observed under calcium-treated plants indicates that calcium also contributes to enhanced disease resistance. Calcium strengthens cell walls through formation of calcium pectate, thereby reducing pathogen penetration and tissue maceration. In addition, calcium acts as a secondary messenger in several plant defense signaling pathways and activates resistance responses against invading pathogens. Lower disease severity under gypsum and dolomite treatments may therefore be attributed to sustained calcium supply and improved plant vigor. Although disease incidence increased progressively with crop age, calcium-treated plants maintained significantly lower infection levels compared to the untreated control. These findings corroborate the reports of Perombelon and Kelman (1980) [18] and Demarty *et al.* (1984) [6].

Overall, the findings of the present investigation demonstrate that calcium nutrition exerts a multifaceted beneficial effect in tomato by improving biochemical quality parameters, minimizing blossom end rot and reducing late blight incidence. Among the different sources tested, soil application of gypsum @ 250 kg ha⁻¹ along with RDF emerged as the most effective treatment and may be considered a promising nutrient management strategy for enhancing tomato fruit quality, marketability and crop health under field conditions.

Conclusion

The present study highlighted soil application of gypsum at 250 kg ha⁻¹ in conjunction with recommended fertilizers and FYM was found to be the most effective treatment for enhancing tomato fruit quality and reducing physiological and disease-related constraints under *Alfisol* conditions. This treatment significantly improved quality attributes, including total soluble solids, ascorbic acid, and lycopene content, thereby increasing fruit acceptability and market value. The incidence of blossom end rot was markedly reduced, indicating improved calcium availability in developing fruits. Furthermore, reduced late blight occurrence reflected better plant health. Overall, optimum calcium supply through gypsum ensured superior fruit quality, minimized physiological disorders and disease incidence, and improved marketable yield.

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Conflict of Interest

The author declares that there is no conflict of interest.

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