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Influence of spraying nutrients and bioregulators on vegetative growth, flowering and productivity of litchi

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Abstract

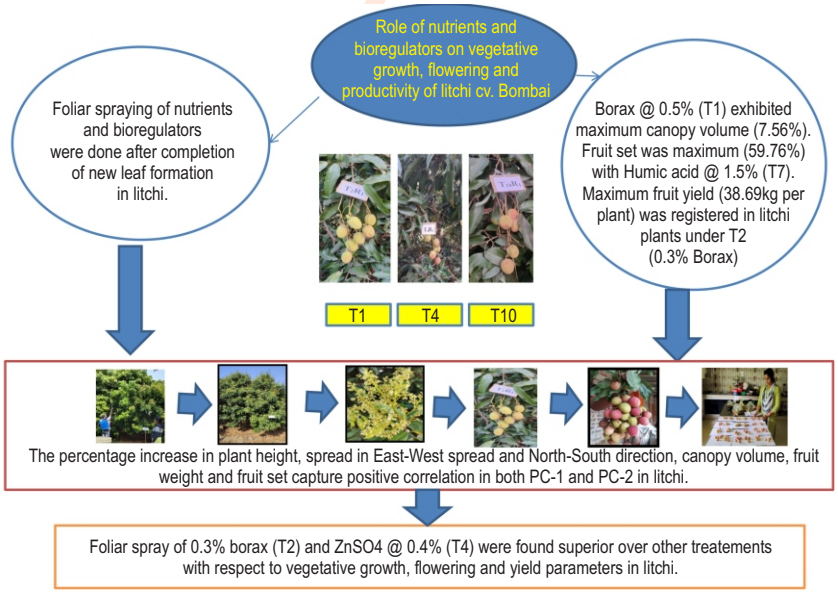
Aim: To investigate the influence of nutrients and bioregulators on the vegetative growth, flowering and productivity of Litchi.

Methodology: The vegetative growth, flowering and productivity of litchi cv. Bombai was assessed through application of nutrients and bioregulators.

Results: The plants receiving treatment with @ 0.5% Borax (T1) showed the highest percentage increase in canopy volume (7.56 %) and plant height (2.46 %) in litchi, outperforming all other treatments. The maximum productivity (38.69 kg per plant) was registered in plants under treatment T2 (0.3% Borax), which was found to be statistically at par (36.68 kg per plant) with plants treated with 0.1% Seaweed extract (T10) . The percentage increase in the plant height, plant spread in East-West and North-South direction, canopy volume, , fruit weight and fruit set capture positive correlation in both PC-1 and PC-2. The total contribution of PC-1 and PC-2 was 60.857 %.

Interpretation: Among all the treatments, T2 (0.3% borax) and T4 ($ZnSO_4$ @ 0.4%) treatments proved superior over other treatements with respect to vegetative growth, flowering and productivity parameters in litchi. However, further investigation need to be carried out with combination of these applied nutrients and bioregulators for getting acceptable results.

Key words: Bioregulators, Flowering, Growth, Litchi, Nutrients



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Introduction

Litchi (*Litchi chinensis* Sonn.) is a popular and ubiquitous fruit belonging to family Sapindaceae. It is referred to as the "queen of fruits" because of its outstanding quality, juicy fruit, well balanced sugar and acid content, unique, pleasant flavor, appealing color, and high nutritional content (Shukla *et al.,* 2004). It is a fruit of great commercial value due to its popular use both for table purpose and processed products. The global demand for fresh litchi fruit is higher than its processed products such as canned, dried, frozen, etc. Litchi fruit is gaining importance due to global export demand, aroma and nutritional content. The flower buds initiated in litchi develop towards the top of mature current-season branches. Low pseudo-hermaphrodite flower rate and high nutrient competition between organs are often associated with low productivity in litchi (Chang and Lin, 2006). Most people believe that managing nutrients appropriately is essential to maximize the productivity of fruit crops. Foliar spraying with macronutrients, particularly primary and micronutrients like Ca, B, Zn, Mn, and Fe, is a common practice in many orchards to prevent deficiency of these elements. In litchi plants, nutrients and bioregulators play a major role in the transition from vegetative to reproductive stages.

Well nourished plants mature more quickly, which improves fruit set and flowering, both of which boost productivity (Okolie *et al.,* 2018). A well-balanced control of plant nutrition is necessary for enhancing growth, stimulate blooming, and maximize productivity in litchi. Foliar spray of Zn can increase the Zn concentration in edible grain fractions as well as increase crop productivity (Singh *et al.,* 2022). Plants can grow and enhance productivity to the fullest extent with the usage of naturally occurring organic products called bioregulators (Lakhran *et al.,* 2021). Biostimulants are employed in fruit production techniques because they can enhance nutrient uptake, encourage plant development, and minimize the requirement of fertilizers (Kunicki *et al.,* 2010). Humic acids are essential for improving the soil's microbial population, structure, texture and ability to store water. These factors enhance the physical and biological activities of soil (Ram and Bose, 2000).

Scientists have reported the significant role of boron, zinc, calcium, humic acid, sea weed extract and auxin on the growth, productivity and quality of litchi fruits in India (Brahmachari *et al*., 1997; Nath *et al*., 2012; Begum *et al*., 2018; Singh and Singh, 2019 and Priyadarshi *et al*., 2018). On increasing the activities of hydrolyzing and oxidizing enzymes, humic acid present in humus can mobilize the reserve food material of the source to the sink. Seaweed extracts are now widely used as foliar fertilizers for fruits and vegetable crops (Jumadi *et al.,* 2023). The extracts are safe for the environment and naturally degradable (Mishra *et al.,* 2020). Seaweeds are undoubtedly utilized in the production of biofuel as well as therapeutics, nutraceuticals, plant growth stimulants in agriculture and cosmetics (Chellamanimegalai *et al.,* 2022). The seaweed extracts can increase the yield and quality of horticultural crops due to their bio stimulant effects, including improvements in plant nutrient-use efficiency and tolerance of abiotic and biotic stresses (Li *et al.,* 2022).

Due to regular fruit cracking, poor fruit set, high fruit shedding and other factors, litchi farmers in Western Odisha, India, are facing challenges of stunted growth, irregular flowering, and low yield due to which farmers in the western part of Odisha achieve an actual productivity of 6.6 t ha^{-1}, which is significantly lower than the productivity of other litchi-producing states in India, such as West Bengal (10.5 t ha^{-1}) and Bihar (8.0 t ha^{-1}). Low soil organic matter content, acidity and insufficient management practices used followed by litchi growers are some potential causes for poor development and low output. However, a number of studies have shown that applying nutrients and bioregulators, such as macro and micro nutrients, Seaweed extracts and humic acids enhance growth, regular flowering and higher productivity with good quality fruits in litchi (Khan *et al*., 2012; Nardi *et al*., 2021; Priyadarshi *et al*., 2018). Taking this into account, a study was carried out in the West Central Table Land Zone of Odisha, to determine the effect of nutrients and bioregulators on the vegetative growth, flowering, and productivity of litchi.

Materials and Methods

Eight-year-old litchi trees, cv. Bombai (*Litchi chinensis* Sonn.), were used as the experimental material. The plants propagated through air layering were planted in July 2012. The litchi plants were planted in a square system of planting, with a spacing of 8 m X 8 m, in a farmer's field in the Jamankira Block of Sambalpur district, Odisha, India. The study area is situated at a height of 171 m above mean sea level. The experimental site has a moderate, semi-arid environment with mild winters and scorching, dry summers. This study was conducted for two seasons (during 2020-2022) and set up in a Randomized Block Design (RBD) with 12 treatments replicated thrice. The treatments details are as follows: T_1: 0.5% Borax; T_2: 0.3% Borax; T_3: 0.75% $ZnSO_4$; T_4: 0.5% $ZnSO_4$; T_5: 0.5% $CaCl_2$; T_6: 0.1% $CaCl_2$; T_7: 1.5% Humic Acid; T_8: 1% Humic Acid; T_9: 0.5% Seaweed extract; T_{10}: 0.1% Seaweed extract; T_{11}: 20 ppm NAA and T_{12}: Water Spray (Control). The nutrients and bioregulators were applied during the first week of November, immediately following the end of fresh leaf production.

During the years 2021 and 2022, the experimental site had experienced a mean monthly temperature (maximum-32.7 °C and minimum- 22.4 °C), (maximum-83.00 % and minimum - 61.43 %) mean monthly relative humidity and a monthly rainfall of 147.69 mm (Regional Research Station and Technology Transfer Station, OUAT, Chiplima). The composite soil sample was collected prior to the start of the experiment and analyzed for a number of chemical parameters. The soil of the experimental site was acidic in nature with low organic carbon, low available phosphorous and medium available nitrogen and potassium content. The plant height, which has been explained as a percentage of promotion, was measured using a marked bamboo pole (15 m long) which stretched from the base at the collar region

of the trunk to the tip of the terminal growth of the central leader. The plant height was first measured in September 2020 i.e., before initiation of the experiment and subsequently, at the end of each year study i.e., in the month of July 2021 and 2022. The girth of the tree trunk was measured in centimeters with a measuring tape at a height of 0.3 m above the ground and calculated as a percentage of promotion. The plant girth, plant spread (East-West and North-South directions) were first measured before initiation of the experiment, and subsequently at the end of each year of study and expressed as percentage of promotion. The canopy volume was calculated by the formula of Westwood (1993).

The leaf area of each leaf was measured using a leaf area meter (SYSTRONICS, Leaf Area Meter-211) having a sensor and read-out unit. The number of days taken for initiation of flowering after spraying in plants was counted from three replications in each treatment and the mean was recorded. The number of days taken for 100% flowering was recorded by counting after 100 days from the date of spraying. Four panicles were randomly selected in four directions of each tree (one in each direction). After fifteen days through full bloom, the number of setted fruits from the marked panicle was counted. The following calculation was used to determine the percentage of fruit set:

Fruit set (%) = (Total number of fruit set on panicle) / (Total number of flowers in panicle) X 100

Ten fruit samples from each replication were collected and weighed on a digital weighing balance for calculating the mean fruit weight and expressed in gram. The total number of fruits on each plant was calculated post harvest. By multiplying the average number of fruits produced by plants by the average fruit weight, the productivity per plant was computed and expressed in kilograms.

Statistical analyses: The data statistically were analyzed according to Panse and Sukhatme (1989) for the Randomized Block Design. The significant variation among the treatments were determined by 'F' test and Critical Difference (CD) at a 5% level of significance to compare the mean values of the treatments for all the characters by Duncan's Multiple Range Test. The principal component analysis decreases the dimensions of a multivariate data to a few principal axes, generates an eigenvector for each axis and produces component scores for the characters and used for reducing multivariate data's dimensionality to a small number of primary axes, each of which is associated to an eigenvector (Jolliffie, 1986). After that, component scores are produced for each individual character. Based on PC1 and PC2, a graph was ploted in this study. The statistical analyses and graphical representations were conducted using Minitab 19, a statistical software package.

Results and Discussion

The results obtained on various parameters regarding vegetative growth, flowering and productivity of litchi were taken during the course of investigation along with statistical analyses and illustrated in this section. Data depicted in Table 1, revealed non-significant findings of the measured percent increase in plant height for various treatments. The highest percentage increase in plant height (2.46 %) in the pooled value for the years 2020–21 and 2021–22, was observed in T1 treatment, T6, T7, and T10 (2.43 % each) treatments. The minimum percentage increase in plant height (2.25%) was observed in the control plants (T12). Boron is essential for cell wall formation and is involved in the regulation of carbohydrate metabolism and it stimulates cells division and elongation, especially in meristematic tissues, and thereby enhances plant height in litchi.

This finding concurs with the study conducted by Kumar *et al.* (2017), who also found that tree growth characters like plant height was not affected by foliar application of nutrients like calcium, zinc and boron in different concentrations in litchi cv. Early Large Red under Haryana condition. Plant height may not always be directly impacted by nutrients and bioregulators, despite the fact that they can have an overall effect on plant health and productivity. The plant height is predominantly determined by genetic factors, intrinsic to the cultivar, being little affected by environmental factors. The percent increase in plant height due to application of $ZnSO_4$ could be a result of its role in synthesis of tryptophan (precursor of auxin) as a growth promoter, in RNA metabolism and ribosomal content in plant cells, leading to the stimulation of carbohydrates, proteins and DNA synthesis (Kumar *et al.*, 2017; Bisen *et al.*, 2020). The increase in plant height with boron application can also be ascribed to the fact that boron promotes cell division and elongation and is especially required for actively growing regions of plant-like apical meristems, thus promoting plant height. With respect to per cent increase in stem girth, the application of nutrients and bioregulators enhanced stem girth, which ranged between 5.30 % (T4) to 4.29 % (T12) (Table 1). Based on the pooled value of two years, the plants under T4 treatment exhibited the highest percentage increase in plant girth (5.30%), followed by treatment T10 (5.29 %). Plant girth was increased by least percentage (4.91%) in the treatment T12 (control).

The macronutrients, micronutrients and secondary metabolites found in seaweed extracts are abundant (Quiterio *et al.,* 2022; Lomartire *et al.,* 2022), application of which might have stimulated the plant growth by improving the uptake of nutrients by plants, efficiency of nutrient use by plants, and resistance of plants to stresses, while, seaweed extract can be beneficial for plant growth and health, its impact on height and girth is influenced by a combination of genetic potential, the specific growth-promoting properties of the extract, environmental conditions, plant health, and application method. The current study's observations of increased plant girth after applying borax and zinc sulphate are in line with the studies conducted on citrus by Khan *et al.* (2012) and Dhurve *et al.* (2018) in pomegranate. While zinc and boron are essential for plant health and development, they are not the primary factors that determine plant girth. Zinc is required for the synthesis of IAA, carbohydrate

Table 1: Influence of spraying of nutrients and bioregulators on the vegetative growth traits of Litchi cv. Bombai

Treatments	Increase in plant height (%) Pooled	Increase in stem girth (%) Pooled	Increase in the East-West canopy spread percentage Pooled	Increase in North-South canopy spread percentage Pooled	Canopy volume (m^3) Pooled	Leaf area (cm^2) Pooled
T_1	2.46[a]	5.15[abcdef]	2.41[a]	2.48[ab]	7.56[a]	31.06[abcdefghij]
T_2	2.38[abcdefg]	5.09[abcdefg]	2.35[ab]	2.34[abcdefghijk]	7.28[abcdefgh]	31.6[abcdef]
T_3	2.39[abcdef]	5.05[abcdefghi]	2.31[abcd]	2.44[abcde]	7.34[abcd]	31.26[abcdefghi]
T_4	2.35[abcdefghij]	5.30[a]	2.32[abc]	2.53[a]	7.3[abcdef]	32.26[abc]
T_5	2.36[abcdefghi]	5.06[abcdefgh]	2.29[abcde]	2.39[abcdefghi]	7.22[abcdefghij]	31.48[abcdefg]
T_6	2.43[ab]	5.18[abcde]	2.25[abcdefg]	2.42[abcdefg]	7.38[abc]	32.15[abcd]
T_7	2.43[abc]	5.01[abcdefghijk]	2.23[abcdefghijk]	2.36[abcdefghij]	7.33[abcde]	31.28[abcdefgh]
T_8	2.40[abcde]	5.24[abc]	2.24[abcdefghi]	2.4[abcdefgh]	7.29[abcdefg]	32.83[ab]
T_9	2.37[abcdefgh]	5.04[abcdefghij]	2.25[abcdefgh]	2.45[abc]	7.26[abcdefghi]	33.41[a]
T_{10}	2.43[abcd]	5.29[ab]	2.29[abcdef]	2.44[abcdef]	7.4[ab]	32.12[abcde]
T_{11}	2.30[abcdefghijk]	5.20[abcd]	2.24[abcdefghij]	2.45[abcd]	7.12[abcdefghijk]	30.99[abcdefghijk]
T_{12}	2.25[abcdefghijk]	4.91[abcdefghijk]	2.17[abcdefghijk]	2.29[abcdefghijk]	6.89[bcdefghijk]	30.17[abcdefghijk]
SE m (±)	0.087	0.201	0.087	0.711	0.211	1.419
C.D.(0.05)	0.18 (NS)	0.40 (NS)	0.17 (NS)	0.14 (NS)	0.43 (NS)	2.86 (NS)

Standard error of means (SE m (±); Critical Difference (CD) at 5% significance level; *abcdefghijk—the non-significant group—represents the significance level of 5%.

metabolism, protein synthesis, internodes elongation for plant girth. The significant increase in plant girth might be due to effect of zinc and boron in the synthesis of chlorophyll, accumulation of photosynthates, nitrogen assimilation, protein synthesis and also as catalytic agents in the activation of enzymes. The data regarding the percentage increase in canopy spread in an east-west direction was found to be non-significant are included in Table 2. The range of the observed value varied between 2.41 % in plants under T_1 to 2.17 % in T_{12} (control). The use of boric acid may have increased the trunk girth because foliar boron application decreased the biomass output in a variety of crops (Yermiyahu *et al.,* 2007). This increase in girth with boron application might be due to the role of boron on uptake of essential plant nutrients, metabolism and transport of essential biomolecules in plants, new cell division in meristamatic tissue, translocation of sugar, starch, nitrogen, phosphorus, certain hormones, synthesis of amino acids and protein, regulation of carbohydrate metabolism, development of phloem, etc. (Stenico *et al*., 2009).

The influence of foliar application of nutrients and bioregulators on the percentage increase in canopy spread in the North-South direction of litchi crop was statistically non-significant (Table 2). It was recorded highest (2.48%) in plants under treatment T_1, while T_{12} had the lowest (2.29%) value. The data on canopy volume for each treatment was non-significant. The pooled value varied from 7.56 (T_1) to 6.89 m^3 (T_{12}). The treatment T_1 showed a highest increase in canopy volume (7.56 m^3), outperforming the effects over other treatments. The control plants (T_{12}) showed the least increase in canopy volume (6.98 m^3). The higher carbohydrate accumulation in leaves facilitated by a favorably influenced combination of zinc and boron application might have lead to higher photosynthetic activities, and ultimately resulting in an increased plant spread and leaf area. The plant spread and leaf area is more directly related to the photosynthetic efficiency. The data depicted in Table 2, revealed non-significant effect of various treatments on leaf area. The maximum leaf area (33.41 cm^2) was noted in the plants under treatment T_9 followed by T_8 (32.83) cm^3 whereas the minimum leaf area was observed in T_{12} (30.17) treatment. The pooled data for two years, exhibited that T_1 recorded the highest percentage increase in plant height (2.46%) and canopy volume (7.56 m^3) in litchi. It was also superior to all other treatments. The application of zinc sulphate and boric acid resulted in an increase in the plant height and canopy volume. This can be explained by the fact that zinc promoted the synthesis of auxins, which in turn led to an increase in the canopy volume and tree height, while boron caused rapid development and differentiation of tissues. The findings of the present study are consistent with those of Babu and Singh (2002), who noted that the application of boric acid (0.3%) and zinc (0.6%) resulted in an increase in the vitality and proliferation of litchi plants. It is apparent from the data provided in Table 2, that the plants treated with 0.3% borax (T_2) produced earliest flowering days (69.24 days) followed by statistically similar treatments at 69.35 days for T_{10}, 69.46 days for T_4, and 69.79 days for T_3, respectively, which were significantly better than all other treatments.

The highest number of days (74.36 days) required for the first flowering of treatment T_{11} was statistically comparable to treatments T_6 (74.19 days), T_{12} (74.36 days), and statistically distinct from treatment T_7 (72.50 days). The findings of the current investigation concur with the findings of Pathak and Mitra (2008)

Table 2: Influence of spraying of nutrients and bioregulators on days required for initiation and 100 % flowering in Litchi cv. Bombai

Treatments	Days to initiation of flowering	Days to 100 percent flowering	Fruit set (%)
	Pooled	Pooled	Pooled
T_1	70.41^{ef}	105.33^{ghi}	53.07^{cde}
T_2	69.24^{ghi}	109.17^{ab}	53.11^{cd}
T_3	69.79^{g}	105.67^{defgh}	52.10^{cdefg}
T_4	69.46^{gh}	110^{a}	51.88^{cdefgh}
T_5	73.93^{abcd}	105.17^{ghij}	$51.84^{cdefghi}$
T_6	74.19^{ab}	106.67^{cd}	$51.76^{cdefghij}$
T_7	72.50^{d}	106^{cdefg}	59.76^{a}
T_8	71.89^{de}	109.5^{ab}	58.17^{ab}
T_9	71.00^{ef}	106.5^{cde}	53.53^{c}
T_{10}	69.35^{ghi}	107^{c}	52.73^{cdef}
T_{11}	74.00^{abc}	106.5^{cdef}	$51.60^{cdefghij}$
T_{12}	74.36^{a}	104.5^{ij}	46.49
SE m (±)	0.42	0.359	1.03
CD (0.05)	0.85	0.72	2.08

SE m (±)—Standard Error of means; Critical Difference (CD) at 5% level of significance; *abcdefghijk—represents the non-significant group—5% level of significance.

in litchi under West Bengal condition. The beneficial role of boron may be assigned to its optimal level which might have played important role in flowering processes, nitrogen metabolism, hormone synthesis and cell division. The plants treated with 0.3% Borax (T_2) was found best treatment for early flowering in litchi which confirms that boron is essential for flowering and fruit set and its deficiency may result in flower and fruit drop as well as misshapen fruit. It has been demonstrated that zinc induces flowering, which is crucial during several phases of plant growth and development, including photosynthesis, root and shoot growth, flowering, and fruit formation (Singh *et al*., 2016; Dhruve *et al*., 2018). In the current research, boron application initiated flowering in litchi plants, more benefitable by maintaining a higher nutritional state.

There were considerable variations among treatment with respect to number of days required for 100% flowering (Table 2). Treatment T_4 had the highest days to 100% blooming (110.00 days), followed by statistically identical T_8 (109.50 days), and statistically dissimilar T_{10} and T_6 (107.00 and 106.67 days), however, T_{12} (104.50 days) showed the lowest days to 100% flowering, followed by significantly different T_5 (105.17 days), T_1 (105.33 days) and T_3 (105.67 days), respectively. The present outcome lined up with the research conducted by Sarthak kumar *et al.* (2022), who suggested that the use of 0.25 % Borax and 0.25 % $ZnSO_4$ led to enhanced development, flowering, and fruiting characteristics in papaya cv. Red Lady grown in Shivamogga, Karnataka. Table 2, presents the results of the application of various nutrients and bioregulators on the percentage of fruit set percentage in litchi. Treatment T_7 (1.5% humic acid), recorded the highest fruit set (59.76%) which was statistically comparable to the plants treated with T8 (58.17%).

However, T_{12} treatment showed the lowest fruit set (46.49%) and thus, it became apparent that this treatment was statistically inferior to other treatments. Since boron plays a role in flowering and fruiting processes, pollen germination, cell division, active salt absorption, and hormonal movement as well as fertilization processes, glucose metabolism, hydrocarbons and their transport, regulation of metabolism and translocation of carbohydrates, cell wall development, and RNA synthesis, it is possible that foliar spraying of boron will result in superior fruit set (Ram and Bose, 2000). Application of 1% and 1.5% humic acid, raised, the fruit set percentage in litchi. Application of humic acid helps the plants to absorb nutrients from the soil by acting as a chelating agent. The findings of the current study are in consistent with those of Khattab *et al.* (2012), who investigated the effects of humic acid in pomegranates and observed that higher rates of humic acid spraying led to larger percentage of fruit set.

Data presented in Table 3 shows that T_2 treated plants had the highest fruit weight (20.85 g). This fruit weight was found to be statistically equivalent to T_3 (20.39 g), T_{10} (20.02 g), and T_5 (19.81 g) treatments. The fruit weight of T_{12} treated plants was found to be lowest (18.26 g). The observed augment in fruit weight in T2 could have resulted from either a rapid increase in cell size or due to foliar application of boron, which maintained a smaller quantity of auxins in different parts of the fruits, thereby promoting fruit growth (Haq *et al.,* 2013). The increased fruit weight in litchi may be due to direct acceleration of cell division and elongation caused by boron treatment. Fruits developed rapidly and translocated more food from the production site to storage organs as a result of nutritional supply, making fruits heavier. Kumar *et al.* (2009) had previously observed similar effect in litchi following boron treatment. The increase in fruit weight due to boron application might be due to its effect on rapid increase in the size

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Table 3: Influence of spraying of nutrients and bioregulators on fruit weight, number of fruits per plant and productivity in Litchi cv. Bombai

Treatments	Fruit weight (g)	Number of fruit per plant	Productivity per plant (kg)
T_1	18.91^{bcdefg}	1636.31^{defghij}	30.44^{efghijk}
T_2	20.85^{a}	1858.03^{abc}	38.69^{a}
T_3	20.39^{ab}	1717.80^{bcdefghi}	34.73^{bcdef}
T_4	18.30^{efghijk}	1972.08^{a}	35.85^{abcd}
T_5	19.80^{abcd}	1625.68^{efghijk}	31.10^{efghij}
T_6	18.59^{cdefghij}	1801.94^{abcde}	32.97^{bcdefg}
T_7	18.63^{cdefghi}	1730.42^{bcdefgh}	32.10^{defghi}
T_8	18.84^{cdefgh}	1864.91^{ab}	34.93^{abcde}
T_9	19.81^{bcde}	1785.04^{bcdef}	36.41^{abc}
T_{10}	20.02^{abc}	1836.79^{abcd}	36.68^{ab}
T_{11}	18.95^{bcdef}	1735.27^{bcdefg}	32.79^{bcdefg}
T_{12}	18.26^{efghijk}	1627.77^{efghijk}	29.65^{efghijk}
SE m (±)	0.51	69.74	1.53
CD (0.05)	1.04	140.56	3.09

SE m (±)—Standard Error of means; Critical Difference (CD) at 5% level of significance; *abcdefghijk—represents the non-significant group—5% level of significance.

of cells or by maintaining lighter level of auxins in various parts of the fruits which enhanced fruit growth. Boron also helps in hastening the process of cell division and cell elongation due to which fruit weight would have improved.

Data depicted in Table 3 showed significant variation in the number of fruits per plant due to different treatments. Treatments T_8, T_2 and T_{10} recorded 1864.91, 1858.03 and 1836.79 fruits per plant have been demonstrated to be statistically equivalent to T_4, which yielded the maximum total number of fruits per plant (1972.08). T_{12} treated plants, produced least number of fruits per plant (1627.77). Plants sprayed with (0.5% $ZnSO_4$) (T_4) produced the maximum total number of fruits per plant followed by those treated with (1% humic acid) (T_8). The results of this study corroborate with Brijpal *et al.* (2020), who recorded highest number of fruits per plant, when zinc sulfate (0.6%) was sprayed on guava trees because it is considered as an essential plant nutrient that helps in enzyme activation, protein synthesis, photosynthesis, hormone regulation and nutrient uptake, which ultimately resulted in production of more number of fruits per plant. Plants under treatment T_2 (0.3% Borax) showed highest productivity (38.69 kg per plant). The result was found to be statistically equivalent to the plants treated with 0.1% Seaweed extract (T_{10}) with 36.68 kg per plant; 0.5% Seaweed extract (T9, with 36.41 kg per plant), and 0.5% $ZnSO_4$ (T_4, with 35.85 kg per plant). In T_{12} treated plants (Control), the lowest fruit yield of 29.65 kg per plant was noted. It has been demonstrated that each treatment ($_{T2}$, T_{10}, T_9, and T_4) had a statistically significant effect on the quantity of fruit that each plant produced.

Application of boron, zine as well as bioregulation might have promoted production improved growth, improved flowering, and enhanced fruit set. The optimum amount of boron can subsequently be added to processes that help in fruit productivity, including hormone synthesis, auxin production, nitrogen breakdown, cell division, and mobilization of food material for fruit. Overall fruit productivity was highest in plants treated with 0.3% foliar application of borax (T_2), and this was statistically similar to plants treated with 0.1 % (T_{10}) and 0.5 % (T_9) seaweed extract. This outcome is in line with Rana *et al.* (2023), who found that of application seaweed extract to Kiwi fruit increased overall fruit productivity compared to control. Seaweed extracts are rich in essential macro and micro nutrients (Margal *et al.,* 2023). Plants treated with 1% humic acid (T_8), produced 34.93 kg of fruits per plant. According to Serenella *et al.* (2002), humic acid may act as a bio-stimulant, aiding in an array of physiological processes in the crop, including photosynthesis and increased root growth activity and cell permeability. This increases nutrient uptake, which contributes to higher productivity (Canellas *et al.,* 2002). The rise in fruit weight and number per plant, as well as a multitude of fruit-related physical characteristics, may be the reason improved production.

Principal component analysis was applied on 12 parameters studied in this experiment viz., percent increase in plant height, percent increase in stem girth, percent increase in canopy spread in both east-west and north-south directions, canopy volume, leaf area, days required for initiation and 100 percent flowering, fruit set, fruit weight, total number of fruits per plant and total productivity (Fig. 1). In the results of principal component analysis (PCA), the eigen values for each principal component (PC) are given, along with the proportion of variance each explains and the cumulative variance was explained. A common rule of thumb for determining the number of PCs to retain is the Kaiser criterion, which suggests keeping PCs with eigen values greater than one. The total contribution of PC-1 and PC-2 was 60.857 %. The results revealed presence of 5 PCs with

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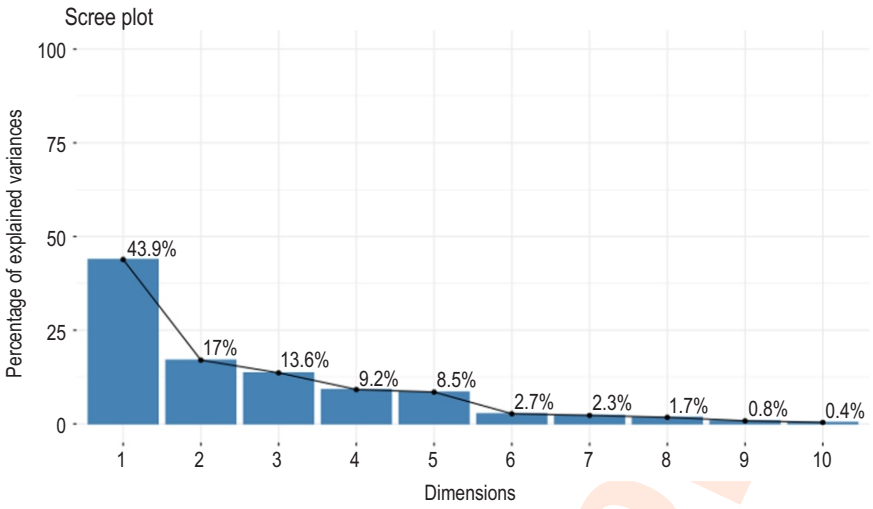

Fig.1: Principal components with their cumulative variance.

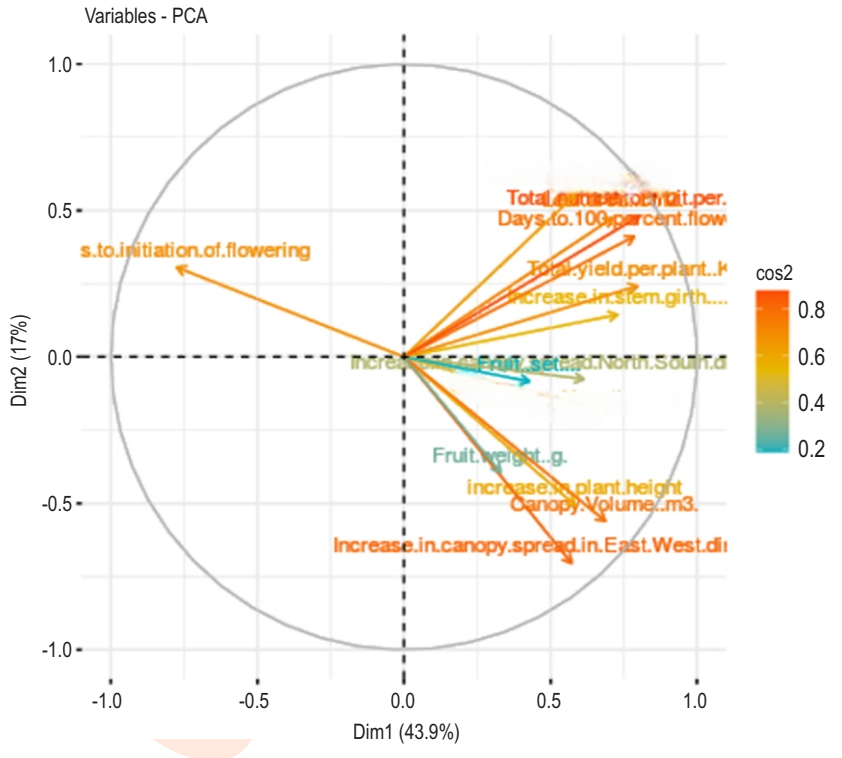

Fig. 2: Principal component analysis with 12 morphological and yield related traits in litchi.

their eigen values accounting for 92.083% of cumulative proportion of variances. In this case 5 principal components (PCs) were identified extracting cumulative proportion of variance of 92.083%. As observed from the loading plot, PC-1 (43.862%) and PC-2 (16.995%) presented a cumulative variance of 60.857% (Fig. 1). Fig. 2 shows the loading of 12 variables for top two principal components (PC1 and PC2). Dim1 and Dim 2 represent PC1 and PC2, respectively. The vectors originating from centre of the plot represents positive or negative correlation among variables based on their relative position on four

quadrants and their closeness determines the strength of correlation. The length of the vectors indicates the strength of correlation of variables with PC. PC1 showed strong positive loadings with many variables, such as increase in plant height, increase in stem girth, increase in canopy spread in both East-West and North-South directions, canopy volume, and leaf area, days to 100 % flowering, number of fruits per plant, total yield etc (Fig. 2). It suggests that PC1 captures a general pattern related to plant growth and development. There are negative loadings with "days to initiation of flowering. PC2 showed strong positive loadings for plant height, percentage increase in spread in East-West spread and North-South direction, canopy volume, fruit weight and fruit set percentage. The plant height, spread in East-West and North-South direction percentage, canopy volume, fruit weight and fruit set capture positive correlation in both PC-1 and PC-2. However, days required for initiation of flowering contribute negatively to both PC-1 and PC -2 (Fig. 2) (Massay, 1965; Jolliffie,1986).

Application of nutrients and bioregulators had no significant effect on vegetative growth in litchi. However, among all the nutrients and bioregulators studied in this experiment, Borax @ 0.3 % was found to be more effective improvement of most of the characteristics studied viz., fruit weight and fruit yield. Hence, foliar spray of borax @ 0.3 % proved to be beneficial and best for better flowering and yield of litchi *cv*. Bombai.

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References

Babu, N. and A.R. Singh: Effect of micronutrients spray on fruit cracking of litchi fruits. *Haryana J. Hort. Sci.,* **13**, 18-21(2002).

Begum, M.; B.C . Bordoloi, D.D. Singha and N.J Ojha : Role of seaweed extract on growth, yield and quality of some agricultural crops: A review. *Agricultural Rev*.,**39**, 321-326 (2018).

Bisen, B. , J.P. Tiwari, K.K. Mishra and S. Lal: Effect of zinc sulphate on vegetative growth, yield and leaf nutrient status of guava (*Psidium guajava* L.). *Int. J. Current Microb. Appl. Sci.*, **9**, 1265-1273 (2020).

Brahmachari, V.S., G.S. Yadav and N Kumar. Effect of foliar feeding of calcium, zinc and boron on field and quality attributes of litchi (*Litchi chinensis* Sonn.). *Orissa. J. Hort.*, **25**, 49-52(1997).

Brijpal, B., J.P. Tiwari, K.K. Mishra and S. Lal: Effect of zinc sulphate on vegetative growth, productivity and leaf nutrient status of guava (*Psidium guajava* L.). *Int. J. Curr. Microbiol. App. Sci.,* **9**, 1265-1273 (2020).

Canellas, L.P., B.D. Leonardo and C. Silva: Humic acids cross interactions with root and organic acids. *Ann. Appl. Biol.,* **153**, 157-166 (2002).

Chang, J.C. and T.S. Lin: GA3 increases fruit weight in 'Yu Her Pau' litchi. *Sci. Hortic.,* **108**, 442–443 (2006).

Chellamanimegalai, P., A.K. Balange, A.P. Kumar, A. Dwivedi and G. Deshmukhe: Biochemical properties of different species of seaweeds (*Grateloupia*) from the Indian coast and analysis of spatial variation in two selected species. *J. Environ. Biol.,* **43**, 733-738 (2022).

Dhurve, M.K., T.R. Sharma, M.S. Bhooriya and G.Lodha: Effect of foliar application of zinc and boron on growth, reproductive and yield of pomegranate *cv*. Ganesh in Hast bahar. *Int. J. Chem. Stu.*, **6,** 499-503 (2018).

Haq, I., A. Rab and M. Sajid: Foliar application of calcium chloride and borax enhance the fruit quality of litchi cultivars. *Animal Plant Sci.,* **23**, 1385-1390 (2013).

Ilyas A., M.Y. Ashraf., M. Hussain,M. Ashraf, R. Ahmed and A.Kamal. Effect of micronutrients (Zn, Cu and B) on photosynthetic and fruit yield attributes of (*Citrus reticulata* Blanco) var. Kinnow. *Pak. J. Bot.*, **47**, 1241-1247(2015).

Jolliffe, I.T.: Principal Component Analysis and Factor Analysis. In: Principal Component Analysis, 2nd Edn., Springer, New York, pp.115-128 (1986).

Jumadi, O. , A.D. Annisi, Y.A. Djawad, N. Bourgougnon, N.A. Amaliah, A. Asmawati, A.B. Manguntungi and K. Inubushi: Brown algae (*Sargassum* sp.) extract prepared by indigenous microbe fermentation enhanced tomato germination parameters. *Biocatalys. Agric. Biotech*., **47**,102601(2023).

Khattab, M.M., A.E. Shaban, A.E. Shrief and A. Mohamed: Effect of humic acid and amino acids on pomegranate trees under deficit irrigation. Growth, flowering and fruiting. *J. Hort. Sci. Orn. Plants,* **4**, 253−259 (2012).

Khan, A.S., W. Ullah, A.U. Malik, R. Ahmed, B.A. Saleem and I.A. Rajwana: Exogenous applications of boron and zinc influence leaf nutrient status, tree growth and fruit quality of Feutrells Early (*Citrus reticulata* Blanco). *Pakistan J. Agric. Sci.,* **49**, 113-119 (2012).

Khan, A.S., B. Ahmad, M.J. Jaskani, R. Ahmad and A.U. Malik: Foliar application of mixture of amino acids and seaweed (*Ascophylum nodosum*) extract improve growth and physico-chemical properties of grapes. *Int. J. Agric. Biol*.,**14**, 383-388 (2012).

Kumar, D., M. Suleman, K. Rajesh and C Subhash: Effect of different nutrient sprays on growth, fruit productivity and quality of litchi (*Litchi chinensis* Sonn.) cv. Early Large Red. *Res. Crops,* **18**, 61-65 (2017).

On Line Copy

Kumar, M., R. Kumar and R.P. Singh: Effect of micronutrients and plant growth regulators on fruiting of litchi. *Int. J. Agric. Sci.,* **5**, 521–524 (2009).

Kunicki, E., A.S. Grabowska, A. Ekara and R. Wojciechowska: The effect of cultivar type, time of cultivation, and biostimulants treatment on the productivity of spinach (*Spinacia oleracea* L.). *Folia Hortic.,* **22**, 9–13 (2010).

Lakhran, H., O.P. Sharma, R. Bajiya, J.R. Choudhary, S. Kanwar and M. Choudhary: Effect of foliar application of bioregulators for improving high temperature tolerance of wheat (*Triticum aestivum* L.). *J. Environ. Biol.,* **42**, 1078-1084 (2021).

Li, J., G.T. Van and D. Geelen: A meta-analysis of biostimulants yield effectiveness in field trials. *Front. Plant Sci.,* **13**, 836702 (2022).

Lomartire, S. and A.M.M. Gonçalves: Novel technologies for seaweed polysaccharides extraction and their use in food with therapeutically applications—a review. *Foods*, **11**, 2654 (2022).

Massay, W. F.: Principal components regression in exploratory statistical research. *J. Amer. Statist. Assoc.*, **60,** 234-246 (1965).

Margal, P.B., R.S. Thakare, B.M. Kamble, V.S. Patil, K.B. Patil and N.S. Titirmare: Effect of seaweed extracts on crop growth and soil: a review. *J. Exper. Agric. Int.,* **45**, 9–19 (2023).

Mishra, A., S. Sahni, S. Kumar and B.D. Prasad: Seaweed—An eco-friendly alternative of agrochemicals in sustainable agriculture. *Curr. J. Appl. Sci. Technol.,* **39**, 71–78 (2020).

Nardi,S., M. Schiavon and O. Francioso: Chemical structure and biological activity of humic substances define their role as plant growth promoters. *Molecules*, **26**, 2256 (2021).

Nath, S., M. Kumar, O.K. Ojha and K.K. Jha: Yield and physico-chemical properties of litchi fruits as affected by different rates of pruning and chemical spray. *Progress. Hort*, **44**, 166-169 (2012).

Okolie C. L., B. Mason and A.T. Critchley: Seaweeds as a source of proteins for use in pharmaceuticals and high-value applications. In: Novel Proteins for Food, Pharmaceuticals, and Agriculture: Sources, Applications, and Advances (Ed.: M. Hayes). Hoboken, NJ: Wiley, NJ, USA, pp. 217- 225 (2018).

Panse, V.G. and P.V. Sukhatme: Statistical Methods for Agricultural Workers, Indian Council of Agricultural Research, New Delhi (India), pp. 152-165 (1989).

Pathak, P.K. and S.K. Mitra: Effect of phosphorus, potassium, sulphur and boron on litchi. *Indian J. Hortic.,* **65**,137-140 (2008).

Priyadarshi, V., K. Mehta, D. Hota, G. Mishra and A. Jogur: Effect of growth regulators and micronutrients spray on vegetative growth of litchi (*Litchi chinensis* Sonn.) *cv*. Calcuttia. *Agric.Update.,***12**, 707-712 (2018).

Quiterio, E., C. Grosso, R. Ferraz, C.D. Matos and C.A. Soares: Critical comparison of the advanced extraction techniques applied to obtain health-promoting compounds from seaweeds. *Marine Drugs,* **20**, 677 (2022).

Ram, R.A. and T.K. Bose: Effect of foliar application of magnesium and micronutrients on growth, productivity and fruit quality of mandarin orange (*Citrus reticulata* Blanco.). *Indian J. Hort.,* **57**, 215-220 (2000).

Rana, V.S., V. Sharma, S. Sharma, N. Rana, V. Kumar, U. Sharma, K.R. Almutairi, G.D. Avila-Quezada, E.F. Abd-Allah and K.K. Gudeta: Seaweed extract as a biostimulant agent to enhance the fruit growth, yield and quality of kiwifruit. *Horticulturae,* **9**, 432 (2023).

Serenella, N., A. Pizzeghelloa, N. Muscolob and A. Vianello: Physiological effects of humic substances on higher plants. *Soil Biol. Biochem.,* **34**, 1527-1536 (2002).

Sharathkumar, K.H., M. Shivanna, S. Anilkumar, M.K. Honnabyraiah, G.S.K. Swamy and R. Venkat: Effect of foliar spray of potassium and micronutrients on productivity and quality of papaya (*Carica papaya* L.) cv. Red Lady. *Int. J. Plant Soil Sci.,* **34**, 856-863 (2022).

Shukla, A.K., A.K. Shukla ans B.B. Vashishtha: Fruit Breeding: Approaches and Achievements. **Volume1**, International Book Distributing Company, Fruit, 342 pages (2004).

Singh, S. and J.P. Singh: Effect of foliar sprays of NAA and boron on flowering, fruiting, fruit retention and yield of litchi (*Litchi chinensis* Sonn.). *Int. J.Chem. Stud*., **7**, 1995-1999 (2019).

Singh, U., J. Dong, C. Jian and K.K. Hazra: Optimizing zinc foliar spray for zinc fortification and productivity improvement in wheat. *J. Environ. Biol*., **43**, 739-745 (2022).

Singh, N., A. Kaur and B.S. Gill: Effect of foliar application of zinc and boron on yield and fruit quality of litchi cv. Dehradun. *Int. J. Dev. Res.*, **6,** 8686-8688 (2016).

Stenico, S.M.E., F.T. Pacheco Pereira, E.R. Filho, J.L. Rodrigues, A.N. Souza., A. Etchegaray, J.E. Gomes and S.M. Tsai: Nutritional deficiency in citrus with symptoms of citrus variegated chlorosis disease. *Braz. J. Biol.*, **69**, 859-864 (2009).

Westwood, M.N.: Plant efficiency: Growth and productivity measurements, Temperate zone pomology, W.H. Freeman and company (San Francisco), pp. 275-282 (1993).

Yermiyahu, U., A.B. Gal, P. Sarig and E. Zipilevitch: Boron toxicity in grapevine (*Vitis vinifera* L.) in conjunction with salinity and rootstock effects. *J. Hort. Soc. Biotechnol.,* **82**, 547-554 (2007).

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