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Effect of calcium, boron and their interactions on quality of hybrid tomato (*Solanum lycopersicum*. L)

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Abstract
The field experiment on "effect of calcium, boron and their interactions on quality of hybrid Tomato (*Solanum lycopersicum* L.)" was conducted during Rabi season of 2018 at College of Sericulture, Chintamani, Karnataka, India. The experiment was laid out in a RCBD design with 9 treatments replicated thrice. Calcium (20 and 30 kg/ha) and boron (10 and 15 kg/ha) alone as wel as combination along with recommended NPK & FYM were applied to soil at the time of planting. The results revealed that application of recommended NPK and FYM along with calcium (30 kg/ha) and boron (10 kg/ha) recorded highest total soluble solids (5.30^0 brix), fruit firmness (3.93 kg/cm²), reduced physiological loss in weight (6.23 %), reduced blossom end rot (9.08 %) reduced and fruit cracking (8.83 %).

Keywords: Calcium, Boron, Quality, Hybrid tomato, Interactions.

Introduction
Tomato (*Solanum lycopersicum*. L) is an important solanaceous fruit vegetable cultivated extensively for its edible fruits of rich in nutritional value. Tomato is a good source of vitamin-c and phyto-chemical lycopene (Anti-oxidant) (Anon, 2017) [2]. Tomato being a heavy feeder and exhaustive crop removes substantial amount of macro and micro-nutrients from soil. Hybrid tomato crop requires more of nutrients for higher yield and quality of fruits and this can be achieved by application of recommended quantity of organic and inorganic nutrients. It is believed that adequate quantities of secondary and micro-nutrients are present in Indian soils and in the past growers were advised to apply required doses of NPK for higher crop yields. Now, it is realized that recommended doses of NPK alone are not sufficient to increase production with quality fruits and thus the need of application of macro and micronutrients has been felt.

The deficiency of secondary and micro-nutrients in soil may affect the yield and quality of tomato. Among the secondary and micronutrients calcium and boron deserves special attention in tomato cultivation. The deficiency of calcium and boron have proved to be a limiting factor in production and quality.

Calcium is the key component of cells holding the structure of cell walls and stabilizing cell membranes. It also has a direct influence on salt balance with in plant cells and activates potassium to regulate the opening and closing of stomata to allow movement of water from the plant. It also enhances and regulates some enzyme systems of cells and conductive tissues. It has key specific influence on tomato fruit quality especially blossom end rot.

Boron plays a vital role in pollen tube growth, pollen germination, flowering, fruiting, photosynthesis, sugar translocation and rooting (Chadha, 2006, Singh *et al*. 2017a; Singh *et al*. 2017b; Singh *et al*. 2017c; Singh *et al*. 2018; Tiwari *et al*. 2018; Tiwari *et al*. 2019a; Tiwari *et al*. 2019b; Kour *et al*. 2019; Singh *et al*. 2019) [5, 17, 18, 19, 20, 21, 22, 23]. But very small quantity of boron is necessary for normal growth and production of most of the vegetable crops. Boron is found to be antagonistic to the uptake of potassium and a few other cations, but favours the absorption of calcium in tomato. Its deficiency causes terminal buds fail to open or abort, fruit cracking and flower drop is a very common in tomato.

Soils of Eastern Dry Zone of Karnataka (Zone 5) are slightly acidic in nature and deficient with calcium and boron. About 60 per cent of soils are deficient with calcium and 80 per cent of soils are deficient with boron. In these soils, farmers are cultivating hybrid tomato throughout the year and it is causing physiological disorders such as blossom end rot and fruit cracking in addition to reduction in yield and quality. There is a need to provide suitable recommendation through line departments to address the problem of tomato growers. This will help in enhancing yield and income of tomato growers.

Material and Methods

The experiment was carried out in the Eastern Dry Zone of Karnataka (Zone-5), in the experimental block of Department of Horticulture, College of Sericulture, Chintamani-563125, Chickkaballapur District, Karnataka. Total rainfall received during the experimentation period from September to February was 154.70 mm. The experiment was laidout in RCBD design with 9 treatments and 3 replications using Arka Rakshak hybrid tomato under standard package of practice. The treatments includes

T1: Control (RDF=NPK-250:250:250 kg/ha + FYM 38 t/ha)
T2: RDF + Soil application of calcium 20 kg/ha
T3: RDF + Soil application of calcium 30 kg/ha
T4: RDF + Soil application of boron 10 kg/ha
T5: RDF + Soil application of boron 15 kg/ha
T6: RDF + Soil application of calcium 20 kg/ha + boron 10 kg/ha
T7: RDF + Soil application of calcium 20 kg/ha + boron 15 kg/ha
T8: RDF + Soil application of calcium 30 kg/ha + boron 10 kg/ha
T9: RDF + Soil application of calcium 30 kg/ha + boron 15 kg/ha
RDF =Recommended dose of fertilizers (NPK-250: 250: 250 kg/ha and FYM 38 t/ha)

Soil of the experimental site was red sandy loamy with randomly rich in fertility having pH of 5.5. The soil samples were collected at depth of 0-30 cm before the initiation of experiment and analysis of samples were subjected for various physical and chemical properties. Experimental soil having sandy loam in texture with acidic pH and medium organic carbon content. Available soil nitrogen, phosphorus and potassium concentrations were low, medium and high with deficient with Calcium, Boron and Sulpur in the soil.

The following quality parameters were recorded by standard procedure prescribed for the same

TSS and firmness of fruits

A drop of tomato juice from each entry was placed on the prism of Brix Hand Refractometer and reading was recorded. The necessary temperature corrections were made to room temperature (28 °C) and expressed in ° brix.

Fruit firmness

The firmness of five randomly selected fruits from each treatment was determined by using Penetrometer by rupturing in six places opposite to each other in radial axis with plunger and required pressure. It was expressed in kilogram per centimeter square.

Physiological loss in weight (PLW)

The physiological loss in weight was recorded at room temperature on 10, 20 and 30 days after harvest and expressed in terms of percentage.

Percentage of fruits affected with blossom end rot and fruit cracking

From the five tagged plants in each treatment, the number of fruits affected with blossom end rot and cracked fruits were recorded.

Results and discussion

Effect of calcium, boron and their interactions on qualitative parameters

Total soluble solids (^{0} brix)

The data on total soluble solids as influenced by application of calcium, boron and their interactions are presented in Table 1. Application of boron alone or in combination with calcium resulted in significant variation in total soluble solids. The maximum total soluble solids were recorded in T8 which received RDF + Soil application of calcium 30 kg/ha + boron 10 kg/ha (5.30 ^{0} brix) followed by T9 which received RDF + Soil application of calcium 30 kg/ha + boron 15 g/ha (5.20 ^{0} brix) and T7 with RDF + Soil application of calcium 20 kg/ha + boron 15 g/ha (5.10 ^{0} brix). The lowest total soluble solids were recorded in control (4^0 brix). The TSS content of fruits is a major quality parameter studied by Ali *et al*., (2004) [1]. Pre-harvest calcium and boron application may affect the chemical composition of fruits (Mahajan and Sharma 2000; Sathya *et al*., 2010) [12, 16]. It was observed that there was no increase in TSS was observed with the application of calcium alone, but boron and calcium were resulted in a significant increase in the TSS content of tomato fruit. This indicates that the interaction of calcium and boron may enhances the TSS content of tomato fruits (Hasan and Jana, 2000) [7]. The results obtained were in close agreement with the research findings of Oyinlola and Chude (2004) [14], Babu Naresh (2002) [3], Jyolsna and Mathew (2008) [9] and Meena (2010) [13].

Fruit firmness (kg/cm^2)

Similar trend was noticed in fruit firmness on application of calcium and boron. The maximum fruit firmness was recorded in T8 which receives RDF + Soil application of calcium 30 kg/ha + boron 10 kg/ha (3.93 kg/ cm^2) followed by T9 which received RDF + Soil application of calcium 30 kg/ha + boron (3.63 kg/ cm^2) and T7 which received RDF + Soil application of calcium 20 kg/ha + boron 15 kg/ha (3.53 kg/ cm^2). However, the lowest fruit firmness was recorded in control (2.0 kg/ cm^2) (Table 1). The results showed that application of calcium and boron were significantly increased the fruit firmness. The combination of both nutrients resulted in higher fruit firmness in T8 (3.93 kg/cm^2). This might be due to involvement of boron not only in promoting calcium metabolism in cell walls, but may also promote cell wall integrity as well as delay in cell wall degradation (Ryden *et al.*, 2003; Lester and Grusak, 2004) [15, 14]. The combined application of both Ca and B may enhance fruit firmness (Smit and Combrink, 2005) [25].

Table 1: Effect of calcium, boron and their interactions on quality parameters of tomato fruits

Treatments	Total soluble solids (°brix)	Fruit firmness (kg/ cm2)
T1	4.00	2.00
T2	4.20	2.17
T3	4.50	2.37
T4	4.80	3.17
T5	4.90	3.33
T6	5.00	3.40
T7	5.10	3.53
T8	5.30	3.93
T9	5.20	3.63
SEm ±	0.30	0.39
CD (5 %)	1.02	1.16

Effect of calcium, boron and their interactions on physiological loss in weight (%) (PLW)

The data on physiological loss in weight at 10, 20 and 30 days after harvest as influenced by soil application of calcium, boron and their interaction effects are presented in Table 2. A significant variation in physiological loss in weight was observed among the treatments. After ten days of harvesting lowest per cent of PLW was recorded in T8 (6.23 %) which was on par with the T9 (7.36 %), T7 (7.84 %) and T6 (8.26 %), and higher per cent of physiological loss in weight was indicated in control (12.05 %). At 20 days after harvest physiological loss in weight was varied significantly among the treatments. Whereas lowest per cent of PLW of fruits was recorded in T8 (16.06 %) and it is on par with T9 (16.38 %), T7 (17.68 %) and T6 (18.62 %) compared to control (21.73 %). Similarly, after 30 days of harvest, significant variation was observed for PLW among treatments. Treatment T8 (28.05 %) recorded the lowest per cent of physiological loss in weight and it is on par with T9 (29.31 %), T7 (28.18 %) and T6 (36.21 %) compared to control (45.73 %).

The combined application of calcium and boron were significantly reduced the physiological loss in weight of fruits at 10, 20 and 30 days after harvest compared to control. But the application of calcium during growth increases calcium accumulation in leaves as calcium pectate, making the tissues highly resistant to deterioration. In addition, boron may function in cell wall metabolism by maintaining calcium pectate association in tomatoes (Davis *et al*., 2003) [6]. Both B and Ca play a vital role in cell -wall synthesis and structure by cross-linking pectic compounds (Loomis and Durst, 1992) [11]. Ca-interacts with B, which had a stabilizing influence on Ca complexes in the middle lamella of fresh-market tomatoes (Huang and Snap, 2004) [8]. As cell compactness increases the shelf-life and tomato fruits retain their firmness for longer period.

Table 2: Effect of calcium, boron and their interaction on per cent physiological loss in weight of harvested fruits

Treatments	PLW (%)		
	10 DAH	20 DAH	30 DAH
T1	12.05	21.73	45.73
T2	11.26	20.88	43.65
T3	10.81	20.13	42.06
T4	9.95	19.97	39.88
T5	9.10	19.65	38.40
T6	8.26	18.62	36.21
T7	7.84	17.68	28.18
T8	6.23	16.06	28.05
T9	7.36	16.38	29.31
SEm ±	0.42	0.55	1.05
CD (5 %)	1.27	1.65	3.16

Effect of calcium, boron and their interactions on Physiological disorders

Blossom end rot (%)

The data on percentage of fruits affected from blossom end rot as influenced by application of calcium, boron and their interaction are presented in Table 3. Soil application of calcium, boron and their interaction were resulted in significant variation in per cent fruits affected by blossom end rot. The lowest per cent of fruits affected by blossom end rot were recorded in T8 (9.08 %) followed by T9 (10.01 %) and T7 (10.68 %). However, highest per cent of fruits affected by blossom end rot were recorded in control (16.00 %). The results revealed that application of calcium with boron recorded lowest per cent of fruits affected with blossom end rot incidence. This is may be due to application of boron which encourages the uptake of Ca, Mg, Na and Zn and it reducesd blossom end rot by increasing calcium metabolism in tomato fruits (Smit and Combrink, 2005: Davis *et al*., 2003) [26, 6].

Fruit cracking (%)

Significant variation in per cent fruit cracking was observed among the treatments. The T8 (8.83 %) recorded lowest per cent of fruits affected with fruit cracking followed by T9 (9.97 %) and T7 (10.68 %) and higher percent of fruits affected with fruit cracking was recorded in control (13.67 %) (Table 3.) The results revealed that an application of calcium and boron maintaining calcium pectate association in tomatoes (Davis *et al*., 2003) [6]. Both boron and calcium play a vital role in cell wall synthesis and structure by cross-linking pectic compounds (Loomis and Durst, 1992) [11]. Hence, both the elements are responsible for reducing fruit cracking.

Table 3: Effect of calcium, boron and their interactions on percent of fruits affected with blossom end rot and fruit cracking in tomato

Treatments	Blossom end rot fruits (%)	Cracked fruits (%)
T1	16.00	13.67
T2	12.33	12.33
T3	12.18	12.17
T4	13.63	11.83
T5	13.74	11.60
T6	11.13	11.13
T7	10.68	10.68
T8	9.08	8.83
T9	10.01	9.97
SEm ±	1.13	0.54
CD (5 %)	3.41	1.61

Conclusion

The present study revealed that maximum vegetative growth coupled with higher fruit set, total yield and quality characters could be obtained by soil application of RDF + calcium at 30 kg/ha and boron at 10 kg/ha in hybrid tomato (Arka Rakshak). Hence, this recommendation through line departments would be helpful for tomato growing farmers of eastern dry zone of Karnataka to obtain higher yield and quality

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