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Effect of Foliar Feeding of Nutrients and Bioregulators on Yield and Quality Attributes of Litchi cv. Bombai

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Article

Effect of Foliar Feeding of Nutrients and Bioregulators on Yield and Quality Attributes of Litchi cv. Bombai

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Abstract: Litchi (Litchi chinensis Sonn.) is considered as one of the most important sub-tropical fruits of the World. Under western part of Odisha, India, the litchi growers are facing problem of unstable and lower marketable yield and inferior quality due to higher incidence of fruit cracking, fruit drop, low sugar content and higher fruit acidity. Keeping in mind the positive effects of nutrients and bioregulators, the current study was conducted to elucidate their impact on fruit yield, and quality in the farmers field of Jamankira block in Sambalpur district of Odisha under Odisha University of Agriculture and Technology, India. For the studies, eight years old litchi trees were selected. With 12 treatments, the experiment was set up in a randomized block design replicated thrice viz, T_1: Spray treatment of Borax @ 0.5%; T_2: Spray treatment of Borax @ 0.3%; T_3: Spray treatment of $ZnSO_4$ @ 0.75% ; T_4: Spray treatment of $ZnSO_4$ @ 0.5%; T_5: Spray treatment of $CaCl_2$ @ 0.5%; T_6: Spray treatment of $CaCl_2$ @ 0.1%; T_7: Spray treatment of Humic acid @ 1.5%; T_8: Spray treatment of Humic acid @ 1%; T_9: Spray treatment of Seaweed extract @ 0.5%; T_{10}: Spray treatment of Seaweed extract @ 0.1 %; T_{11}: Foliar spray of NAA @ 20 ppm and T_{12} : Control (water spray).The current study compared foliar feeding of different nutrient and bioregulators treatments, which were applied during the first week of December, just after completion of new leaf formation and untreated control. The total number of fruits per plant was recorded highest in plants sprayed with ZnSO4 @ 0.5% (T_4) followed by those treated with humic acid @ 1% (T_8). The highest total fruit yield was recorded in plants with foliar feeding of 0.3% Borax (T_2) which was found to be statistically similar to plants treated with seaweed extract @ 0.1% (T_{10})and seaweed extract @ 0.5% (T_9).Among the treatments better response for higher number of marketable fruits and marketable yield was recorded in plants treated with both 0.3% Borax (T_2) followed by 0.5% Zinc sulphate (T_4), 1% Humic acid (T_8) and 0.1% $CaCl_2$ (T_6) in litchi. Application of 1% Humic acid (T_8) followed by 1.5% Humic acid (T_9) enhanced the fruit set (%) and fruit retention (%) along with reduction in fruit drop (%). The enhanced fruit size (fruit length and fruit breadth) and higher fruit weight was obtained in plants treated with 0.3% Borax in litchi. The foliar application of 0.3% Borax (T_2) had also resulted in higher TSS, total sugars, reducing sugar, lower acidity, highest aril weight and lower seed weight in litchi cv. Bombai.

Keywords: yield; quality; fruit cracking; nutrients; humic acid; sea weed extract; litchi

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Introduction

Litchi belongs to the family Sapindaceae and sub-family Nepheleae comprising about 150 genera and 2000 species [1] and is native to Southern China. By virtue of its delicious taste, excellent flavour, pleasant fragrance, attractive appearance and high nutritional values, it has gained popularity in many parts of the world opening up new vistas for accelerated export opportunity. The principal chemical components of litchi fruits are carbohydrates, organic acids, vitamins, pigments, protein and fat. The fruit is very much enjoyed as a table fruit as well as in dried and canned forms. Jam, jelly, squash and cordial are also prepared from this fruit. Generally, the harvest maturity of the fruit is judged by the development of red colour on epicarp and flattening of tubercles [2].

The foliar application of nutrients and bioregulators in specific plant developmental and critical stages improves the yield and quality. Foliar application of micronutrients has gained importance because it is a well-established operation to complete and boost plant nutrition. Foliar application can meet the expense of nutrients where absorption of nutrients from the soil is unavailable due to plant stress or in adverse soil conditions [3].Application of plant bioregulators results in increased flowering, fruiting and fruit retention. Yield and quality of litchi fruit have been positively influenced by application of nutrients and plant growth regulators [4].Reduced flower induction and fruit set, leading to inferior fruit quality are caused by zinc and boron deficiency [5].The fruit quality is mainly affected by calcium via calcium pectate formation, which is associated with increase in the strength of cell wall and middle lamella [6]. Micronutrients applied in optimum concentrations results in better plant growth which causes better flowering, higher fruit set that ultimately leads to higher yield [7]. Zinc and boron take part in various enzymatic reactions and helps in sugar accumulation in fruit from source to sink [8]. Boron is the only micronutrient not only specifically associated with either photosynthesis or enzyme function, but it is also associated with the carbohydrate chemistry and reproductive system of the plant.

Bioregulators are the product of natural and organic origin that stimulates plant to achieve their maximum growth and yield potential. Humic acid is especially beneficial in release of nutrients in the soil so that they are made available to the plant when needed. Humic acids play several important roles such as enhanced soil physical and biochemical activities by improving structure, texture, water holding capacity and microbial population [9]; increase soil nutrients availability, especially micronutrients by chelating and co-transporting micronutrients to plants [10].

Seaweeds are qualified to be used as biofertilizers, not only because they have a biological impact, but also because of their biocompatibility as they contribute to common biological compounds with plants. Seaweed extract are known as bio-stimulants due to presence of multiple growth regulators (cytokinin, auxins, gibberellins), macronutrients (Ca, P and K) and micronutrients (Fe, Cu, Zn, B, Mn, Co and Mo), which are necessary for plant growth and development [11]. The foliar spray of seaweed extract is a common method to increase yield in many commercial crops [12]. Multiple growth regulators have been found in seaweed extracts, including cytokinins, auxins, and gibberellins [13]. Seaweed extracts have currently gained much beneficial significance because they can induce speedy growth and yield in cereals, vegetables, and fruit orchards, as well as in horticultural plants [14]. Despite the unique and desirable characteristics, the major constraint in litchi cultivation causing lower yield and return are: poor fruit set [15], heavy fruit drop [16] [4], fruit cracking [16] and inferior fruit quality [17]. Fruit drop in litchi is often thought to be associated with interruption in the endogenous hormonal level [18], failure of fertilization, embryo abortion, internal nutrition and hormonal imbalance and internal factors like high temperature, low humidity and strong winds [19]. Fruit cracking of developing fruits is a worldwide problem in litchi cultivation. High temperature, low humidity and low soil moisture conditions during fruit development promote this disorder [20]. Due to the above constraints, there is a massive gap between demand and production of litchi, which increases the market price. To reduce this gap, many nutrients and bio-regulators are applied with recommended irrigation. Several investigations have been reported different benefits of seaweed extracts on growth, development and increased yield of many crops [21,22].

Bioregulators and nutrients are being used by the growers to increase the yield by improving the yield attributing parameters in litchi. The effect of nutrients in enhancing yield and fruit quality of litchi is a predetermined conclusion, but the valuable effect of nutrients in combination with bioregulators was yet to be fully explored. Under western part of Odisha, India, although the litchi growers are facing problem unstable and lower marketable yield and quality due to higher incidence of fruit cracking, fruit drop, low sugar content, higher acidity etc but no research has been conducted yet to study about the effect of bioregulators and nutrients on litchi. Based on this context, an experiment was conducted to assess the influence of bioregulators and nutrients on yield and fruit quality of Litchi cv. Bombai in western part of Odisha in India.

2. Materials and methods

2.1. Experimental material

The experimental materials were eight-year-old litchi tree cv. Bombai (*Litchi chinensis* Sonn.). The plants were produced by layering and planted on July 2012. Plants were planted in square system with a spacing of 8m × 8m.

2.2. Experimental site & Design

The present investigation was conducted in the farmer's field at Jamankira block (21° 54' N latitude, 84° 39' longitude and altitude 171 m above the mean sea level, Sambalpur district, Odisha, India during the year 2020-2022 in a Randomized Block Design (RBD) with 12 treatments (Table-2.1) replicated thrice.

Table 2.1. Treatment details.

Sl. No.	Treatments	Details of Treatments
1.	T_1	Borax @ 0.5%
2.	T_2	Borax @ 0.3%
3.	T_3	$ZnSO_4$ @ 0.75%
4.	T_4	$ZnSO_4$ @ 0.5%
5.	T_5	$CaCl_2$ @ 0.5%
6.	T_6	$CaCl_2$ @ 0.1%
7.	T_7	Humic acid @ 1.5%

8.	T_8	Humic acid @ 1%
9.	T_9	Seaweed extract @ 0.5%
10.	T_{10}	Seaweed extract @ 0.1%
11.	T_{11}	NAA @ 20 ppm
12.	T_{12}	Control (Water Spray)

The nutrients and bioregulators were applied during the first week of December, just after completion of new leaf formation. The experimental site is characterized by warm and semi dry climate with hot and dry summer and mild winter. The meteorological data recorded at meteorological observatory, Regional Research and Technology Transfer Station (RRTTS), Chiplima, during the period of investigation (2020-21 and 2021-22) is presented in Figure 1 and Figure 2.

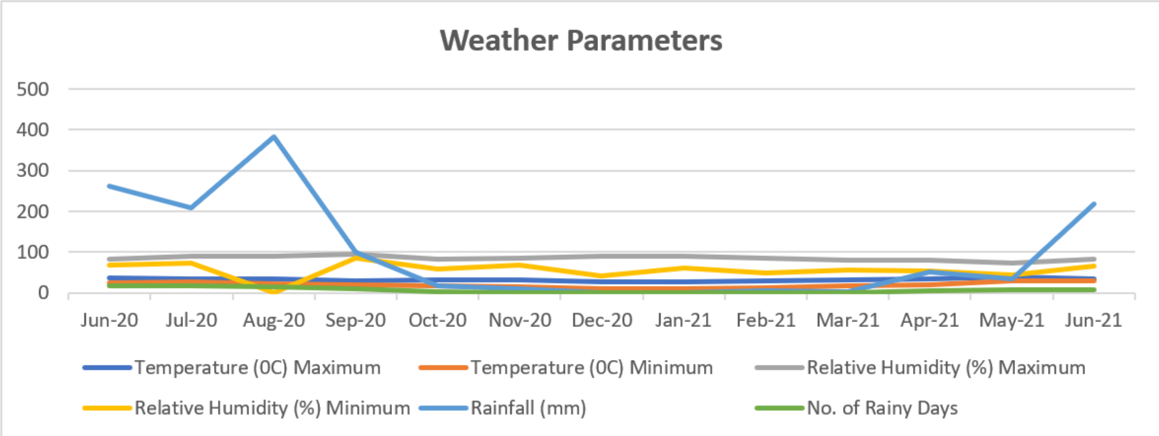

Figure 1. Various weather parameters for the first year (2020-21).

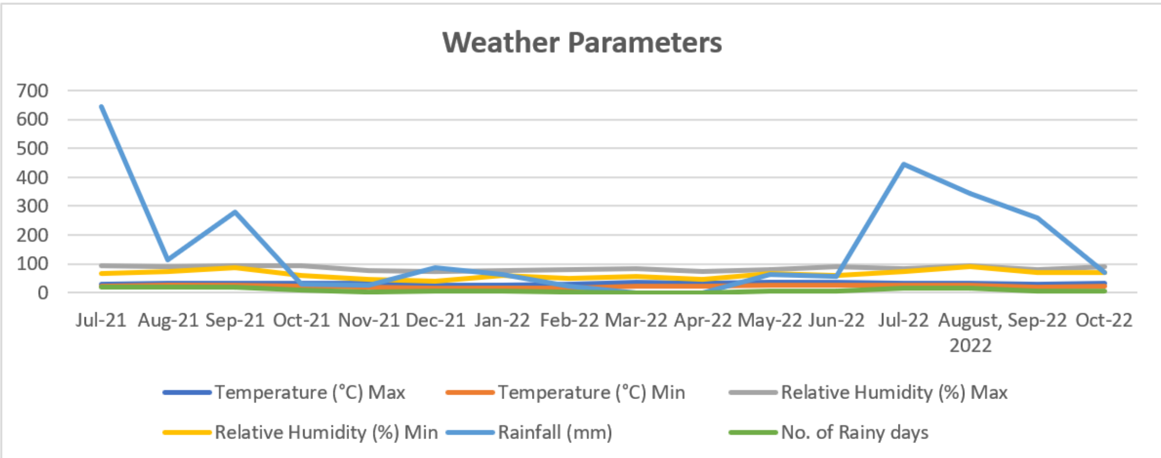

Figure 2. Various weather parameters for the first year (2021-22).

2.3. Trait measurement

The fruits were harvested when the colour changes from green to red in colour and were evaluated for yield parameters *i.e.*, total number of fruits, total number of marketable fruits, total yield and total marketable yield; physico-chemical parameters *viz*., fruit weight, aril weight, seed weight, pericarp weight, fruit length & breadth, nut length & breadth and biochemical parameters viz., TSS, titrable acidity, total sugars, reducing sugar, non-reducing sugar, TSS: acid ratio, ascorbic acid content.

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2.3.1. Determination of fruit and aril weight

The average fruit weight, aril weight, seed weight and pericarp weight of 10 samples from each replication were analyzed by using electronic weighing balance and their average weight was determined and expressed in grams (g).

2.3.2. Determination of fruit and nut size

The length and breadth of fruit and nut were measured by using a digital slide caliper and the mean was expressed in centimeter (cm).

2.3.3. Biochemical parameters

2.3.3.1. Determination of Total soluble solids (^{0}Brix)

TSS was generally measured by digital refractometer (0-32°Brix). TSS stands for total soluble solid which include sugar, vitamins, amino acids, acids and other soluble solids present in the juice. To measure the TSS of litchi fruit, two to three drops of juice were kept on the prism of the refractometer and observations were recorded. Before and after taking the reading the refractometer were properly washed. The reading of refractometer was expressed in percentage or ^{0}Brix.

2.3.3.2. Determination of Titrable Acidity (%)

The total acidity of fruit was determined by titrating the known amount of aqueous extract against an alkali solution of known normality. It is expressed in equal-volume of any organic acid e.g., malic acid, citric acid [23] (A.O.A.C., 2016). The titratable acidity is calculated in term of malic acid and expressed in percentage [24].

$$Total\ acidity\ (\%) =$$

$$\frac{titrated\ value\ \times normality\ of\ NaOH\ \times volume\ made\ up\ \times Equivalent\ weight\ of\ acidity(67)}{volume\ of\ aliquote\ taken\ \times volume\ of\ sample\ taken \times 1000} \times 100$$

2.3.3.3. Determination of Total sugars (%)

The total sugar content in the fruit aril was estimated by following the procedure described by [25] using the Fehling's A and Fehling's B solution. It was titrated against the sample in burette till break red colour appear which shows the endpoint. It was calculated using the following formulae:

$$Percentage\ of\ total\ sugar = \frac{dilution\ factor\ (0.05) \times dilution(100)}{titrte\ value\ \times volume\ of\ sample\ taken} \times 100$$

2.3.3.4. Determination of Reducing sugar (%)

The reducing sugar content is determined by the procedure described by Ranganna, (1986), It was calculated as follows:

$$Percentage\ of\ reducing\ sugar = \frac{dilution\ factor\ (0.05) \times dilution(100)}{titrate\ value \times volume\ of\ the\ sample\ taken} \times 100$$

2.3.3.5. Determination of Non-reducing sugar (%)

Non- reducing sugar was estimated by subtracting reducing sugar from the total carbohydrate and then multiplying it with 0.95.

2.3.3.6. Determination of TSS: acid ratio

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The TSS: Acid ratio was estimated mathematically by dividing the value of TSS with titratable acidity and the data so obtained was expressed as TSS : acid ratio.

TSS: acid ratio = TSS/ titratable acidity

2.3.3.7. Determination of Ascorbic acid content (mg/100g)

Ascorbic content of the litchi fruits was determined by using 2,6-dichlorophenol indophenol visual titration method by [25]. This was expressed in terms of mg ascorbic acid per 100g of fruit aril and was calculated by using following formula.

$$Ascorbic\ acid\ (mg/100g) = \frac{titret\ reading \times dye\ factor\ \times dilution\ \times 100}{aliquote\ of\ extract\ \times weight\ of\ sample\ taken}$$

3.0. Results

3.1. Fruit set (%)

The observations on fruit set percentage in litchi as influenced by application of various nutrients and bioregulators are given in Table 1. The pooled data revealed that the maximum fruit set (59.76 %) was recorded with T_7 i.e. Humic acid @ 1.5 % treated trees which was statistically at par with plants applied with Humic acid @ 1 % i.e. T_8 (58.17%), while the minimum fruit set (46.49 %) was observed in T_{12} (control) which was found to statistically inferior to the rest of treatments. and was followed by T_9 (53.53 %), T_2 (53.11%) and T_1 (53.07%).

3.2. Fruit drop (%)

From the perusal of pooled data presented in the Table 1 and Figure 3, it was obvious that the extent of fruit drop varied from 65.94 to 80.91 per cent. The minimum fruit drop (65.94 %) was recorded in plants under T_8 (Humic acid @ 1%) treatment which was followed by statistical similar treatment T_7 (70.19%), while the maximum fruit drop (80.91 %) was recorded in T_{12} (Control) which was followed by statistically similar treatments T_3 (79.59%) and T_4 (80.01%). The pooled data further showed that the mean value of all the concentrations of Humic acid had the lowest value (65.94 % in T_8 and 70.19 % in T_7) followed by Seaweed extracts (73.72% in T_9 and 74.18% in T_{10}).

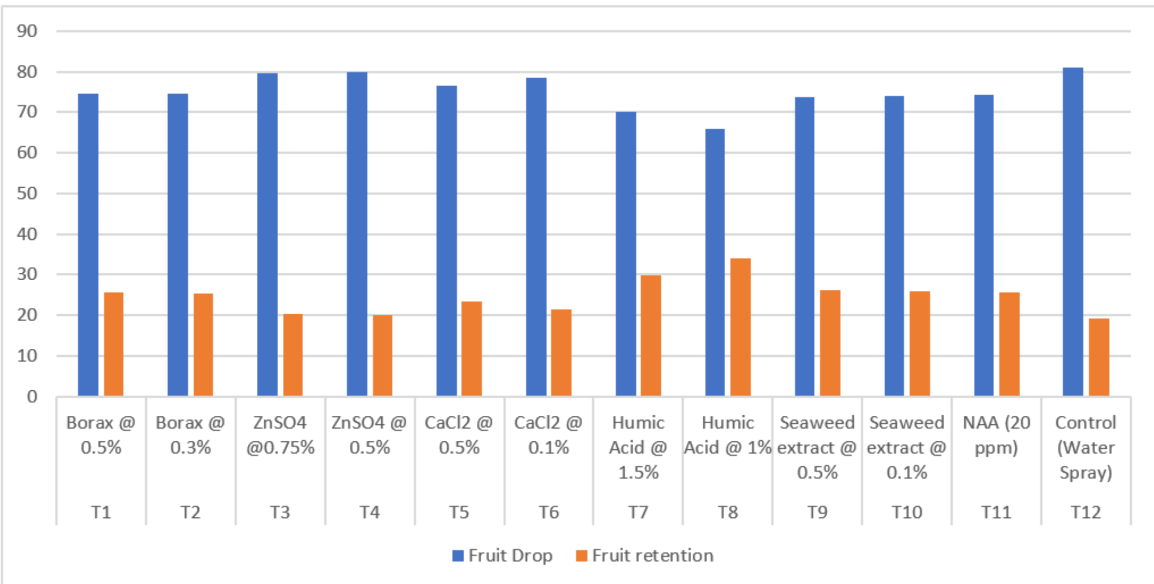

Figure 3. Effect of foliar feeding of nutrients and bioregulators on fruit drop and fruit retention percentage of Litchi cv. Bombai.

3.3. Fruit retention (%)

The maximum fruit retention (34.07 %) was recorded with T_8 (Humic acid @1 %) which was statistically higher than all other treatments followed by T_7 (Humic acid @ 1.5% %) (29.81 %). The minimum fruit retention (19.10 %) was observed in T_{12} (Control) which was observed to be statistically different and inferior to rest of the treatments (Table 1 and Figure 3). All other treatments significantly improved the fruit retention over control.

3.4. Fruit cracking (%)

From the perusal of pooled data given in Table 1 and Figure 4, it is ascertained that foliar feeding of different nutrients and bioregulators significantly reduced the fruit cracking percentage in litchi cv. Bombai and the values ranged from 8.46 % in T_2 to 30.36 % in control (T_{12}).It is evident from the pooled data that the minimum fruit cracking (8.46 %) was recorded with T_2 (Borax @ 0.3%) treatment which was found statistically at par with T_1 (8.73%) and all other treatments recorded more cracking than T_2 while the maximum fruit cracking (30.36 %) was recorded in untreated control trees (T_{12}).

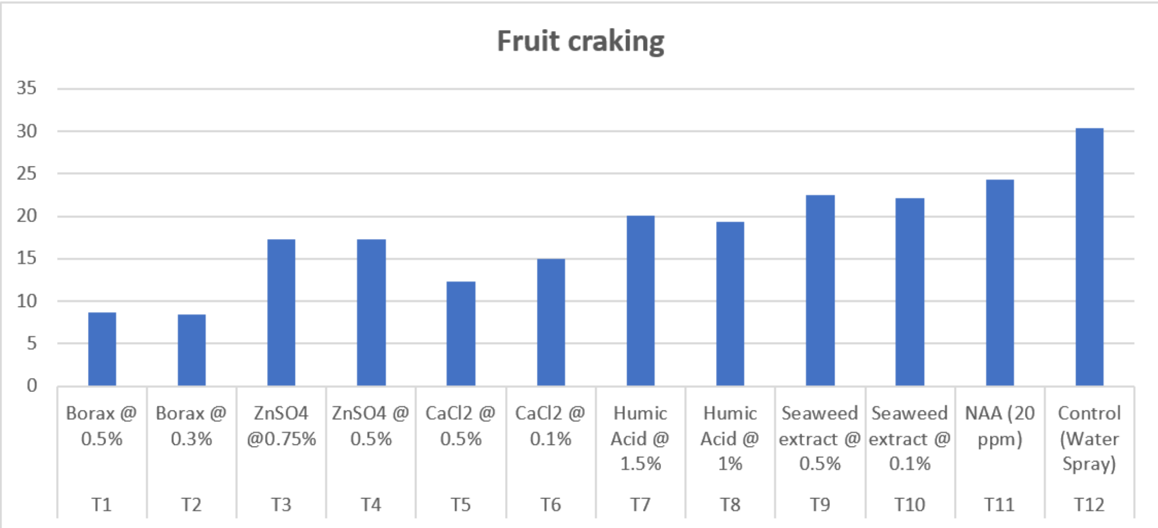

Figure 4. Effect of foliar feeding of nutrients and bioregulators on fruit cracking percentage of Litchi cv. Bombai.

Table 1. Effect of foliar feeding of nutrients and bioregulators on fruit set percentage of Litchi cv. Bombai.

Treatment	Treatment Details	Fruit set (%)	Fruit drop (%)	Fruit retention (%)	Fruit cracking (%)
T_1	Borax @ 0.5%	53.07	74.47	25.53	8.73
T_2	Borax @ 0.3%	53.11	74.69	25.32	8.46
T_3	ZnSO4 @0.75%	52.10	79.59	20.41	17.25
T_4	ZnSO4 @ 0.5%	51.88	80.01	19.99	17.27
T_5	CaCl2 @ 0.5%	51.84	76.70	23.30	12.36
T_6	CaCl2 @ 0.1%	51.76	78.53	21.47	14.99
T_7	Humic Acid @ 1.5%	59.76	70.19	29.81	20.07
T_8	Humic Acid @ 1%	58.17	65.94	34.07	19.40
T_9	Seaweed extract @ 0.5%	51.60	73.72	26.28	22.54

T_{10}	Seaweed extract @ 0.1%	52.73	74.18	25.82	22.18
T_{11}	NAA (20 ppm)	53.53	74.29	25.71	24.31
T_{12}	Control (Water Spray)	46.49	80.91	19.10	30.36
SE m (±)		1.03	0.67	1.58	0.39
CD (0.05)		2.08	1.36	3.18	0.78
CV (%)		3.37	1.55	11.06	3.70

3.5. Total number of fruits per plant

The number of fruits per plant varied significantly due to different treatments and reflected in Table 2 and Figure 5. The highest total number of fruits per plant (1972.08) was obtained in T_4 ($ZnSO_4$@0.5%) that was found to be statistically at par with T_8 (Humic acid @1%), T_2 (Borax @0.3%) and T_{10} (Seaweed extract @0.1%) recording 1864.91, 1858.03 and 1836.79 number of fruits per plant respectively. The control plants (T_{12}) had produced the lowest number of fruits per plant (1627.77).

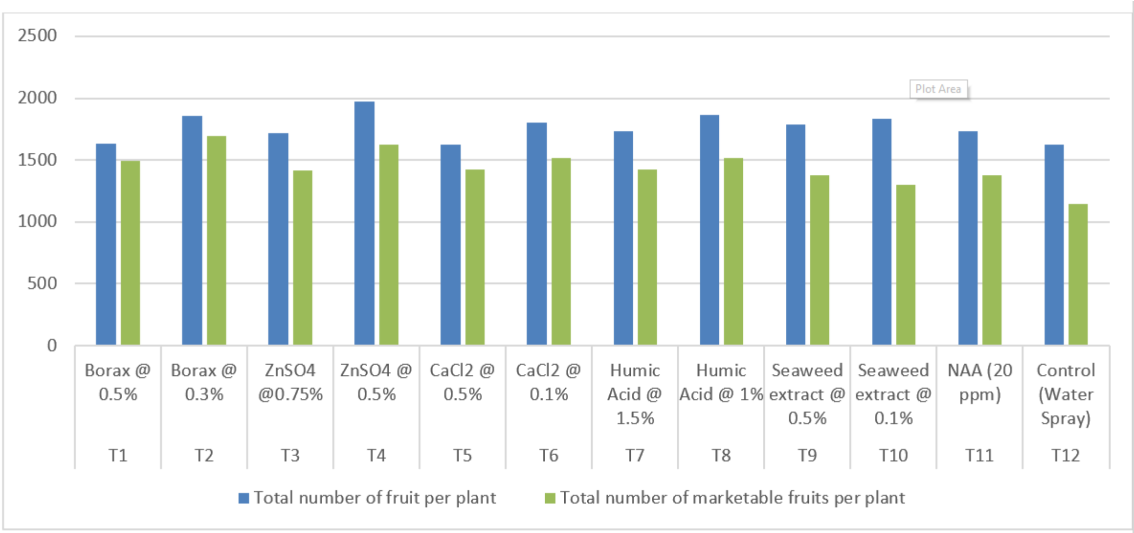

Figure 5. Effect of foliar feeding of nutrients and bioregulators on total number of fruits per plant and total number of marketable fruits per plant of Litchi cv. Bombai.

3.6. Total number of marketable fruits per plant

Pooled data presented in the Table 2 and Figure 5, showed that the maximum number of marketable fruits (1698.46) was observed in plants under treatment T_2 (borax @0.3 %), which was found superior to all other treatments. It was statistically at par (1632.43) with T_4 ($ZnSO_4$) while all other treatments recorded higher number of marketable fruits than T_{12} (control). The control plants (T_{12}) recorded the lowest number of marketable fruits per plant (1144.18) amongst all the treatments and found to be significantly inferior to rest of the treatments.

3.7. Total yield per plant

The maximum total fruit yield (38.69 kg/plant) was recorded in plants under treatment T_2 (0.3% Borax), which was found to be statistically at par with T_{10} (36.68 kg/plant), T_9 (36.41kg/plant) and T_4(35.85 kg/plant) and also observed superior to all other treatments whereas the minimum fruit yield (29.65 kg/plant) was found in T_{12} (Control). The treatments (T_2, T_{10}, T_9 and T_4) were recorded to be statistically at par with each other and had similar effect on fruit yield per plant. The pooled data further showed that the mean fruit yield obtained from T_2 (38.69 kg/plant) which registered 23.3% higher than the control and followed by 19.16 % higher yield under T_{10} over the control (Table 2).

3.8. Total marketable yield

From the pooled data presented in the Table 2, it was revealed that the maximum marketable yield (35.34 kg/plant) was recorded in litchi plants under T_2 (i.e. Borax @ 0.3 %) which was found statistically superior to all other treatments. The treatments T_4 (29.56 kg/plant), T_5 (28.29 kg/plant), T_6 (28.11 kg/plant), and T_8 (28.39 kg/plant) were observed to be statistically at par with each other. The lowest marketable fruit yield (20.88 kg/plant) was registered under treatment T_{12} (Control) which was found to be significantly inferior to all other treatments. The pooled mean value of marketable yield obtained from all the treatments revealed that T_2, T_4, T_5 and T_8 had registered 41.03 %, 29.76%, 26.19% and 25.72% higher marketable fruit yield over the control.

Table 2. Effect of foliar feeding of nutrients and bioregulators on number of fruits per plant and yield of Litchi cv.Bombai.

Treatment	Treatment Details	Total number of fruit per plant	Total number of marketable fruits per plant	Total yield per plant (Kg)	Total marketable yield per plant (Kg)
T_1	Borax @ 0.5%	1636.31	1491.91	30.44	28.12
T_2	Borax @ 0.3%	1858.03	1695.05	38.69	35.34
T_3	ZnSO4 @0.75%	1717.80	1416.23	34.73	28.68
T_4	ZnSO4 @ 0.5%	1972.08	1622.14	35.85	29.56
T_5	CaCl2 @ 0.5%	1625.68	1425.05	31.10	28.29
T_6	CaCl2 @ 0.1%	1801.94	1518.85	32.97	28.11
T_7	Humic Acid @ 1.5%	1730.42	1421.51	32.10	26.33
T_8	Humic Acid @ 1%	1864.91	1519.29	34.93	28.39
T_9	Seaweed extract @ 0.5%	1785.04	1373.86	36.41	26.68
T_{10}	Seaweed extract @ 0.1%	1836.79	1297.67	36.68	25.92
T_{11}	NAA (20 ppm)	1735.27	1374.69	32.79	26.02
T_{12}	Control (Water Spray)	1627.77	1144.18	29.65	20.88
SE m (±)		69.74	56.57	1.53	1.09
CD (0.05)		140.56	114.02	3.09	2.20
CV (%)		6.84	8.80	7.84	6.83

3.9. Physico-Chemical parameters

3.9.1. Fruit length (cm)

All the plant bioregulators and nutrients significantly increased fruit length in comparision to control. The pooled data presented in the Table 3, revealed that, maximum fruit length (3.66 cm) was observed from the plants under treatment T_2 (foliar feeding of Borax @ 0.3 %). The treatment, T_3 i.e. foliar feeding of 0.75 % $ZnSO_4$ (3.53 cm), T_5 i.e. foliar feeding of 0.5 % $CaCl_2$ (3.56 cm) , T_9 i.e. foliar feeding of 0.3 % Seaweed extract (3.43 cm) and T_{10} i.e. foliar feeding of 0.1 % Seaweed extract (3.45 cm) were found to be statistically similar with each other with respect to fruit length in litchi. The minimum fruit length (2.83 cm) was recorded under treatment T_7 (Humic acid @1%).

3.9.2. Fruit breadth (cm)

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From the data depicted in the Table 3, it was found that different foliar treatments had no significant effect on fruit breadth of litchi. From the pooled data, it was inferred that foliar application of Borax @ 0.3 % (T_2) had produced the highest fruit breadth (3.12 cm) followed by plants under T_5 (3.08 cm) and T_{10} (3.02 cm). The lowest fruit breadth (2.61 cm) was obtained in plants under treatment (T_8).

3.9.3. Nut length (cm)

The average length of the nut was not found statistically significant by different treatments in litchi (Table 3). The treatment T_{12} (control) showed maximum average nut length (2.85 cm), while T_4 ($ZnSO_4$@ 0.5%) recorded the lowest (2.31 cm) nut length.

3.9.4. Nut breadth

The nut breadth of litchi cv. Bombai did not record any significant variation among different foliar treatments and from the pooled data, it ranged from a maximum of 1.73 cm in T_{12} (control) to a minimum of 1.44 cm in T_6 ($CaCl_2$ @ 0.1%).

Table 3. Effect of foliar feeding of nutrients and bioregulators on fruit and nut size of Litchi cv.Bombai.

Treatment	Treatment Details	Fruit length (cm)	Fruit breadth (cm)	Nut length (cm)	Nut breadth (cm)
T_1	Borax @ 0.5%	3.14	3.02	2.53	1.49
T_2	Borax @ 0.3%	3.66	3.12	2.49	1.70
T_3	ZnSO4 @0.75%	3.53	3.01	2.61	1.58
T_4	ZnSO4 @ 0.5%	3.33	2.95	2.31	1.64
T_5	CaCl2 @ 0.5%	3.56	3.08	2.38	1.53
T_6	CaCl2 @ 0.1%	3.41	2.91	2.43	1.44
T_7	Humic Acid @ 1.5%	3.03	2.95	2.33	1.61
T_8	Humic Acid @ 1%	2.83	2.61	2.26	1.56
T_9	Seaweed extract @ 0.5%	3.43	2.92	2.48	1.57
T_{10}	Seaweed extract @ 0.1%	3.45	3.02	2.50	1.65
T_{11}	NAA (20 ppm)	3.05	2.87	2.64	1.54
T_{12}	Control (Water Spray)	3.27	2.66	2.85	1.73
SE m (±)		0.12	0.12	0.14	0.06
CD (0.05)		0.24	0.25	0.28	0.12
CV (%)		6.36	7.28	9.86	6.41

3.9.5. Fruit weight

The average weight of litchi fruit was significantly affected by different treatment during study period.The pooled data exhibited in the Table 4, it is obvious that the maximum fruit weight (20.85 g) was recorded in plants treated with Borax @0.3% (T_2), which was statistically found to be at par with T_3 (20.39 g), T_{10} (20.02 g) and T_5 (19.81 g).. The lowest fruit weight (18.26 g) was obtained in control plants (T_{12}) which was found statistically similar with treatments T_4 (18.30 g), T_6 (18.59 g), T_7 (18.63 g), T_8(18.84 g), and T_1(18.91 g).

3.9.6. Aril weight

From the data recorded with respect to aril weight in litchi as affected by foliar feeding of nutrients and bioregulators treatments are presented in Table 4.The pooled data exhibited significant variation among the treatments with respect to aril content in litchi cv. Bombai. It was recorded highest in T_2 (16.01 g) followed by T_5 (15.70 g) which were found to be statistically at par with each other. The lowest aril content (12.20g) was recorded in T_{12} which was found be to be statistically different from rest of the treatments (Table 4)

3.9.7. Seed weight

From the data depicted in the Table 4, it was revealed that the plants treated with 0.3% Borax (T_2) had recorded the lowest seed weight (2.19 g) and was found to be statistically different from rest of the treatments. The untreated control plants (T_{12}) had recorded the highest seed weight (3.09 g) and found to be significantly higher than rest of the treatments.

3.9.8. Pericarp weight

There was non-significant effect of various treatments on pericarp weight of litchi cv. Bombai (Table 4). Yet the T_2 had minimum pericarp weight and the control plants had recorded the highest pericarp weight. From the pooled data, it was obtained minimum (2.23 g) in T_2 and maximum (2.54 g) in T_{12} (control).

3.9.9. Aril: seed ratio

A perusal of pooled data presented in Table 4, showed that the aril: seed ratio was obtained maximum (7.31) in plants with foliar feeding of Borax @ 0.3% (T_2) and found to be significantly superior to rest of the treatments. On the other hand, minimum aril: seed ratio (3.95) was found in T_{12} (control) which was observed to be statistically similar to treatments T_4 (4.47), T_7 (4.82), T_9(4.71) and T_{11}(4.49).

3.9.10. Aril: Pericarp ratio

It is evident from the pooled data, that maximum aril: pericarp ratio (7.18) was found in T_2 whereas it was recorded minimum in control (T_{12}) plant (4.81) (Table 4). The aril: pericarp ratio was found to be significantly superior in all the treatments as compared to the control.

Table 4. Effect of foliar feeding of nutrients and bioregulators on fruit weight, aril weight, seed weight and pericarp weight of Litchi cv. Bombai.

Treatment	Treatment Details	Fruit weight (g)	Aril weight (g)	Seed weight (g)	Pericarp weight (g)	Aril :seed ratio	Aril: pericarp ratio
T_1	Borax @ 0.5%	18.91	14.17	2.65	2.35	5.35	6.04
T_2	Borax @ 0.3%	20.85	16.01	2.19	2.23	7.31	7.18
T_3	ZnSO4 @0.75%	20.39	14.86	2.45	2.30	6.07	6.45
T_4	ZnSO4 @ 0.5%	18.30	13.07	2.92	2.28	4.47	5.75
T_5	$CaCl_2$ @ 0.5%	19.80	15.70	2.38	2.33	6.62	6.77
T_6	$CaCl_2$ @ 0.1%	18.59	14.04	2.81	2.35	5.07	5.98
T_7	Humic Acid @ 1.5%	18.63	13.50	2.82	2.43	4.82	5.56
T_8	Humic Acid @ 1%	18.84	13.86	2.65	2.37	5.27	5.84
T_9	Seaweed extract @ 0.5%	19.48	13.39	2.86	2.40	4.71	5.59
T_{10}	Seaweed extract @ 0.1%	20.02	14.40	2.57	2.30	5.61	6.26
T_{11}	NAA (20 ppm)	18.95	13.48	3.00	2.43	4.49	5.64
T_{12}	Control (Water Spray)	18.26	12.20	3.09	2.54	3.95	4.81
SE m (±)		0.51	0.35	0.08	0.08	0.27	0.25
CD (0.05)		1.04	0.71	0.16	0.15	0.54	0.51
CV (%)		4.63	4.37	5.08	5.58	8.77	7.28

3.9.11. Total Soluble Solids (^{0}Brix)

There was significant effect of the treatments on the total soluble solids (TSS) content of the litchi fruits (Table 5 and Figure 6). From the pooled data, it was inferred that the highest TSS was recorded in T_2 (14.07 ^{0}Brix) followed by significantly similar T_1 (14.02^{0}Brix), T_8 (13.73^{0}Brix), T_7 (13.42^{0}Brix) and T_{10} (13.22^{0}Brix).However, the lowest TSS was estimated in control i.e. T_{12} (9.82^{0}Brix), which was statistically different than the treated ones. It was followed by the statistically significant T_3 (11.47^{0}Brix), T_{11} (11.78 ^{0}Brix),T_4 (11.98^{0}Brix) and T_6 (12.55^{0}Brix).

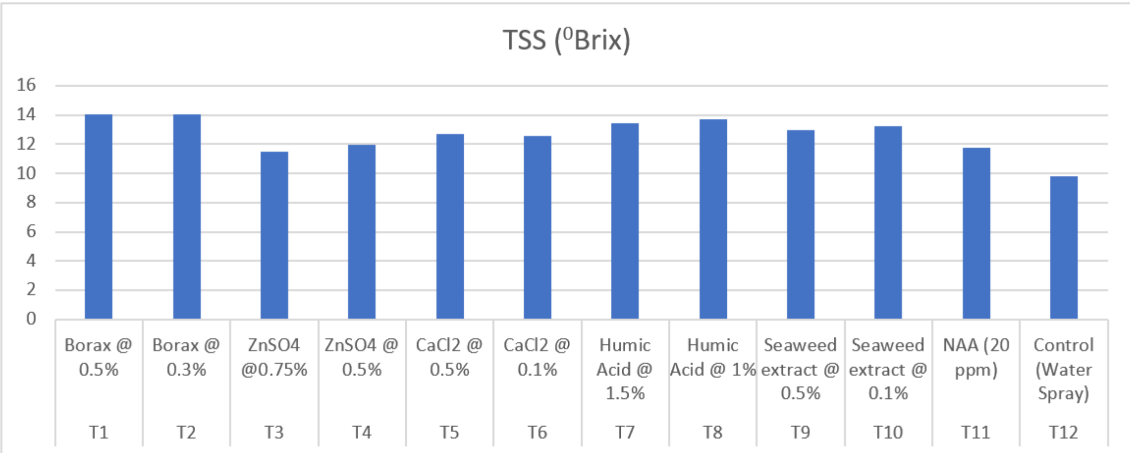

Figure 6. Effect of foliar feeding of nutrients and bioregulators on TSS content of Litchi cv. Bombai.

3.9.12. Titratable acidity (%)

A significant effect for titratable acidity (%) was observed in the fruits treated with various nutrients and bioregulators (Table 5). The lowest titratable acidity was obtained in T_2 (0.72%), which was followed by significantly similar treatments T_1 (0.78%), T_8 (0.79%) and T_7 (0.80%), However, the highest titratable acidity was estimated in control i.e. T_{12} (1.00%), followed by statistically at par T_{10} (0.91%) and statistically different T_9 (0.88%), T_4 (0.85%) and T_3 (0.85%).

3.9.13. Total sugar (%)

There was significant effect of the treatments on the total sugar (%) content of the litchi fruits (Table 5). In the pooled data, the highest total sugar was observed in the T_2 (10.40%), which was followed by statistically similar T_1 (10.12%). These were followed by statistically different T_8 (9.98%) and T_7 (9.88%).However, the lowest total sugar was estimated in control i.e. T_{12} (7.85), which was followed by statistically different T_{11} (8.63%) and T_3 (8.88%). But T_{11} and T_3 were statistically similar to each other.

3.9.14. Reducing sugar (%)

From the pooled data of the two years presented in the Table 5, the highest reducing sugar was observed in the T_2 (8.15%), followed by statistically similar T_1 (7.93%). These were followed by statistically different T_8 (7.88%) and T_7 (7.82%). However, the lowest reducing sugar was estimated in control (6.08%), which was followed by statistically similar T_4 (6.65%) and statistically different T_{11} (6.78%) and T_7 (7.01%).

3.9.15. Non-reducing sugar (%)

There was non-significant effect of the treatments on the non-reducing sugar (%) content of the litchi fruits (Table 5). In the pooled data of the two years, the highest non-reducing sugar was observed in the T_2 (2.14%), which was followed by statistically similar T_1 (2.07%), T_8 (2.00%) and T_7 (1.96%). However, the lowest non-reducing sugar was estimated in control (1.69%), which was followed by statistically similar T_4 (1.75%), T_{11} (1.76%) and T_3 (1.78%).

Table 5. Effect of foliar feeding of nutrients and bioregulators on total soluble solids and titratable acidity content of Litchi cv. Bombai.

Treatment	Treatment Details	TSS (^{0}Brix)	Titratable acidity (%)	Total sugar (%)	Reducing sugar (%)	Non-reducing sugar (%)
T_1	Borax @ 0.5%	14.02	0.78	10.12	7.93	2.07
T_2	Borax @ 0.3%	14.07	0.72	10.40	8.15	2.14
T_3	$ZnSO_4$ @0.75%	11.47	0.85	8.88	7.01	1.78
T_4	$ZnSO_4$ @ 0.5%	11.98	0.85	8.49	6.65	1.75
T_5	$CaCl_2$ @ 0.5%	12.70	0.82	9.03	7.12	1.82
T_6	$CaCl_2$ @ 0.1%	12.55	0.82	9.02	7.08	1.84
T_7	Humic Acid @ 1.5%	13.42	0.80	9.88	7.82	1.96
T_8	Humic Acid @ 1%	13.73	0.79	9.98	7.88	2.00
T_9	Seaweed extract @ 0.5%	12.95	0.88	9.28	7.27	1.92
T_{10}	Seaweed extract @ 0.1%	13.22	0.91	9.53	7.49	1.94
T_{11}	NAA (20 ppm)	11.78	0.93	8.63	6.78	1.76
T_{12}	Control (Water Spray)	9.82	1.00	7.85	6.08	1.69
SE m (±)		0.43	0.05	0.34	0.31	0.33
CD (0.05)		0.86	0.09	0.68	0.62	0.66
CV (%)		5.86	9.41	6.34	7.35	30.07

3.9.16. TSS: acidity ratio

The TSS: acid ratio varied significantly due to different treatments and reflected in Table 6 and Figure 7. From the pooled data, the highest TSS: acidity ratio was observed in the T_2 (20.33), which was followed by statistically significant T_1 (18.76) and statistically different T_8 (17.96), T_7 (17.25), and T_5 (16.35). However, the lowest TSS: acidity ratio was estimated in control i.e. T_{12} (9.99), which was statistically different than all other treatments. It was followed by T_{11} (12.74), T_3 (14.39), T_4 (14.74) and T_{10} (14.98).

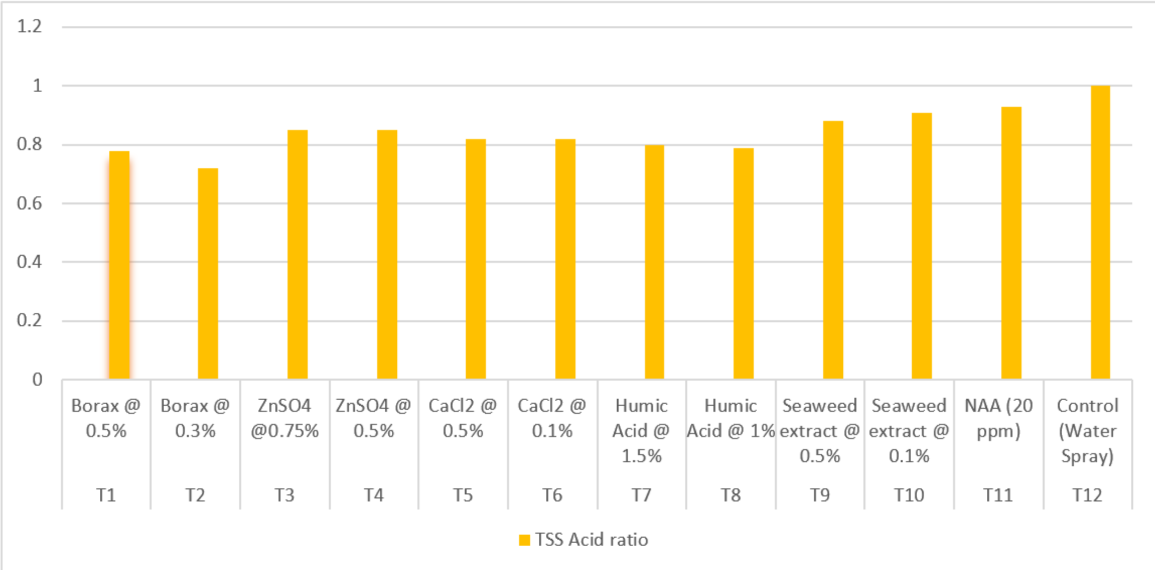

Figure 7. Effect of foliar feeding of nutrients and bioregulators on TSS:acid ratio of Litchi cv. Bombai.

3.9.17. Ascorbic content (mg/100 g)

There was significant effect of the treatments on the ascorbic content (mg/100 g) of the litchi fruits (Table 6). In the pooled data, the highest ascorbic was observed in the T_2 (32.22 mg/100 g), which was followed by statistically similar T_1 (32.06 mg/100 g). This was followed by statistically different T_7 (30.67 mg/100 g) and T_8 (30.56 mg/100 g). The lowest ascorbic was estimated in control i.e. T_{12} (27.06 mg/100 g), which was followed by statistically different to T_{11} (27.83 mg/100 g), T_3 (28.11 mg/100 g) and T_4 (28.50 mg/100 g).

Table 6. Effect of foliar feeding of nutrients and bioregulators on TSS: acid ratio and ascorbic acid content of Litchi cv. Bombai.

Treatment	Treatment Details	TSS :acid ratio	Ascorbic acid (mg/100g)
T_1	Borax @ 0.5%	18.76	32.06
T_2	Borax @ 0.3%	20.33	32.22
T_3	$ZnSO_4$ @0.75%	14.39	28.11
T_4	$ZnSO_4$ @ 0.5%	14.74	28.50
T_5	$CaCl_2$ @ 0.5%	16.35	29.61
T_6	$CaCl_2$ @ 0.1%	16.00	28.72
T_7	Humic Acid @ 1.5%	17.25	30.67
T_8	Humic Acid @ 1%	17.96	30.56

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T_9	Seaweed extract @ 0.5%	15.17	30.00
T_{10}	Seaweed extract @ 0.1%	14.98	30.11
T_{11}	NAA (20 ppm)	12.74	27.83
T_{12}	Control (Water Spray)	9.99	27.06
SEm (±)		1.25	0.33
CD (0.05)		2.52	0.67
CV (%)		13.75	1.95

4.0. Discussion

The study provides well defined results than those carried out previously, since our research predicted that foliar application of nutrients and bioregulators exhibited positive responses in enhancing yield and physico-chemical parameters of litchi fruits.

The total number of fruits per plant was recoded highest in plants sprayed with $ZnSO_4$ @ 0.5% followed by those treated with humic acid @ 1%. This result corroborates the findings of [26], who obtained maximum number of fruits per tree with spraying of zinc sulphate (0.6 %) in litchi. Similar findings were also reported by [27]. Humic acids might act as a medium for transporting nutrients from the soil to the plant because they can hold onto ionized nutrients, preventing them from leaching away. When they arrive at the roots, they bring along water and nutrients to the plant. This would have helped the better availability and utilization of nutrients [28]. The production of plant hormones and enzymes as well as the increase in root and shoot weight, chlorophyll content, and photosynthetic rate following humic acid application, might have also been shown to improve yields [29].

The highest total fruit yield was recorded in plants with foliar feeding of 0.3% Borax which was found to be statistically similar to plants treated with seaweed extract @ 0.1% and seaweed extract @ 0.5%. This result was in closeness with the findings of [30] who recorded enhanced total fruit yield over the control due to application of seaweed extract in Kiwi fruit. The essential nutrients contained in seaweed extracts viz. nitrogen, potassium, phosphorous, calcium, magnesium, sulphur, iron, sodium, zinc, and copper [31], might reduces the production losses caused by cracking without compromising either the quality or the yield in crops. The results are also in agreement with those reported higher yield per plant using humic acid on peach [32]; peach and apple [33], pear [34]. The increase in yield by boron application may be accredited to the positive effect of boron on increasing the rates of carbohydrate and RNA metabolism [35] as well as on accelerating the transport of photosynthates from the leaves to the developing fruits [36].

Among the treatments better response for higher number of marketable fruits and marketable yield was recorded in plants treated both 0.3% borax followed by 0.5% Zinc sulphate. Application of 1% Humic acid and 0.1% $CaCl_2$ also enhanced the marketable yield in litchi. This result was in line with the findings of [37] who reported higher yield of marketable fruits per plant due to application of boron. The beneficial role of boron may be assigned to its optimal level which might have played important role in flowering and fruiting processes, nitrogen metabolism, hormone synthesis and cell division [38]. It might helped in mobilization of food material to the fruits, thereby increasing the yield of healthy fruits. The findings are also in accordance with the reports of [39]. Boron is also related to biosynthesis of auxin in the meristem of plants. Boron deficiency leads to a decreased level of bound auxin and a reduction of IAA oxidase activity [40]. The marketable fruits represent the number of fruits excluding the cracked, pest and disease affected fruits. The data presented on fruit cracking in litchi in our experiment was fully supported with the findings of [41] who concluded that extent of fruit cracking was reduced significantly with the application of boron. Reduction in fruit cracking with the application of boron has also been reported in litchi by [42] and [43]. Uptake of water and solutes are governed by the presence of boron, zinc and other micronutrients. In case of enhanced water uptake, solutes accumulate in the fruits and minimize the pressure on the skin resulting in less cracking. Auxin stimulation both due to application of bioregulators might be the reason for accumulation of building block at a faster rate and better execution of source-sink relation registering higher fruit setting, retention and less cracking.

Application of 1% Humic acid followed by 1.5% Humic acid enhanced the fruit set (%) and fruit retention (%) along with reduction in fruit drop (%) in litchi. The application of humic acid works as a chelating agent for nutrients already present in the soil and make them available to plant. The results obtained through this study is in line with findings of [44] who studied the effect of humic acid in pomegranate and registered higher fruit set and fruit retention percentage with increasing rate of humic acid application. They also reported reduction in fruit drop percentage on higher humic acid rates. Positive and significant effect of humic acid has also been reported on grapes [45] and on pear [46,47].

The enhanced fruit size (fruit length and fruit breadth) and fruit weight was obtained in plants treated with 0.3% Borax in litchi. This increase in length of litchi fruit may be due to boron application which have direct role in hastening the process of cell division and cell elongation due to which size and weight would have improved. The increase in the size of fruits was due to the rapid fruit development and the greater mobilization of food materials from the site of production to storage organs under the influence of applied nutrients. A similar result found with treatment of boron had also been reported in litchi [48]. The present finding also corroborates with the finding of [49] who reported no obvious differences in fruit vertical diameter, transverse diameter, lateral diameter and fruit shape index among fruits of all treatments and control. These results are in conformity with those reported by [50] in guava and [51] in litchi. The increase in fruit weight might be due to the rapid increase in the size of cells or it is also due the fact that foliar application of boron increased the fruit weight eventually by maintaining lighter level of auxins in various parts of the fruits which helped in increasing the fruit growth [52].

The highest aril weight and lower seed weight was observed in plants treated with 0.3% Borax. The application of boron enhanced the aril weight and reduced the seed weight which as a consequence gave high aril /seed ratio. These findings are in line with the findings of [51] in litchi and [18] in apricot. The aril weight also depends on the fruit and seed size [53] but is affected by the plant nutrition [54]. Boron produced fruits with smaller seed. This may be due to involvement of boron in IAA metabolism which reduces seed size. The decrease in seed weight may be due to the fact that auxins induced parthenocarpic effect to some extent there by resulting lesser seed weight [55].

There were no significant differences observed in plants treated with nutrients and bioregulators with respect to pericarp weight in litchi. Similar findings in mango were also opined by [56] who reported that borax (1.0%) resulted no significant variation among treatments on peel weight of mango cv. Amrapali. Similarly, [57] concluded a non significant effect of borax (0.5 and 1.0%) and calcium nitrate (2.0 and 3.0%) on peel weight of litchi fruits cv. Rose Scented.

Aril: seed ratio is the ratio between the weight of aril and weight of seed. The maximum aril: seed ratio was recorded in the fruits harvested from plants treated with boron and the minimum was observed in untreated fruits. It pertains to the fact that application of boron enhanced the pulp weight and reduced the stone weight which as a consequence gave high pulp/stone ratio [58]. Similar findings are obtained by [18] and [59] in litchi.

The foliar application of borax had resulted in higher TSS and lower acidity in litchi cv. Bombai. Total sugars and reducing sugars were also improved due to application of borax. This is similar to the findings of [60] who reported that pre-harvest application of boric acid resulted in higher TSS, total sugar, reducing sugar and lower titratable acidity. The data presented on acidity of litchi was fully supported with the findings of [61] who observed that foliar spray of boric acid reduced acid levels in fruits of litchi. Lower acidity in fruits might be owing to increased sugar build up, improved sugar release into fruit tissues, and the conversion of organic acids to sugars [62]. Another possible cause for limiting the titratable acidity might also be due to fast acid consumption of organic acid in respiration.The higher TSS : acid ratio and ascorbic acid content were obtained in litchi due to foliar application of 0.3% borax followed by humic acid @ 1.5% and humic acid @1% in litchi. Similar findings were also reported by [63] who concluded that spraying of borax @ 0.5% or 1% increased

TSS and decreased the acidity content in litchi fruits. [59] also reported that spray of 0.4 per cent borax increase TSS, sugar and ascorbic acid content in litchi cv. Purvi while acidity was lowest.

5.0. CONCLUSION

The centre of attention of this research was to determine the efficacy of nutrients and bioregulators application for improving fruit yield and quality in litchi. All the treatments improved the fruit yield and yield attributing parameters of fruits viz., fruit length, fruit breadth, and fruit weight compared with the control in litchi during both the years of study. The increment in the yield could be explained as a result of increasing fruit physical characteristics such as fruit weight and number of fruits per plant. On the other hand, the improvement of fruit quality may be attributed to better growth of plant with different treatments of humic acid which might have favoured the production of better quality fruit. The increase in the fruit yield might also be due to the accumulation of sugars and other soluble solids in the fruits.

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Data Availability Statement: Available data is provided in the publication and any other information will be provided on demand.

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