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Influence of nutrients and plant bioregulators on yield and fruit quality of litchi cv. Deshi

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ABSTRACT

The present study was carried out with foliar spray of nutrients and plant bioregulators (PBRs) on yield and fruit quality of litchi cv. Deshi. The fruit trees were sprayed (10 days after fruit set) with different concentrations of K_2SO_4 (1 & 2 %), KNO_3 (1 & 2 %), $CaCl_2$ (1 & 2 %), and $MgCl_2$ (1 & 2 %). Another set of spray [foliar at colour break stage] was done of abscisic acid (ABA) @ 150 ppm, ethephon @ 500 ppm and ABA @ 150 ppm + ethephon @ 500 ppm. The pre-harvest spray of KNO_3 (1 & 2 %) caused the higher yield (82.03 & 79.47 kg tree^{-1}, respectively) as compared to the control trees (65.79 kg tree^{-1}). The spray of KNO_3 (1 & 2 %), also recorded better fruit length (3.47 cm; 3.43 cm), diameter (2.54 cm; 2.51 cm), fruit weight (17.51 g; 16.68 g), peel weight (2.78 g; 2.75 g), aril weight (10.11 g; 9.96 g) and seed weight (3.61 g; 3.56 g, respectively). However, the spray of ABA @ 150 ppm alone proved best for bringing high TSS, TSS/Acid ratio, total sugars and anthocyanin contents in the fruits. The control trees had highest titratable acidity and vitamin C content. Further, the fruit colour of the litchi pericarp was much better in almost all treatments as compared to the control trees. Thus, pre-harvest spray of KNO_3 (1 % or 2 %) improved the fruit yield and many quality attributes. TSS, total sugar and anthocyanin content of the fruits was improved because of spray of ABA @ 150 ppm (alone) in litchi cv. Deshi.

Key words: Pre-harvest, ethephon, anthocyanin, fruit colour, pericarp.

INTRODUCTION

Litchi (*Litchi chinensis* Sonn.) is a subtropical fruit crop, a native of the region bounded by Southern China, Vietnam and Northern Malaysia. It is an important summer season fruit crop with attractive red colour, high economic and nutritional value. Litchi fruits contains 83.6 g of moisture, 0.7 g of protein, 0.1 g of fat, 15.0 g of carbohydrates, 4.0 mg of calcium, 32.0 mg of phosphorus, 0.7 mg of iron, 0.02 mg of thiamine, 0.07 mg of riboflavin, 1.1 mg of niacin, and 15.0 mg of ascorbic acid with short duration of harvesting (Menzel, 11). The fruit skin colour is desirable characters to fetch premium price by the litchi growers, but litchi cultivar Deshi has light red colour at maturity time. This cultivar is famous for its medium to large fruit, attractive bright red fruit colour, small seed, sweet taste, good flavour, and is one of the early maturing cultivars with regular bearing ability, and suitability to grow in Bihar and West Bengal.

Potassium sulphate sprayed on litchi fruit tends to develop attractive red colour (i.e. lowest H, S, and B values), because the lower H value represents a redder colour in the fruit (Su *et al.*, 18). Spray of K and Mg salts on litchi fruits decreases the build-up of yellowish pigments, but increased the accumulation of red ones. There would be slightly reduced anthocyanins in KH_2PO_4-sprayed fruit, with reduction in pericarp pH; the spray of K_2SO_4 generates the higher percentage of cyanidin-3-glucoside over all pigments in pericarp. So, it can be an effective approach to improve fruit pigmentation, and can be used in attractive litchi fruit production (Su *et al*., 18).

KNO_3 can enhance flowering especially in tropical regions, where cold temperature for floral induction may not be sufficient. Foliar application of potassium on bearing trees increases fruit size, quality and shipping quality (Lester *et al*., 10). Potassic compounds like potassium nitrate (KNO_3) can be used for dormancy breaking in buds. Among the different sources of potassium fertilizers, KNO_3 is used exclusively for foliar spray in fruit crops (Fernandez *et al*., 4). However, the potassium sulphate (K_2SO_4) has been reported to be an excellent source of potassium nutrition for many fruit trees. Kumar *et al*. (7) obtained highest fruit yield (88.13 kg tree^{-1}) of *Deshi* litchi, while treated with K_2SO_4 @1%.

The roles of plant growth regulators (PGR) such as abscisic acid (ABA) and ethylene have been established for peel colour development during

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maturation and ripening of non-climacteric fruits like litchi (Wang *et al*., 19). Currently ethylene (as ethrel) is the main plant bio-regulator, used to improve the fruit colouration. Its application advances fruit maturity, allows early harvest, and increases the red colour of fruit peel (Ban *et al.,* 2). It has been reported that abscisic acid, naturally synthesized by plants, is also related with anthocyanin synthesis (Leng *et al.,* 9).

Therefore, an investigation was conducted to evaluate the role of different nutrients and PBRs on yield, fruit quality, anthocyanin content and peel's pericarp pigmentation in litchi fruit, with an objective to identify the chemical(s) to improve fruit quality, pericarp colour and fruit yield of litchi cv. Deshi, being grown in eastern part of the country.

MATERIALS AND METHODS

The experiment was carried out at litchi orchard of Horticultural Garden, Bihar Agricultural University, Sabour, Bhagalpur, Bihar (India) during 2020-22, on 25 years old healthy trees of litchi cv. Deshi, planted at 10.0 m × 10.0 m apart. The experiment was laid out in randomized block design (RBD), and replicated thrice involving twelve treatments including a control. The details of treatments tested were T_1: simple water spray (control); T_2 : K_2SO_4 @ 1 %; T_3: K_2SO_4 @ 2 %; T_4 : KNO_3 @ 1 %; T_5: KNO_3 @ 2 %; T_6 : $CaCl_2$ @ 1 %; T_7 : $CaCl_2$ @ 2 %; T_8 : $MgCl_2$ @ 1 %; T_9: $MgCl_2$ @ 2 %; T_{10} : abscisic acid @ 150 ppm; T_{11}: ethephon @ 500 ppm); T_{12} : abscisic acid @ 150 ppm + ethephon @ 500 ppm). All the treatments were applied after 10 days of fruit set, except T_{10}, T_{11}, $T_{12,}$ which were applied during colour break stage. The trees were sprayed with hand operated knapsack sprayer during early morning hours after dissolving calculated dose of respective treatment. The uniform cultural practices were followed to all the trees as per the strict schedule of cultural operations.

The fruit length (at the longest positions of each harvested fruit) and fruit diameter (at the widest positions) was measured with the help of a digital Vernier Calliper. Average fruit weight was calculated by weighing the weight of 10 fruits in each replication on physical balance. Average seed weight, pericarp/ peel weight and aril weight was recorded by weighing separated seed/or peel/or pulp of 10 fruits in each replication. The fruit yield was estimated by weighing all the fruits per tree with the help of a top pan balance.

The TSS was recorded with the help of hand refractometer. The acidity of the litchi fruits was determined as per the procedure given by Ranganna (14). By dividing the TSS value by the titratable acidity, the TSS/Acid ratio was calculated computationally, and the outcome of that calculation was expressed as the TSS/acid ratio. Total and reducing sugars in the litchi fruit juice were determined by the Lane and Eynon method as described in AOAC (1). The ascorbic acid content was determined by titration of a known weight of sample with 2, 6-dichlorophenol indophenol dye using oxalic acid (AOAC, 1). This was expressed in terms of mg ascorbic acid per 100 g of fruit aril. For measurement of anthocyanin, UV-VIS spectrophotometric methods was used as standardized by Mazza *et al*. (11). The results were expressed as milligrams of cyanidin-3-glucoside equivalents per 100 g of fresh weight of aril. The colour of the whole litchi pericarp was observed by Descriptors for litchi released by The International Plant Genetic Resources Institute (IPGRI, 6). The data were subjected to statistical analysis as per the method of Gomez and Gomez (5).

RESULTS AND DISCUSSION

The perusal of data from Table 1 clearly indicated that pre-harvest application of potassium nitrate @ 1 % or 2 %, led to highest yield [T_4 : 82.03 kg per tree T_5 : 79.47 kg tree^{-1}] as compared to the control (T_1 : 65.79 kg tree^{-1}) trees. Pandey *et al.* (12) also found higher fruit yield (89.8 kg tree^{-1}, 78.8 kg tree^{-1}and 73.4 kg tree^{-1}) in litchi cv. Dehradun after foliar application of KNO_3 (1%, 1.5 % and 2 %, respectively) as compared to the control which might be attributed to increase in yield-related factors such as individual fruit weight and size. Kumari *et al*. (8) also obtained the highest yield (55.42 kg tree^{-1}) and pulp content (up to 65.35 %) in litchi cv. China because of spray of KNO_3 (2.0 %). However, Das and Dutta (3) observed that instead of KNO_3 (2.0 %), K_2SO_4 (2%) along with fixed doses of N (1000 g^{-1} tree^{-1} year^{-1}) and P_2O_5 (500 g^{-1} tree^{-1} year^{-1}) brings highest yield (72.60 kg tree^{-1}), average fruit weight (23.03 g), average fruit length (4.08 cm), aril weight (15.99 g), TSS (19.17 °Brix), total sugar (14.98 %), vitamin C (32.83 mg 100 g^{-1} pulp) and anthocyanin content (38.02 mg 100 g^{-1} pulp) in litchi cv. Bombai.

There was significant effect on fruit length, diameter, fruit weight, aril weight, pericarp weight, seed weight as the results are presented in Table 1. The pre-harvest application of KNO_3 (1 % and 2 %) caused higher fruit length [T_4: 3.47 cm T_5: 3.43 cm)], fruit diameter [T_4: 2.54 cm T_5: 2.51 cm] and average fruit weight [T_4:17.51 g T_5: 16.68 g] in as compared to the control (T_1: 3.21 cm, 2.32 cm, 14.87 g, respectively) trees. Pathak and Mitra (13) also reported that spray of KNO_3 produces larger [in diameter] fruit than the unsprayed trees in litchi. Kumar *et al*. (7) also concluded that K_2SO_4 (1% and 2%) spray at stone hardening stage significantly improved fruit weight, length, pulp weight, juice percent, total sugar, reducing sugar and anthocyanin in litchi cv. Deshi.

Table 1: Effect of pre-harvest spray of nutrients and PBRs on fruit yield, physical attributes of fruits in litchi cv. Deshi.

Treatment	Fruit yield (kg tree^{-1})	Fruit length (cm)	Fruit diameter (cm)	Fruit weight (g)	Pericarp weight (g)	Aril weight (g)	Seed weight (g)
*Control (tap water)	65.79^{d}	3.21^{a}	2.32^{b}	14.87^{b}	2.53^{b}	8.23^{c}	3.29^{b}
*Potassium Sulphate (1 %)	72.07^{c}	3.30^{a}	2.41^{a}	15.42^{b}	2.67^{a}	8.74^{b}	3.52^{a}
*Potassium Sulphate (2 %)	74.34^{b}	3.38^{a}	2.43^{a}	16.27^{a}	2.67^{a}	9.09^{b}	3.45^{a}
*Potassium Nitrate (1 %)	82.03^{a}	3.47^{a}	2.54^{a}	17.51^{a}	2.78^{a}	10.11^{a}	3.61^{a}
*Potassium Nitrate (2 %)	79.47^{a}	3.43^{a}	2.51^{a}	16.68^{a}	2.75^{a}	9.96^{a}	3.56^{a}
*Calcium Chloride (1 %)	76.37^{b}	3.33^{a}	2.36^{a}	16.25^{a}	2.72^{a}	9.26^{b}	3.48^{a}
*Calcium Chloride (2 %)	73.88^{b}	3.38^{a}	2.38^{a}	15.42^{b}	2.69^{a}	9.48^{a}	3.50^{a}
*Magnesium Chloride (1 %)	74.20^{b}	3.30^{a}	2.37^{a}	15.72^{b}	2.70^{a}	9.42^{a}	3.54^{a}
*Magnesium Chloride (2 %)	75.46^{b}	3.41^{a}	2.41^{a}	15.68^{b}	2.70^{a}	9.39^{a}	3.52^{a}
**ABA (150 ppm)	72.79^{b}	3.32^{a}	2.39^{a}	15.51^{b}	2.69^{a}	9.20^{b}	3.46^{a}
**Ethephon (500 ppm)	74.26^{b}	3.36^{a}	2.40^{a}	15.36^{b}	2.68^{a}	8.99^{b}	3.49^{a}
**ABA (150 ppm) + Ethephon (500 ppm)	71.50^{c}	3.34^{a}	2.34^{a}	15.24^{b}	2.68^{a}	9.31^{b}	3.50^{a}
SEm ±	1.36	0.10	0.07	0.48	0.08	0.27	0.10

*Foliar spray after 10 days of fruit set; **foliar spray at colour break stage.
Value indicates mean of three replicates; Different letters in the same column indicate significant differences at P≤0.5 (Duncan's Multiple Range Test)

Further, the application of KNO_3 (1 % and 2 %) caused higher pericarp weight [T_4: 2.78 g, T_5: 2.75 g)], aril weight [T_4: 10.11 g, T5: 9.96 g)] and seed weight [T_4:3.61 g, T_5: 3.56 g] (Table 1) as compared to the control (T_1: 2.53 g, 8.23 g, 3.29 g, respectively) trees. These outcomes are in line of the finding of Sharma *et al*. (16) who observed that fruit weight and pulp content in mango cv. Langra are best over the control trees after the foliar sprays of KNO_3 (3%) during the flowering stage.

The significant impact on TSS of fruits of litchi cv. Deshi was observed due to spray of different chemical nutrients and growth inhibitors (Table 2). It was found that application of ABA @ 150 ppm at colour break stage (i.e. T_{10}) improved TSS (18.46 ^{0}Brix), TSS/ acid ratio (50.58), reducing sugar (11.46 %), total sugar (15.37 %) and reduces titratable acidity (0.37 %) as compared to the control trees (16.26 ^{0}Brix, 38.25, 10.84 %, 14.47 % and 0.43 % respectively). In earlier works also, the ethephon (2500 ppm) spray not only improved anthocyanin levels in the fruit pericarp but also increased TSS, sugars with declined acidity in pulp of litchi cv. Bombai (Sadhu and Chattopadhyay, 15).

Influence of pre harvest foliar spray of chemical nutrients and PGRs on vitamin C content of litchi cv. Deshi variety is presented in Table 3. Data showed that maximum vitamin C (41.07 mg100 g^{-1} pulp) was recorded with control trees while minimum in the trees which got spray of ABA @ 150 ppm (38.94 mg 100 g^{-1} pulp). Data in this investigation showed significantly reduction in vitamin C content in all treatments as compared to the control trees might be due to stress imparted by ABA that led to less production of ROX like L-ascorbic acid.

The anthocyanins are the vacuolar pigments, responsible for the red colour of litchi pericarp. The data showed in (Table 3), the anthocyanin content with spray of ABA @ 150 ppm was maximum (T_{10}: 33.78 mg/100 g) as compared to the control trees (29.86 mg/100 g). Similar finding was also recorded by Singh *et al.* (17) as pre-harvest exogenous applications of ABA (150 ppm, 300 ppm) at colour break stage in litchi cv. Calcuttia exhibited 2-fold higher concentrations of total anthocyanin compared to the control trees. However Su *et al*. (18) observed that spray of KCl, K_2SO_4, and $MgSO_4$ decreased the concentrations of flavanols and flavonols, but increases the levels of anthocyanins (responsible for the red colour of the peel in litchi), thus spray of potassium improves fruit pigmentation indicating that anthocyanin synthesis is enhanced because these both compounds are the precursors of the later. Similarly, Wang *et al.* (19) also observed highest anthocyanin levels in litchi cv. Nuomici after spray of ethrel (800 ppm) scheduled at colour break stage.

The effect of different treatments on fruit colour of litchi cv. Deshi was also significantly influenced. The pre-harvest application of ABA @ 150 ppm (i.e. T_{10}) led to highest score (12 marks) on fruit colour in both the years as compared to the control (3 marks) trees. Similar results were also obtained by Wang *et al.* (19) as ABA (25 and 200 ppm) application at 3-4 weeks before

Table 2: Effect of pre-harvest spray of nutrients and PBRs on biochemical attributes of fruits in litchi cv. Deshi.

Treatment	TSS (ºBrix)	Titratable acidity (%)	TSS: acid ratio	Reducing sugars (%)	Total sugars (%)
*Control (tap water)	16.26^{c}	0.43^{a}	38.25^{d}	10.84^{c}	14.47^{d}
*Potassium Sulphate (1 %)	17.65^{a}	0.41^{a}	43.72^{c}	11.40^{b}	15.18^{c}
*Potassium Sulphate (2 %)	17.51^{a}	0.40^{a}	43.44^{c}	11.39^{b}	15.17^{c}
*Potassium Nitrate (1 %)	17.38^{b}	0.41^{a}	42.97^{c}	11.39^{b}	15.16^{c}
*Potassium Nitrate (2 %)	17.43^{a}	0.40^{a}	43.20^{c}	11.41^{b}	15.18^{c}
*Calcium Chloride (1 %)	17.31^{b}	0.41^{a}	42.75^{c}	11.41^{b}	15.19^{c}
*Calcium Chloride (2 %)	17.46^{a}	0.39^{b}	45.36^{b}	11.39^{b}	15.16^{c}
*Magnesium Chloride (1 %)	17.51^{a}	0.40^{a}	44.38^{b}	11.42^{a}	15.27^{b}
*Magnesium Chloride (2 %)	18.30^{a}	0.38^{b}	48.18^{a}	11.44^{a}	15.30^{b}
**ABA (150 mg/L)	18.46^{a}	0.37^{b}	50.58^{a}	11.46a	15.37^{a}
**Ethephon (500µL/L)	18.04^{a}	0.38^{b}	47.11^{b}	11.42^{a}	15.27^{b}
**ABA (150 mg/L) + Ethephon (500µL/L)	17.40^{b}	0.39^{b}	44.50^{b}	11.43^{a}	15.27^{b}
SEm ±	0.35	0.01	0.98	0.01	0.02

*Foliar spray after 10 days of fruit set; **foliar spray at colour break stage.
Value indicates mean of three replicates; Different letters in the same column indicate significant differences at P≤0.5 (Duncan's Multiple Range Test)

Table 3: Effect of pre-harvest spray of nutrients and PBRs on vitamin C, total anthocyanin content and fruit colour in litchi cv. Deshi.

Treatment	Vitamin C (mg 100g pulp^{-1})	Total anthocyanin (mg 100g pulp^{-1})	Fruit colour score by IPGRI***
*Control (tap water)	41.07^{a}	29.86^{d}	3
*Potassium Sulphate (1 %)	40.22^{b}	31.11^{c}	4
*Potassium Sulphate (2 %)	40.11^{b}	31.13^{c}	7
*Potassium Nitrate (1 %)	40.30^{a}	31.04^{c}	7
*Potassium Nitrate (2 %)	40.09^{b}	31.10^{c}	7
*Calcium Chloride (1 %)	40.71^{a}	31.09^{c}	11
*Calcium Chloride (2 %)	40.13^{b}	31.05^{c}	11
*Magnesium Chloride (1 %)	40.02^{b}	31.78^{b}	7
*Magnesium Chloride (2 %)	39.85^{b}	32.14^{b}	10
**ABA (150 ppm)	38.94^{c}	33.78^{a}	12
**Ethephon (500 ppm)	39.80^{b}	32.41^{b}	11
**ABA (150 ppm) + Ethephon (500 ppm)	39.82^{b}	31.97^{b}	11
SEm ±	0.26	0.25	-

*Foliar spray after 10 days of fruit set; **foliar spray at colour break stage.
Value indicates mean of three replicates; Different letters in the same column indicate significant differences at P≤0.5 (Duncan's Multiple Range Test)
***1: Green; 3: Greenish Red; 4: Pinkish Red; 10: Rosy Red; 12: Deep Pink (Kumar *et al*., 7)

anticipated harvest of litchi fruit enhances biosynthesis and accumulation of anthocyanin in the pericarp.

Therefore, it can be concluded that pre-harvest foliar application (10 days after fruit set) of potassium nitrate (1 % or 2 %) considerably improves the fruit yield while foliar application (at colour break stage) of ABA @ 150 ppm, enhanced the fruit quality traits (TSS, reducing sugars, total sugars, anthocyanin content and over all bright colour of pericarp) as compared to the untreated trees.

AUTHORS' CONTRIBUTION

Conceptualization of research (AKP, SS, FA, SKS); Designing of the experiments (AKP, SS, SKS); Contribution of experimental materials (AKP, SS); Execution of field/lab experiments and data handling (AKP); Analysis of data and interpretation (AKP, WS, SP); Preparation of the manuscript (AKP, SKS); Review and Editing (SKS, SS, FA).

DECLARATION

The authors declare no conflict of interest.

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