https://doi.org/10.56093/ijas.v90i6.1047796

*Indian Journal of Agricultural Sciences* **90** (6): 1176–9, June 2020/Article

# Effect of calcium and boron on biomass yield and nutrients uptake by tomato (*Solanum lycopersicum*)

AJIN S ANIL, V K SHARMA*, MANDIRA BARMAN, S P DATTA, K K BANDYOPADHYAY, P K SINGH and KAPIL A CHOBHE

*ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India*

Received: 02 September 2019; Accepted: 18 September 2019

ABSTRACT

A pot experiment was conducted in acid soil (Alfisol) using four levels of lime ($CaCO_3$) based on lime requirement (LR), viz. 0, 1/3, 2/3, and 1 and four levels of boron (B), viz. 0, 1.0, 1.5 and 2 mg/kg to evaluate the effect of applied calcium (Ca) and boron (B) on biomass yield, nutrient uptake of tomato (*Solanum lycopersicum* L.) and soil properties. The results indicated that application of Ca @ 2/3 LR and 1 LR significantly increased biomass yield of tomato by 21% and 16%, respectively over control. Boron application @ 1.0 mg/kg recorded highest biomass yield (19.6 g/pot) of tomato as compared to other boron treatments. Applied Ca @ 2/3 LR significantly increased the uptake of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulphur (S), zinc (Zn) and copper (Cu), whereas iron (Fe), manganese (Mn) and B uptake increased only up to Ca @ 1/3 LR treatment. Application of B increased the nutrients uptake over control, whereas it was observed significantly higher with B @ 1.5 mg/kg treatment. Applied Ca significantly enhanced the pH and available Ca in post-harvest soil, whereas salicylic acid extractable boron (SAE-B) was declined. The combined application of calcium @ 2/3 LR and B @ 1.5 mg/kg was most effective in enhancing the yield and nutrient uptake of tomato.

**Key words**: Alfisol, Boron, Lime, Nutrient uptake, Tomato

Boron (B) is the second most deficient micronutrient in acid soils of total cultivable area of India. Availability of B is generally low in acid soils of high rainfall areas, because of its leaching and adsorption by aluminium (Al) and iron (Fe) oxide minerals (Barman *et al.* 2014). About 100 M ha land in India suffer from soil acidity of which about 49 M ha, *i.e.* 34% is cropped land (Maji *et al.* 2012). Addition of liming materials to acid soils is a common practice to raise the pH, decrease Al and Fe toxicity and increase calcium (Ca) and magnesium (Mg) concentration in soils. However, this practice further decreases B availability due to its adsorption on freshly precipitated Al and Fe hydroxides (Tsadilas *et al*. 2005). Beside B deficiency, Ca deficiency is also predominantly seen in acid soils. Calcium has close relationship with B, both in soil and plant. It increases B requirement of plants due to similarity in function and reduces availability of B in soil due to the formation of Ca-metaborate complex and antagonistic relationship existing between Ca and B (Tsadialas *et al*. 2005). As liming lead to significant changes in soil properties and these influences the adsorption-desorption behavior of B in soil (Sarkar *et al*. 2015). Presence of $CaCO_3$ in soils increases B fixation through rise in soil pH and adsorption (Barman *et al*. 2014). Boron deficiency causes large losses in crop production and grain quality. Tomato (*Solanum lycopersicum* L.) is one of the major vegetable crop grown worldwide which require adequate amount of Ca and B for sustainable production.

In recent years, the dose of lime is significantly reduced and commonly applied to the tunes of 1/2 – 1/10$^{th}$ of the lime requirement (LR) due to uneconomical and unsustainable practice of full dose of LR. The availability of B in Alfisol at lower levels of applied lime in Jharkhand is scanty. Therefore, present study was undertaken to optimize the dose of Ca and B fertilizer for better plant growth and nutrients uptake and their interactive effect on biomass yield of tomato in acid soil.

## MATERIALS AND METHODS

The greenhouse pot experiment on tomato was conducted during 2017-18 using bulk acid surface soil (0-15 cm) of Alfisol from Ranchi, Jharkhand with three replications in completely randomized design. Soil was sandy clay loam in texture. The initial chemical characteristics of soil, viz. *p*H 4.24, electrical conductivity 0.09 ds/m (1:2.5 soil: water suspension), soil organic carbon (0.23%), available-N (78 kg/ha), available-P (12.1 kg/ha), available-K (317 kg/ha), available-Ca (287 kg/ha), available-Mg (108 kg/ha), Salicylic acid extractable B (0.17 kg/ha) and DTPA

*Corresponding author e-mail: vksharma.iari@gmail.com

extractable Zn, Cu, Fe and Mn were 3.50, 6.80, 20.4, and 7.50 mg/kg, respectively. The soil had a cation exchange capacity (CEC) of 13.2 [cmol ($p^+$)/kg] and LR of 3.40 (tonnes/ha).

The experiment comprised four levels of lime, viz. 0, 1/3, 2/3, and 1 of LR and four levels of B; 0, 1.0, 1.5 and 2 mg/kg. Lime and B were applied in the form of $CaCO_3$ and borax ($Na_2B_4O_7$. 10 $H_2O$) respectively. Pots were fertilized using recommended dose of N, P and K (100: 80: 80) through urea, diammonium phosphate and muriate of potash. The tomato (var. Pusa Gaurav) was transplanted (2 plants/pot) on October 11 and experimental pots were kept in green house. The biological yield was recorded at flowering stage and plant samples were also collected at same stage for estimating the uptake of nutrients by plants. The samples were ground and processed samples were analyzed for their nutrient contents by digesting the samples using di-acid mixture of $HNO_3$: $HClO_4$ (10:4) followed by estimation of Zn, Fe, Mn, Cu, Ca and Mg using an AAS. Phosphorus, K and S were determined by vanadomolybdo phosphoric yellow colour method, flame photometer (Jackson 1973) and turbidimetric method (Chesnin and Yien 1951), respectively. Nitrogen content in plant samples were determined by Kjeldahl method as described by Jackson (1973). Boron was analyzed through Azomethine-H method (John *et al*. 1975). The uptake of nutrients by tomato crop was calculated by multiplying their content values with corresponding yield. After harvesting of the crop, soil samples were collected and analyzed for *p*H (suspension using combined electrode by digital *p*H meter), EC (conductivity bridge) and available Ca and B by Jackson (1973). Analyses of variance method was followed to assess the effect of lime and B application on available boron content, boron uptake and biomass yield of tomato adopting factorial concept through completely randomised design (Snedecor and Cochran 1967).

Table 1 Effect of calcium and boron application on biomass yield (g/pot) of tomato and selected soil properties of post-harvest soil

| Treatment | Biomass yield (g/pot) | *p*H | EC (dS/m) | Amm-Ca (mg /kg) | SAE-B (mg/ kg) |
|---|---|---|---|---|---|
| *Levels of Ca (LR)* | | | | | |
| 0 | 15.9 | 5.22 | 0.19 | 241 | 0.35 |
| 1/3 | 18.9 | 6.27 | 0.20 | 327 | 0.32 |
| 2/3 | 19.3 | 6.84 | 0.21 | 566 | 0.31 |
| 1.0 | 18.5 | 7.19 | 0.23 | 834 | 0.29 |
| SEm (±) | 0.17 | 0.13 | 0.02 | 13.1 | 0.01 |
| CD (P=0.05) | 0.49 | 0.39 | NS | 37.9 | 0.03 |
| *Levels of boron (B), mg/kg* | | | | | |
| 0 | 15.7 | 6.49 | 0.20 | 491 | 0.16 |
| 1 | 19.6 | 6.38 | 0.20 | 513 | 0.30 |
| 1.5 | 19.4 | 6.34 | 0.21 | 489 | 0.38 |
| 2 | 18.1 | 6.30 | 0.22 | 476 | 0.43 |
| SEm (±) | 0.17 | 0.13 | 0.02 | 13.1 | 0.01 |
| CD (P=0.05) | 0.49 | NS | NS | NS | 0.03 |
| L × B | 0.99 | NS | NS | 75.8 | NS |

LR* = Lime requirement

## RESULTS AND DISCUSSION

*Biomass yield*: Application of different levels of Ca resulted significant improvement in the biomass yield of tomato over control (Table 1). The significantly higher biomass yield of tomato (19.3 g/pot) was recorded with application of Ca at 2/3 LR being 21.4 % higher over control (15.9 g/pot), but treatment applied Ca @ 1/3 LR (18.9 g/pot) was statistically at par with applied 2/3 LR (19.3 g/pot) and 1.0 LR (18.5 g/pot). Application of Ca reduced to the tune of 4.3% under higher dose of Ca @ 1.0 LR (18.5 g/pot) over Ca @ 2/3 LR treatment (19.3 g/pot). Application of B improved the biomass yield significantly over control. Significant highest biomass yield (19.6 g/pot) of tomato was obtained with application of B @ 1.0 mg/kg as compared to control but at par with application of B @ 1.5 mg/kg which increased by 24% and 23% higher respectively over control. However, biomass yield of tomato under different treatments of B was decreased as compared to application of B @ 1.0 mg/kg. The result indicated that interactive effect of Ca (LR) and applied B on the biomass yield was significant. Significantly higher biomass yield (21.3 g/pot) of tomato was recorded under combined application of Ca @ 2/3 LR and B @ 1.5 mg/kg, which was statistically similar to Ca @ 2/3 LR and B @ 1.0 mg/kg treatment combination. Barman *et al.* (2014) also reported that increasing dose of Ca and B from different sources significantly increased the growth and yield of the crop, whereas with application of Ca @ 1 LR decreased the yield due to the deficiency of applied boron (Karakurt *et al.* 2009).

*Uptake of nitrogen, phosphorus and potassium*: All calcium treatments, *i.e.* Ca @ 1/3 LR, 2/3 LR and 1.0 LR significantly differed in N, P and K uptake by tomato plant. Application of Ca @ 2/3 LR recorded significantly higher N, P and K uptake (640, 38.6 and 611 mg/pot) by tomato plant at flowering stage as compared to other treatments (Table 2). However, applied Ca @ 1.0 LR was statistically at par with treatments of Ca @ 1/3 LR and 2/3 LR in respect of N and P uptake. As regards the K uptake, application of Ca @ 1/3 (586 mg/pot) and 1 LR (555 mg/pot) were statistically similar to each other. However, N, P and K uptake were slightly decreased under applied Ca @ 1.0 LR treatment compared to Ca @ 2/3 LR treatment. Boron treatments like 1.0 mg/kg and 1.5 mg/kg recorded statistically similar N, P and K uptake but significantly higher as compared to B @ 2.0 mg/kg and control except P uptake, which showed non-significant response between B treatments. Interactive effect of Ca and B on N and P uptake by tomato plant at flowering stage was non-significant however, it was significant for K uptake. Barman *et al.* (2014) also reported the enhanced concentration of N in sunflower as a result of supply of Ca and B at different doses. Most of the studies related with application of Ca through lime in acid soils indicate

Table 2 Effect of calcium and boron application on nutrient uptake (mg/pot) by tomato at flowering stage

| Treatment | Macro nutrients | | | | | | Micro nutrients | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | Ca | Mg | S | Fe | Mn | Zn | Cu | B |
| *Levels of Ca (LR*)* | | | | | | | | | | | |
| 0 | 506 | 27.3 | 478 | 400 | 110 | 45.8 | 5.98 | 5.56 | 0.72 | 0.25 | 557 |
| 1/3 | 616 | 36.5 | 586 | 512 | 157 | 84.0 | 6.61 | 3.95 | 1.06 | 0.34 | 591 |
| 2/3 | 640 | 38.6 | 611 | 547 | 177 | 94.5 | 6.41 | 2.96 | 1.14 | 0.38 | 516 |
| 1.0 | 625 | 34.0 | 555 | 563 | 164 | 65.3 | 6.70 | 2.32 | 1.06 | 0.34 | 468 |
| SEm (±) | 9.6 | 2.3 | 8.8 | 21.2 | 6.20 | 2.0 | 0.15 | 0.13 | 0.02 | 0.02 | 15.2 |
| CD (P=0.05) | 27.8 | 6.6 | 25.4 | 61.4 | 17.9 | 5.9 | 0.44 | 0.38 | 0.05 | 0.05 | 44.1 |
| *Levels of boron (B), mg/kg* | | | | | | | | | | | |
| 0 | 506 | 29.4 | 448 | 448 | 128 | 50.2 | 5.61 | 3.24 | 0.84 | 0.31 | 266 |
| 1 | 645 | 37.5 | 621 | 539 | 159 | 79.7 | 6.75 | 4.26 | 1.07 | 0.36 | 550 |
| 1.5 | 648 | 36.4 | 617 | 554 | 164 | 83.1 | 6.82 | 3.90 | 1.06 | 0.34 | 665 |
| 2 | 589 | 33.2 | 545 | 481 | 157 | 76.6 | 6.54 | 3.39 | 1.01 | 0.31 | 652 |
| SEm (±) | 9.6 | 2.3 | 8.8 | 21.2 | 6.20 | 2.0 | 0.15 | 0.13 | 0.02 | 0.02 | 15.2 |
| CD (P=0.05) | 27.8 | NS | 25.4 | 61.4 | 17.9 | 5.9 | 0.44 | 0.38 | 0.05 | NS | 44.1 |
| LR × B | NS | NS | 50.7 | NS | NS | 11.8 | NS | 0.75 | NS | NS | 88.2 |

LR* = Lime requirement

a positive effect of liming in plant P uptake (Kulhavy *et al.* 2009). However, some researchers reported that there was negative relationship in P uptake in plant when applied with Ca (Tariq and Mott 2007). Our findings were similar with Barman *et al*. (2014) that P uptake in plant was neither affected by Ca nor by applied B.

*Uptake of calcium, magnesium and sulphur*: Highest Ca uptake (563 mg/pot) with Ca @ 1 LR and Mg (177 mg/pot) and S (94.5 mg/pot) uptake under Ca @ 2/3 LR was recorded (Table 2). Increasing rates of Ca increased the Ca uptake at flowering stage from 512 mg/pot (1/3 LR) to 563 mg/pot (1 LR). Whereas, Mg (177 mg/pot) and S (94.5 mg/pot) uptake was significantly increased up to 2/3 LR over 1/3 LR treatment. The Mg (164 mg/pot) and S (65.3 mg/pot) uptake decreased at higher dose of Ca, *i.e.* 1 LR. All treatments of Ca showed non-significant difference with each other for Ca uptake but Mg and S uptake in Ca @ 2/3 LR was significantly different from Ca @1/3 LR and all other Ca treatments respectively. Significantly higher Ca (554 mg/pot) and S uptake (83.1 mg/pot) by tomato plant was recorded under application of B @ 1.5 mg/kg as compared to applied B @ 2.0 mg/kg. Whereas, applied B @ 1.5 mg/kg recorded significantly higher Mg uptake over control but similar to rest of the two treatments, *i.e.* B @ 1 and 2 mg/kg. Interactive effect of applied Ca and B on Ca uptake and Mg uptake by tomato plant was non-significant but it was significantly higher for S uptake. Barman *et al*. (2014) also found that increase dose of lime increase the Ca, Mg and S uptake by sunflower. Higher dose of B improve Ca uptake due to interactive effects.

*Uptake of iron, manganese, zinc and copper*: Significantly higher Fe uptake was observed under Ca @ 1 LR treatment followed by 1/3, 2/3 and control (Table 2). Increasing rates of Ca significantly decreased the Mn uptake from 5.56 mg/pot (control) to 2.32 mg/pot (Ca @ 1.0 LR) to the tune of 58.3% over control. Significant highest Zn uptake (1.14 mg/pot) was recorded with Ca @ 2/3 LR as compared to other treatments of Ca, while Ca @ 1/3 LR and 1.0 LR gave similar uptake of Zn by tomato plant at flowering stage. All treatments of Ca recorded significantly higher Zn uptake by tomato (1.06-1.14 mg/pot) as compared to control (0.72 mg/pot). Copper uptake by tomato plant was decreased at applied Ca @ 1.0 LR (346 µg/pot) as compared to applied Ca @ 2/3 LR (389 µg/pot). The highest Cu uptake (389 µg/pot) was observed under applied Ca @ 2/3 LR treatments as compared to other treatments. All treatments of applied Ca were statistically at par with each other in respect of Cu uptake by tomato plant.

Iron uptake was significantly increased under all the applied B treatments over control and found statistically similar to each other. Significantly higher Fe uptake (6.82 mg/pot) was recorded with B @ 1.5 mg/kg treatment as compared to control. The Mn uptake (4.26 mg/pot) was significantly increased with applied B @ 1.0 mg/kg over control and thereafter, decreasing trend was observed with increase the rates of B (from 4.26 to 3.39 mg/pot). Boron treatments @ 1.0 mg/kg (4.26 mg/pot) and @ 1.5 mg/kg (3.90 mg/pot) were statistically similar to each other and significantly higher over applied B @ 2.0 mg/kg. Zinc uptake by tomato plant ranged from 0.84 mg/pot (control) to 1.07 mg/pot (B @ 1.0 mg/kg) under applied B treatments and all treatments of B recorded significantly higher Zn uptake as compared to control. Higher Cu uptake (0.36 mg/pot) by tomato plant was recorded in applied B @ 1.0 mg/kg as compared to other treatments of B. Application of B @ 0 mg/kg recorded similar results as Cu uptake to the 2.0 mg/kg treatment. Interaction of Ca and B was statistically significant for Mn uptake only. Similar results were presented by Anetor and Akinrinde (2006) and Tariq and Mott (2007).

*Uptake of boron*: Application of Ca @ 1/3 LR increased the B uptake by tomato plant to the tune of 6.1% over control, whereas it was significantly decreased to the tune of 12.6% and 20.8% at applied Ca @ 2/3 LR and @ 1.0 LR treatments, respectively over applied Ca @ 1/3 LR treatment (Table 2). Significant highest B uptake (591 µg/pot) by tomato plant was recorded under applied Ca @ 1/3 LR over applied Ca @ 1.0 LR (468 µg/pot). Among applied B treatments, applied B @ 1.5 mg/kg significantly increased the B uptake by tomato plant to the tune of 20.1% over applied B @ 1.0 mg/kg, while applied B @ 1.5 mg/kg (665 µg/pot) and @ 2.0 mg/kg (652 µg/pot) were statistically similar in B uptake. Similar negative effect of Ca on the plant B concentration was reported by Chaudhuary and Debnath (2008). Several workers have observed negative correlation between soil *p*H and B uptake.

*Selected soil properties of post-harvest soil*: Soil *p*H increased significantly with increasing levels of Ca from 5.22 (control) to 7.19 (Ca @ 1 LR), whereas there was no significant difference in this parameter due to different levels of B (Table 1). There was no significant change in EC with application of different levels of Ca (LR) and B in post-harvest soil. The findings were in line with those of Barman *et al.* (2014). Available Ca in post-harvest soil was significantly increased (241 to 834 mg/kg) with increasing levels of Ca (Table 1). However, increasing rate of applied B reduced the availability of Ca from 513 to 476 mg/kg in post-harvest soil. Interaction effect of Ca and B on available Ca content in soil was significant. The considerable increase in available Ca content in soil with increased levels of Ca may be explained on the basis of differential amount of Ca added through various treatments. The result validated the work done by Tariq and Mott (2006), which showed the positive correlation of available Ca concentration in soil solution with increasing levels of applied Ca and B. Higher salicylic acid extractable B (0.35 mg/kg) in post-harvest soil was found in control treatment as compared to other Ca treatments (Table 1). Salicylic acid extractable B (SAE-B) of post-harvest soil was significantly declined under Ca @ 1.0 LR (0.29 mg/kg) over control (0.35 mg/kg), which was statistically at par with Ca @ 2/3 LR (0.31 mg/kg) and 1/3 LR (0.32 mg/kg). The application of different B rates significantly increased the SAE-B from 0.16 mg/kg (control) to 0.43 mg/kg (B @ 2.0 mg/kg). Interaction of Ca and B on SAE-B in post-harvest soil was non–significant. The negative effect of applied Ca on SAE-B in soil has been reported earlier by several researchers (Chaudhuary and Debnath 2008 and Barman *et al.* 2014)

Based on present study it may be concluded that the combined application of Ca @ 2/3 LR and B @ 1.5 mg/kg significantly enhanced the biomass yield, nutrient uptake and also improved the soil *p*H with availability of Ca. The SAE-B of post-harvest soil was significantly decreased under Ca applied @ 1.0 LR and increased with increasing levels of B. Thus combined application of Ca @ 2/3 LR and B @ 1.5 mg/kg was most effective in enhancing the biomass yield and nutrient uptake of tomato.

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