Effect of Plant Growth Regulators and Micronutrients on Vegetative Growth, Flowering and Yield Attributes of Litchi (*Litchi chinensis* Sonn.)

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**Authors’ contributions**

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

**Article Information**

DOI: 10.9734/IJPSS/2021/v33i1830587  
Editor(s):  
(1) Dr. Muhammad Shehzad, The University of Poonch Rawalakot, Pakistan.  
Reviewers:  
(1) Noor-ul-Huda Altaf, University of Agriculture Faisalabad, Pakistan.  
(2) Isaias Vitorino Batista de Almeida, Brazil.  
Complete Peer review History: https://www.sdiarticle4.com/review-history/72976

**ORIGINAL RESEARCH ARTICLE**

**ABSTRACT**

The experiment was conducted to observe the effect of plant growth regulators (GA₃ and NAA) and micronutrients (ZnSO₄ and Borax) on vegetative growth, flowering and yield attributes of litchi (*Litchi chinensis* Sonn.). ZnSO₄ applied @ 0.4% resulted in maximum per cent increase in plant height and canopy spread, i.e. 5.78% and 6.65% respectively. Whereas, application of Borax @ 0.4% exhibited maximum per cent increase in plant girth (8.72%). NAA @ 2.5 ppm was effective in improving the flowering parameters of litchi. With respect to physical parameters of fruit and yield component, application of borax @ 0.4% resulted in maximum fruit set (43.76%), number of fruits per tree (1128.67), fruit yield (25.11 kg/tree), fruit weight (22.24 g), aril weight (15.65 g) and minimum fruit cracking (5.08%). Lowest fruit drop percentage (60.91%) was however caused by application of ZnSO₄ @ 0.4%.

**Keywords:** PGR; micronutrients; vegetative; flowering; yield; litchi.

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1. INTRODUCTION

Litchi (Litchi chinensis Sonn.) is considered as one of the most important sub-tropical fruit crops. It belongs to the family Sapindaceae and sub-family Nepheleae comprising about 150 genera and 2000 species [1]. India retains the title of second largest producer of litchi in the world after China with an area and production of 92,000 hectares and 6, 86,000 MT respectively during 2017-2018 [2]. Cumulative production of Bihar, West Bengal, Jharkhand and Assam accounts for 64.2% of the total litchi production in the country. In Arunachal Pradesh, the commercial cultivation of litchi is in nascent stage with an area and production of 40 hectares and 80 MT respectively during 2017-2018 [2]. Various problems offer challenges and cause low economic potential in litchi cultivation which include poor fruit set [3], heavy fruit drop [4], fruit cracking [5] and inferior fruit quality [6]. Low rate of pseudo-hermaphrodite flowers and high nutrient competition between organs often result in low yields in litchi [7]. Fruit drop in litchi is often thought to be associated with disturbance in the endogenous hormonal level [8], failure of fertilization, embryo abortion, internal nutrition and hormonal imbalance and internal factors like high temperature, low humidity and strong winds [9]. Postulation made by Fivaz and Robbertse [10] indicates that the high incidence of fruit cusscision in litchi could be caused by a physiological rather than a genetic problem.

Over the years plant growth regulators (PGRs) and micronutrient have been consistently used to augment maximum and sustained economic benefits in litchi production through altering the behaviour of fruit or fruit plants. Yield and quality of litchi fruit have been positively influenced by both micronutrients and plant growth regulators [4]. Application of PGRs results in increased flowering, fruiting and retention of fruit. The supply route of cell sap to fruit is severed by formation of abscission layer and gradually thin cork cells separate resulting in fruit dropping [11]. Early researchers like Adams et al. [12] reported that gibberellins influenced both cell division and cell enlargement. Auxins like Naphthalene acetic acid (NAA) greatly influence plant growth, however, its effectiveness is dependent on the time of application and concentration. Application of NAA in different concentrations successfully control fruit drop in majority of fruit plants although required in very small quantities. Micronutrients have a significant function in improving the growth, yield and quality of litchi. Micronutrients applied in optimum concentrations results in better plant growth which leads to higher yield, better flowering and higher fruit set [13]. Plants require a substantial amount of the total requirement of certain micronutrients to be fed through foliar application which results in improved fruit quality [11]. Metabolic activities of plants greatly depend on zinc. Zinc primarily functions as a metal activator of enzymes like dehydrogenase (Pyridine nucleotide, glucose - 6 phosphodiesterase, carbonic anhydrase etc.). Tryptophan, a precursor of IAA greatly depends on Zinc for its synthesis, it is associated with water uptake and water retention in plant bodies [11]. Boron is invariably essential for important reproduction functions like germination of pollen tube and fertilization. Boron deficiency leads to lesser flower numbers with more of sterile ones, fruits produced are mostly deformed and are rendered commercially unviable [14]. Stunted growth, reduced flower induction and fruit set, eventually leading to inferior fruit quality are caused by zinc and boron deficiency [15]. Based on this context, an experiment was executed to assess the influence of PGRs and micronutrients on vegetative growth, flowering and yield of Litchi var. Muzzaffarpur under the foothill condition of Arunachal Pradesh.

2. MATERIALS AND METHODS

The experiment was carried in 8-9 years old litchi orchard during 2018 and 2019 at Fruit Research Farm, Department of Fruit Science, College of Horticulture and Forestry, Central Agricultural University, Pasighat, Arunachal Pradesh. The geographical location of the research farm is 28° 04’ 43” N latitude and 95° 19’ 26” E longitude and having an altitude of 153 m above mean sea level. The climate of this area is generally humid sub-tropical and maximum rainfall occurs between April to September. The experiment was laid out in Randomized Block Design consisting of twelve treatments (Table 1) with three replications with three plants in each replication. The plants were planted at spacing of 8m x 8m. The experimental materials for the study comprised of plant growth regulators - GA3 and NAA and micronutrients - ZnSO4 as Zn source and borax as B source. They were applied as foliar spray at different concentrations three times at intervals (before flowering, fruit set and at green mature stage). Five litres of prepared solution were sprayed to each tree at each interval. The data were recorded for morphological parameters of tree (per cent increase in plant height, per cent increase in...
plant girth and per cent increase in canopy spread, flowering parameters of tree (time of flowering i.e., number of days taken for flowering after imposition of treatment and duration of flowering) and physical parameters of fruit and yield components viz. fruit set (%), fruit drop (%), maturity, fruit cracking (%), number of fruits per tree, fruit yield (kg/tree), aril weight (g) etc. Observations recorded during field experiment and data obtained from laboratory analysis were subjected to the statistical analysis of variance for RBD. Significance and non-significance of the variance due to different treatments were determined by calculating the respective F values according to the method described by Gomez and Gomez [16].

Table 1. Detailed information of treatments

| Treatments | Details                      |
|------------|------------------------------|
| T1         | GA3 foliar spray @ 5 ppm    |
| T2         | GA3 foliar spray @ 10 ppm   |
| T3         | GA3 foliar spray @ 15 ppm   |
| T4         | NAA foliar spray @ 2.5 ppm  |
| T5         | NAA foliar spray @ 5.0 ppm  |
| T6         | NAA foliar spray @ 7.5 ppm  |
| T7         | Borax foliar spray @ 0.2%   |
| T8         | Borax foliar spray @ 0.4%   |
| T9         | Borax foliar spray @ 0.6%   |
| T10        | ZnSO4 foliar spray @ 0.2%   |
| T11        | ZnSO4 foliar spray @ 0.4%   |
| T12        | ZnSO4 foliar spray @ 0.6%   |

3.2 Effect of PGRs and Micronutrients on Flowering Parameter

The minimum time taken for flowering (10.50 days) and minimum duration of flowering (21.33 days) was recorded in T4 (NAA @ 2.5 ppm) shown in Table 2. Young and Harkness [24] reported that initiation of floral buds takes place after a mandatory period of vegetative dormancy. Vegetative dormancy is successfully induced by administration of exogenous auxins to promote floral initiation in litchi as concluded by Menzel [1]. Levels of auxin produced during periodical shoot flush are likely to form a periodic reserve of concentrated auxin, which moves basipetally to the roots as suggested by Davenport [25]. Thus the elevated auxin concentration arriving at the roots may affect initiation of new root flushes. Sultana et al. [26] reported an increased inflorescence count with 75% inflorescence retention in litchi plant.

3.3 Effect of PGRs and Micronutrients on Physical and Yield Attributes

The physical and yield attributes affected by PGRs and micronutrients is shown in Table 3. T8 (borax @ 0.4%) was most effective in increasing fruit set (43.76%) closely followed by T11 (zinc sulphate @ 0.4%) with fruit set of 43.38%. The increase in fruit set following application of borax might be due improved translocation of carbohydrates, auxins synthesis and increased pollen viability and fertilization, because boron plays a vital role in all these processes as described by Kaur [27]. Similar finding was also reported by Dixit et al. [28] in litchi.

Significant reduction in fruit drop (60.91%) followed by (61.54%) was recorded in T11 (ZnSO4 @ 0.4%) and T12 (ZnSO4 @ 0.6%) respectively. Response to zinc sulphate application was more positive, presumably due to zinc, which is known to be essential for the biosynthesis of auxin (IAA), an activator of the enzyme tryptophan synthesis. Increased fruit retention following the treatments suggests that...
zinc influenced and assisted in maintenance of optimum auxin balance and thus prevented fruit drop. Similar finding was expressed by Singh et al. [29].

Fruit cracking to the tune of 5.08% followed by 5.26% was found to be significantly lowest with T_8 (borax @ 0.4%) and T_3 (GA_3 @ 15 ppm) treatments respectively. This is due to the fact that boron is responsible for pectin synthesis, increasing the elasticity of the cell membranes and prevents the breakdown of vegetative tissues as reported by Marboh et al. [30].

Fruit count per tree (1128.67) and fruit yield (25.11 kg/tree) was observed to increase considerably in treatment T_8 (borax @ 0.4%). This may be due to the fact that boron effects pollinations and development of viable seeds which in turn affect the normal development of fruit as reported by Suman et al. [31]. Apart aiding in cell division, cell elongation, cell enlargement, boron causes reduction of abscission layer which encourages fruit retention and finally results into higher number of fruits per tree as per Salisbury and Ross [32].

Table 2. Effect of PGRs and micro-nutrients on vegetative growth and flowering parameters of litchi (2018-2019 pooled data)

| Treatments | Per cent increase in plant height | Per cent increase in plant girth | Per cent increase in canopy spread | Time of flowering | Duration of flowering |
|------------|----------------------------------|----------------------------------|----------------------------------|------------------|----------------------|
| T_1        | 2.16                             | 5.17                             | 3.65                             | 14.67            | 25.50                |
| T_2        | 2.91                             | 4.59                             | 4.46                             | 13.50            | 24.83                |
| T_3        | 4.23                             | 6.94                             | 5.38                             | 15.50            | 26.33                |
| T_4        | 2.18                             | 5.25                             | 3.12                             | 10.50            | 21.33                |
| T_5        | 2.43                             | 5.51                             | 3.58                             | 11.33            | 22.67                |
| T_6        | 2.80                             | 6.68                             | 4.64                             | 11.67            | 23.17                |
| T_7        | 4.35                             | 7.20                             | 4.99                             | 12.67            | 25.00                |
| T_8        | 5.39                             | 8.72                             | 5.95                             | 11.00            | 22.67                |
| T_9        | 5.21                             | 8.24                             | 5.19                             | 14.00            | 24.83                |
| T_10       | 5.12                             | 6.13                             | 5.15                             | 12.00            | 23.67                |
| T_11       | 5.78                             | 6.37                             | 6.65                             | 10.83            | 21.67                |
| T_12       | 5.37                             | 8.11                             | 5.57                             | 14.33            | 26.00                |
| Mean (s)   | 3.99                             | 6.57                             | 4.86                             | 12.67            | 23.97                |
| S.E. (m) ± | 0.04                             | 0.10                             | 0.07                             | 0.32             | 0.34                 |
| C.D. (5%)  | 0.11                             | 0.29                             | 0.19                             | 0.95             | 1.01                 |

Table 3. Effect of PGRs and micro-nutrients on physical and yield parameters of litchi (2018-2019 pooled data)

| Treatments | Fruit set (%) | Fruit drop (%) | Fruit cracking (%) | Number of fruits per tree | Fruit yield (kg/tree) | Fruit weight (g) | Aril weight (g) |
|------------|---------------|----------------|--------------------|---------------------------|-----------------------|-----------------|-----------------|
| T_1        | 39.86         | 77.43          | 6.99               | 997.00                    | 18.71                 | 18.77           | 11.41           |
| T_2        | 40.95         | 69.58          | 6.33               | 897.50                    | 17.38                 | 19.33           | 12.48           |
| T_3        | 41.72         | 64.99          | 5.26               | 983.50                    | 21.38                 | 21.67           | 13.91           |
| T_4        | 40.26         | 76.22          | 6.54               | 927.00                    | 17.22                 | 18.53           | 11.57           |
| T_5        | 41.44         | 67.50          | 7.48               | 943.50                    | 18.52                 | 19.60           | 12.64           |
| T_6        | 42.21         | 64.16          | 7.83               | 834.67                    | 17.41                 | 20.88           | 14.19           |
| T_7        | 39.95         | 79.59          | 5.99               | 952.17                    | 19.75                 | 20.74           | 14.26           |
| T_8        | 43.76         | 62.50          | 5.08               | 1128.67                   | 25.11                 | 22.24           | 15.65           |
| T_9        | 43.16         | 64.57          | 5.55               | 1069.67                   | 22.94                 | 21.44           | 14.88           |
| T_10       | 40.21         | 74.08          | 6.10               | 858.50                    | 17.36                 | 20.22           | 13.61           |
| T_11       | 43.38         | 60.91          | 5.39               | 1096.00                   | 24.05                 | 21.94           | 15.56           |
| T_12       | 42.16         | 61.54          | 5.64               | 1005.33                   | 21.42                 | 21.29           | 14.54           |
| Mean (s)   | 41.59         | 68.59          | 6.18               | 974.46                    | 20.10                 | 20.55           | 13.72           |
| S.E. (m) ± | 0.50          | 0.52           | 0.26               | 32.38                     | 0.83                  | 0.38            | 0.36            |
| C.D. (5%)  | 1.47          | 1.54           | 0.75               | 94.96                     | 2.44                  | 1.10            | 1.05            |
Maximum fruit weight (22.24 g) was noted in T₈ (borax @ 0.4%) followed by T₁₁ (ZnSO₄ @ 0.4%) with fruit weight (21.94 g). As reported by Haq et al. [33], application of boron and zinc boosted the auxin levels in many parts of fruit affecting the cell size to undergo a rapid expansion which eventually facilitated a significant fruit growth resulting into higher fruit weight.

The maximum aril weight (15.65 g) was significantly increased with the application of borax @ 0.4% (T₅). The application of boron enhanced the aril weight thereby enhancing the juice content of the fruit. Findings from the present study are in conformity with that of Kaur [27] and Singh et al. [34].

4. CONCLUSION

All the observed parameters were significantly influenced by the application of plant growth regulators and micro-nutrients. Application of ZnSO₄ @ 0.4% gave maximum per cent increase in plant height and canopy spread, while borax @ 0.4% gave maximum per cent increase in plant girth. So, ZnSO₄ and borax both @ 0.4% are most appropriate for regulating vegetative growth of litchi. Application of 0.4% borax resulted into maximum fruit set, fruit weight, number of fruits per tree, fruit yield, aril weight and ZnSO₄ @ 0.4% exhibited minimum fruit drop. NAA @ 2.5 ppm was effective in improving the flowering parameters of litchi. Borax and ZnSO₄ @ 0.4% each were recorded to be more effective on most of the characteristics. Therefore, it can be inferred that the foliar spray of borax and ZnSO₄ @ 0.4% proved to be beneficial and best for better vegetative growth, flowering and yield of litchi.

COMPEITING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/72976