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Foliar application of calcium and boron on yield and quality attributes of strawberry

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Abstract
Strawberry is one of the most important crops with small fruits after grapes widespread in different regions of the world due to its many varieties and its ability to grow and adapt to different environmental conditions. The availability of calcium and boron is very important for the growth of plants as the lack of any of them lead to a significant imbalance in growth and yield. Hence, the main aim of this study to determine the effect of calcium and boron on yield and quality attributes of strawberry. This study was carried out during 2021-2022 at Vattavada village, Idukki district in Kerala. The experiment was laid out in a Randomized Block Design with 4 treatments and each treatment replicated thrice. The data recorded on various parameters *viz.*, albinism, fruit malformation, grey mould, number of leaves per plant, number of flowers per plant, fruit setting percentage, fruit length, fruit diameter, number of fruits per plant, fruit weight, total yield per plant, fruit firmness, total soluble solids and fruit acidity were statistically analyzed. Significant differences were observed among different treatments on various yield parameters in Sweet Charlie variety of strawberry. Among the four treatments, combination of calcium and boron spray had recorded significantly the highest number of leaves per plant (45.76), number of flowers per plant (15.83), fruit setting percentage (93.44%), fruit length (39.44 cm), fruit diameter (32.94 cm), number of fruits per plant (13.86), fruit weight (13.56 g), total yield per plant (187.94 g), and also recorded lowest albinism (7.24%), fruit malformation (3.85%) and grey mould (2.14%). In quality characters significant differences were observed among different treatments in Sweet Charlie variety in strawberry. Among all the treatments, combination of calcium and boron spray had recorded significantly the maximum fruit firmness (1.55 N), fruit acidity (1.26%), and also recorded lowest total soluble solids (7.56%). Hence, our studies clearly indicated that combination of calcium and boron application can be recommended for reducing the incidence of albinism, fruit malformation and grey mould in strawberry, and to get higher yield.

Keywords: Strawberry, calcium, boron, yield and quality

Introduction
The genus, Fragaria, of the family Rosaceae (sub-family Rosoideae) includes 20 wild species, three naturally occurring hybrid species and the modern cultivated strawberry (*F. ananassa* Duch.), originated in North America, South America, Asia and Europe (Hummer *et al.*, 2011) [9]. The strawberry plant (*Fragaria ananassa* Duch.) belongs to the Rosaceae family, which includes about 100 genera and 2,500 species. It is one of the most important crops with small fruits after grapes widespread in different regions of the world due to its many varieties and its ability to grow and adapt to different environmental conditions. The availability of macro and micro-nutrients is very important for the growth of plants as the lack of any of them lead to a significant imbalance in growth and yield (Sharma *et al.*, 2006; Singh *et al.*, 2007) [17, 20]. There are some of these elements in the soil in good quantities, but availability of these nutrients to the plant hardly corresponds to the needs of the natural growth of the plant (Al-sa'eedi, 2000) [1]. Fruit calcium concentration is an important factor determining quality. Fruits with low calcium status are sensitive to many physiological and pathological disorders and have a short storage-life (Conway *et al.*, 1992; Fallahi *et al.*, 1997) [2, 5]. Low fruit calcium concentration, particularly in fleshy fruit, results from the fact that calcium is immobile in the phloem. Increased calcium level in fruits usually improves their storage-life. Soil calcium application is not successful in enhancing calcium in fruit tissues (Dunn and Able, 2006; Hernandez-Munoz *et al.*, 2006) [3, 8]. Further, boron is an essential nutrient element and its deficiency reduces pollen germination and growth of pollen tubes, which consequently results in the development of malformed fruits, which lowers crop yield and deteriorates fruit quality. Boron is considered one of the important and necessary micronutrients in plant production and growth, and it is no

less important than the major nutrients, it has many physiological functions in plants, as it has a role in the processes of differentiation and cellular morphology and in the fertilization process as it is necessary in the production of pollen, flowering and seed formation, It affects the formation of the cell wall and the formation of pectin and lignin, as it was found that 50% of the boron present in the plant is concentrated in the cell wall. Moreover, it is generally excepted that soil boron application is less successful in increasing fruit yield than B spray. Therefore, boron sprays are most frequently recommended in fruit production where the risk of boron deficiency is high. However, little is known on effect of boron sprays on strawberry yield and fruit quality (Guttridge and Turnbull, 1975; Lieten, 1989, 1998, 2002; Sharma and Sharma, 2004) [7, 11, 12, 13, 18].

In this concern, the present investigation was undertaken to determine the effect of calcium and boron on yield and quality attributes of strawberry.

Materials and Methods

This study was carried out during 2021-2022 at Vattavada village, Idukki district in Kerala. The experiment pertaining the foliar application of calcium and boron in 'Sweet Charlie' variety of strawberry. The experiment was laid out in randomized block design (RBD) with three replications. Runners of 'Sweet Charlie' strawberry were planted at a spacing of 25 × 25 cm on raised beds during the last week of September. Each treatment consisted of 50 plants in a plot size of 400 × 100 cm. All necessary cultural practices (Singh *et al.*, 2005) [19] were followed uniformly for all the treatments during the entire period of experimentation. The following treatments were applied (Table 1).

Table 1: Treatment details

S. No.	Treatments	
1.	T_1	Five sprays of calcium as calcium chloride to 0.8 kg per acre per spray
2.	T_2	Three spray of boron to 60 g boron per acre per spray
3.	T_3	Combination of boron and calcium spray (1) and (2)
4.	T_4	Plants sprayed with water served as the control.

The first spray (Treatment 1) was performed at petal fall stage and others at weekly intervals; Treatment 2 were spray at the beginning of flowering and other sprays at 15-days interval. The data recorded on various parameters *viz.*, albinism, fruit malformation, grey mould, number of leaves per plant, number of flowers per plant, fruit setting percentage, fruit length, fruit diameter, number of fruits per plant, fruit weight, total yield per plant, fruit firmness, total soluble solids and fruit acidity were statistically analyzed. Fruit yield (gram), length (centimeter), diameter (centimeter) was calculated by taking marketable fruits, which were free from skin injury, albinism and malformation symptoms. Randomly selected 50 normal fruit were taken to calculate mean berry weight on each treatment. The titratable acidity (TA), total soluble solids (TSS) and firmness were determined at harvest and also after 5 days of storage at 10°C and 90% RH. Acidity, TSS, ascorbic acid content were expressed as percentage. Firmness was determined on 25 fruit samples from each replicate with a texture analyzer (TA-Hdi, Stable Micro Systems, UK). Incidence of albinism, fruit malformation and grey mould (*Botrytis cinerea*) were determined at each harvest by counting all albino, malformed fruit and represented as percentage (%). The data obtained from the observations were subjected to analysis, following standard procedures. The critical difference was worked out at five percent (0.05) probability. The results of the experiment were statistically analyzed by SPSS method (Nei, 1978) [15].

Results and Discussions

Yield characters

The data pertaining to the effect of foliar application of calcium and boron on physiological disorders, grey mould and fruit yield of strawberry is presented in Table 2 - 4. Significant differences were observed in albinism, fruit malformation, grey mould, number of leaves per plant, number of flowers per plant, fruit setting percentage, fruit length, fruit diameter, number of fruits per plant, fruit weight and total yield per plant.

Table 2: Effect of foliar application of calcium and boron on physiological disorders and grey mould

S. No.	Treatments	Albinism (%)	Fruit malformation (%)	Grey mould (%)
1.	T_1	10.54	9.47	2.86
2.	T_2	13.51	4.51	5.65
3.	T_3	7.24	3.85	2.14
4.	T_4	17.83	14.85	6.21
Mean		12.28	8.17	4.22
SE (d)		0.188	0.158	0.134
CD (P=0.05)		0.470**	0.395**	0.333**

Among the four treatments, sequential foliar application of calcium and boron has recorded significantly the minimum albinism (7.24%), fruit malformation (3.85%) and grey mould (2.14%) while, control like water spray recorded significantly the maximum albinism (17.83%), fruit malformation (14.85%) and grey mould (6.21%).

Table 3: Effect of foliar application of calcium and boron on yield attributes of strawberry

S. No.	Treatments	Number of leaves / Plant	Number of flowers / Plant	Fruit setting percentage (%)	Fruit length (cm)
1.	T_1	41.84	13.51	82.85	38.57
2.	T_2	32.58	12.86	80.56	33.84
3.	T_3	45.76	15.83	93.44	39.44
4.	T_4	28.51	9.55	75.67	31.69
Mean		37.17	12.94	83.13	35.89
SE (d)		0.957	0.256	1.128	0.875
CD (P=0.05)		2.386**	0.638**	2.814**	2.182**

The combination of calcium and boron spray has recorded significantly the highest number of leaves per plant (45.76), number of flowers per plant (15.83), fruit setting percentage (93.44%), fruit length (39.44 cm), fruit diameter (32.94 cm), number of fruits per plant (13.86), fruit weight (13.56 g) and total yield per plant (187.94 g) (Figure 1) among the four treatments. At the same time, control like water spray has recorded the lowest number of leaves per plant (28.51), number of flowers per plant (9.55), fruit setting percentage (75.67%), fruit length (31.69 cm), fruit diameter (26.44 cm), number of fruits per plant (8.38), fruit weight (10.92 g) and total yield per plant (91.51 g) among the four treatments.

Table 4: Effect of foliar application of calcium and boron on yield attributes of strawberry

S. No.	Treatments	Fruit diameter (cm)	Number of fruits per plant	Fruit weight (g)	Total yield per plant
1.	T_1	30.48	11.56	12.47	144.15
2.	T_2	29.51	9.47	11.99	113.55
3.	T_3	32.94	13.86	13.56	187.94
4.	T_4	26.44	8.38	10.92	91.51
Mean		29.84	10.82	12.24	134.29
SE (d)		0.643	0.358	0.258	2.707
CD (P=0.05)		1.605**	0.892**	0.643**	6.752**

In our study, pre-harvest foliar application of calcium, boron and calcium + boron has influenced albinism, and fruit malformation disorders, incidence of grey mould and fruit yield of 'Sweet Charlie' strawberry at harvest. Fruit harvested from plants, which were sprayed either with calcium or calcium + boron showed lesser incidence of albinism, and grey mould than those harvested from plants either boron alone or not at all sprayed (control). The lower incidence of albinism and grey mould in fruit receiving calcium or calcium + boron might be due to the fact that calcium slows down the ripening and senescence processes in many fruit including strawberry (Ferguson, 1984; Pooviah, 1986; Sharma *et al.*, 2006) [6, 16, 17]. Hence, albino fruit has been produced in lesser proportion in plants, which received calcium or calcium + boron, and because the fruit receiving calcium were firmer, hence less affected by grey mould incidence. Wojcik and Lewandowski (2003) [22] and Naradisorn *et al.* (2006) [14] had also reported that fruit receiving calcium are much firmer and less affected by grey mould. Application of calcium or boron or calcium + boron influenced the marketable fruit yield significantly. However, the significant differences in marketable yield among the treatments were only due to discarding of albino, malformed and grey mould affected fruit. Wojcik and Lewandowski (2003) [22] have also reported that pre-harvest application either of calcium, boron or calcium + boron has no effect on fruit yield in 'Elsanta' strawberry.

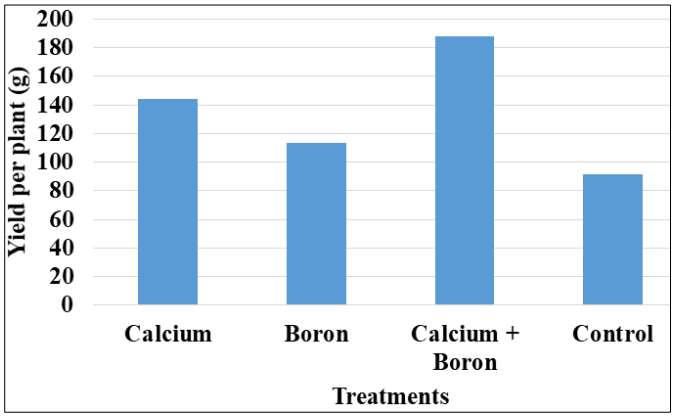

Fig 1: Effect of foliar application of calcium and boron on yield per plant of strawberry

Quality characters

The data pertaining to the effect of foliar application of calcium and boron on quality of strawberry is presented in Table 5. Significant differences were observed in application of calcium and boron on fruit firmness, total soluble solids and fruit acidity of strawberry.

Table 5: Effect of foliar application of calcium and boron on quality attributes of strawberry

S. No.	Treatments	Firmness (N)	TSS (%)	Acidity (%)
1.	T_1	1.37	8.12	1.15
2.	T_2	1.25	9.57	1.01
3.	T_3	1.55	7.56	1.26
4.	T_4	0.92	10.41	0.85
Mean		1.27	8.92	1.07
SE (d)		0.036	0.199	0.021
CD (P=0.05)		0.090**	0.497**	0.051**

Among the four treatments, sequential foliar application of calcium and boron has recorded significantly the maximum fruit firmness (1.55 N), fruit acidity (1.26%), and also recorded lowest total soluble solids (7.56%) while, control like water spray recorded significantly the minimum fruit firmness (0.92 N), fruit acidity (0.85%), and also recorded highest total soluble solids (10.41%).

Plants sprayed with Calcium concentrations gave higher averages in most parameters studies, that's may attribute to the Calcium effect on cells trigger signaling pathways related to growth, development, and responses to both abiotic and biotic stresses including pathogen attack (Thor, 2019) [21]. It also improves the N use efficiency. However, Calcium increases cell wall strength and thickness; therefore, this is a pivotal nutrient for fruit firmness (Easterwood, 2012; Kirsten, 2013) [4, 10]. Better firmness of fruit receiving calcium or calcium + boron may be attributed to the effect of calcium on middle lamella of cells/tissues as it acts as binding agent between the cell walls, as a result, it might have resulted in higher firmness in such fruit, which also resulted in lesser incidence of grey mould. It may be correlated with the firmness of fruit as fruit receiving calcium, boron or calcium + boron, were much firmer than control fruit, and hence they have lower total soluble solids, and higher acidity (Hernandez-Munoz *et al.*, 2006) [8].

Conclusions

Finally in this study showed significant variation for yield and quality characters. Hence, our studies clearly indicated that combination of calcium and boron application can be recommended for reducing the incidence of albinism, fruit malformation and grey mould in strawberry, and to get higher yield.

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