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Growth Regulators for Yield and Quality Enhancement in Litchi (*Litchi chinensis* L) - A Review

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A B S T R A C T

The basic and strategic research programs in litchi aim at developing technologies for enhancing productivity, quality, facilitating processing and value addition for increased net returns. The present literature has been, therefore, reviewed to clear the concepts and approaches involving the use of PGRs paving way for future litchi production. Physiological changes such as heavy fruit drop or early abscission in litchi might be due to the lack of hormones needed for the embryo and fruit development, lack of pollination and/or fertilization etc. Alteration of harvesting period in litchi may prolong the marketing period and application of suitable plant growth regulators may help in achieving it The emphasis need to be given to the action mechanism of these on litchi at various stages of growth, development and storage as it has not been fully exploited for the improvement in fruit yield and quality attributes in Indian conditions.

Introduction

Despite long history of litchi cultivation and its popularity both in domestic and international markets, many areas are experiencing low productivity due to a number of factors such as warm weather at flowering, unsuitable cultivars, improper tree management etc.

The existing gaps in yield potential, production of poor quality, un-attractive fruits and negligible export potential of quality litchi fruit are the main concerns. These need to be combated in modern day fruit production to meet the ever increasing demand to nourish the growing population and increasing the economic returns.

Plant growth hormones play important role in the integrated developmental activities of the fruits, yield as well as quality. Exogenous application of plant bio regulators in small quantities has become an important component for inhibiting or modifying the physiological processes by replacing or supplementing the endogenous hormones when their levels are below than required to bring a positive change in the course of plant development, thereby regulating different aspects such as fruit drop, quality and yield. Keeping all these factors in consideration, the present literature has been reviewed to clear the concepts and approaches involved with the use of different PGRs in relation to litchi fruit growth, development, yield, quality, shelf life etc.

Growth regulators in litchi

In litchi, it is worthwhile to understand the certain basic concepts regarding the use of growth regulators. Physiological changes or abnormalities such as heavy fruit drop or early abscission in litchi might be due to the lack of hormones needed for the embryo and fruit development, lack of pollination and/or fertilization etc. All these can be dealt with effectively by understanding the concepts behind the use of different PGRs being used worldwide in litchi at different stages of growth and development.

Auxins

Chen (1990) investigated endogenous growth substances present at different stages viz leaf expansion, dormant bud (when apical leaves drop), 30 days before flower bud formation, flower bud formation and full bloom in litchi cv Heh Yeh and found that a constant level of IAA was maintained throughout all the five stages. Stern *et al.,* (2001) concluded that the most suitable time, amount and stage of application of auxins was 0.5 g with 15 mm length or 3 weeks after pollination for litchi cv Kaimana, 1-2 g with 22-24 cm length or 4 weeks after pollination for Floridian and 2 g with 22-24 mm in length or 5 weeks after pollination for Mauritius. Synthetic auxins reduced fruit drop and increased the yield of litchi cultivars Mauritius and Kaimana up to 130 to 170 per cent, respectively when applied to trees soon after fruit set (Stern and Gazit, 1997 and 1999). 2,4,5-TP @67 ppm and 3,5,6-TPA @ 50 ppm have were found to increase the number of fruits per tree, doubled the fruit yield, increased fruit size and enhanced the red colour of ripe fruit of 'Fei Zi Xiao' and 'Hei Ye' litchi trees (Stern *et al.,* 2001). Similar results were obtained by Sarkar *et al.,* (1984 b). Drinnan (2014) found that 3,5,6-TPA @50 ppm as foliar spray to the litchi cultivars 'Fay Zee Siu', 'Kaimana', 'Kwai Mai Pink', 'Souey Tung' and 'Tai So' reduced the fruit drop and increased the fruit size when applied to fruit greater than 12 mm in length but increased fruit drop when fruit were smaller. According to Kumar *et al.,* (2009), the highest aril percentage individual fruit weight per tree and number of fruits per tree was recorded in litchi trees of cv Purbi sprayed with 2,4-D @10 ppm.

Three sprays of NAA @ 20 ppm (at pre-bloom, completion of fruit set and before colour break stage) on litchi cv China resulted in least fruit cracking as compared to NAA @ 10 ppm application (Rani and Brahmachari, 2001b). NAA @ 2.5 ppm registered highest initial fruit set (74.25 fruits/ panicle) in litchi cv. Dehradun and 5 ppm NAA registered highest TSS (19%) and ascorbic acid content with increased with 100 ppm NAA. Same findings were registered by Singh and Phogat (1983); Anand *et al.,* (2003) and in litchi cv Calcuttia (Sharma *et al.,* 2005). Cuttings of litchi when immersed in 2000 or 5000 ppm IBA, 2000 ppm IBA + 150 µg B/ml, 1500 ppm NAA, Q-Muda (0.5% IBA), Nafusaku (0.5% NAA) or water, before placing in vermiculite trays showed that the per cent survival, percentage formation of callus, and root formation was the best after 120 days with commercial powder Q-Muda having 0.5 per cent IBA (Leonel *et al.,* 1994). Sinha and Ray (2002) treated the ringed portion of litchi cv Bombai with 5000 ppm IBA, 5000 ppm IBA+200 ppm p-hydroxyl benzoic acid (PHB), 5000 ppm NAA+200 ppm PHB, 5000 ppm IBA+5000 ppm NAA and 5000 ppm NAA to see their effect on rooting and survival and observed that the highest rooting percentage, number of roots and maximum survival percentage of layers was obtained with 5000 ppm NAA + 200 ppm PHB treatments. Ray and Takawale (2013) studied the rooting behavior of eight litchi cultivars namely, Muzaffarpur, Nafarpal, Elaichi, Bombai, Purbi, Bedana, Rose Scented and China with the treatment of NAA @ 5000 ppm + PHB 200 ppm and IBA 5000 ppm +

PHB 200m ppm against control and found that maximum mean number of roots per layer were recorded with NAA+PHB treatment while maximum root length was recorded with IBA+PHB treatment in all the cultivars.

Cytokinins

In pericarp of litchi in many cultivars (Erdanli, Huaizhi and Feizixiao), it was observed that the concentration of cytokinins was high in early blooms and a high CTK: ABA ratio favoured fruit growth in all cultivars of litchi (Li *et al.,* 2005). Chen (1990) found highest levels of cytokinins in Heh Yeh cv of litchi trees in the xylem sap which reached maximum during flower bud formation and full bloom. O'hare and Turnbull (2004) observed that the concentration of a cytokinin, Zeatin Riboside in potted plants of litchi cv 'Tai so' kept at different temperatures increased to maximum in terminal buds just prior to shoot emergence and its exogenous application to dormant buds could initiate the bud break. According to Mishra *et al.,* (2012), the application of BA (benzyl adenine) @ 40 ppm was the best treatment to delay the fruit maturity, and in terms of increase in ascorbic acid content in litchi cv Rose Scented. Stern *et al.,* (2006) observed that application of synthetic cytokinin N-(2-chloro-4-pyridyl)-N'-phenylurea (CPPU) @ 5-10 mg/l to green or slightly red fruitlets of litchi cv Mauritius delayed the harvesting by 2-3 weeks as compared to control and the fruits were more red in colour with 20-25% more size, higher TSS: acid ratio and could be stored well for 6 weeks due to reduced browning.

Gibberellic acid

According to Chen (1990), gibberellin content in litchi cv Heh Yeh was found to be high in xylem sap at stage of leaf expansion and came to a low level 30 days before flower bud formation and during flower bud formation. Interaction between borax 0.4% and GA_3 20 ppm exhibited maximum fruit retention and fruit yield in litchi cv Ambika Litchi-1 (Dixit *et al.,* 2013). Kumar *et al.,* (2009) concluded that 20 ppm GA_3 produced maximum number of fruits per tree, maximum weight of individual fruit and highest fruit yield in litchi cv Purbi in districts of Bihar. Maximum fruit weight and highest aril percentage were obtained with GA 100 ppm in litchi cv China (Rani and Brahmachari, 2001b). The fruits of litchi cv Purbi when sprayed at pea stage and 21 days later with GA_3 @ 50, 100 and 150 ppm showed maximum fruit length, diameter, weight and volume with 50 ppm GA_3 application (Brahmachari *et al.,* 1996).

Mishra *et al.,* (2012) obtained minimum fruit cracking, maximum TSS and total sugars when the trees of litchi cv Rose Scented were sprayed with GA_3 @ 40 ppm. In order to increase the fruit weight of shriveled seed cultivar 'Yu Her Pau' litchi, gibberellic acid was sprayed @ 5 and 10 mg/l 14 days after full bloom and was concluded that both the concentrations of GA_3 significantly increased the fruit diameter, fruit weight, aril and pericarp weight over control (Chang and Lin, 2006).

The fruits of litchi cv Rose Scented when dipped in 200 ppm solution of GA_3 for two minutes and then stored at 5^oC showed minimum physiological loss in weight and spoilage, resulting in increased shelf life of fruits to 5 days than control (Nigam *et al.,* 2001). Chen *et al.,* (2014) studied the effect of GA_3 @ 100 ppm applied foliarly to litchi cv 'Yu Her Pau' and found that it significantly increased the average number of fruits per branch and ultimately the yield. While same concentration in combination with kinetin (25 ppm) sprayed to the trees of litchi cv Bombai at aril development stage delayed the fruit ripening by about 4 days along with improvement in fruit (Dhua *et al.,* 2005).

Ethephon

Olesen *et al.*, (1999) concluded that ethephon could be used to control early red leaf flushes in litchi when applied in May or June resulting in emergence of new buds behind the damaged shoots within a few weeks and it had the advantage of easy application as compared to mechanical pruning. Ethephon @ 2500 ppm resulted in promotion of fruit ripening and colouration in litchi by improving the anthocyanin levels in the peel and increased TSS, sugars, ascorbic acid and decreased acidity in pulp (Sadhu and Chattopadhyay, 1989) while ethrel @ 800 mg/l at colour break was responsible for highest anthocyanin levels in litchi cv Nuomici (Wang *et al.*, 2007). According to Mandal *et al.*, (2014), among paclobutrazol @ 2 and 3 ml a.i./m^2 canopy, ethrel 1and 2 ml/l and cincturing in Sept-Oct, application of ethrel @ 2 ml/l was the most effective for flower and fruit induction in litchi cv Bombai, earlier reported in litchi cv 'Hong Huay' by Subhadrabandhu and Duang (1987), but it failed to promote flowering after reducing the flower number in variety Ouxia of litchi, in contrary to previous results. Li *et al.*, (1992) reported that application of ethephon inhibited the germination of winter shoots for 22-27 days in Baila, Heiye and Guiwei litchi and its spray at flower bud differentiation reduced the flower number on each panicle improving fruit quality. Flowering of 'Sijimi' was induced by 75 mg/L PP333 + 142.8 mg/L ethrel during young shoots turning green, by 37.5 mg/L PP333 and 142.8 mg/L ethrel during terminal bud germination, and by 25.5 mg/L PP333 during flushing (Zhu *et al.*, 2011). Xu *et al.*, (2011) found 233 mg/L ethephon + 90 mg/L paclobutrazol, or 300 mg/L ethephon + 90 mg/L paclobutrazol to be more effective in preventing leafy panicles and encouraging for development of pure panicles in 'Shixia' longan trees when sprayed at the panicle emergence. Mahajan and Sharma (1995) found that ethrel @ 500 ppm was the most effective in improving the fruit quality and hastening the ripening in litchi cv Dehradun. According to Diao (2006), ethephon (0.05 to 0.06%) in combination with paclobutrazol (0.05%) on litchi trees had inhibitory effect on shoot tip growth and could reduce number of male flowers and the nutrient consumption of the tree. In a survey, it was observed that high concentration of ethephon (700 mg/kg or above) when sprayed on litchi trees might cause phytotoxicity, while leaf abscission rate decreased with the reduction of its concentration (Yu, 2008). Tang (2006), in his study concluded that combined spray of ethephon at higher concentration (800 mg/l) and paclobutrazol in lower concentration (400 mg/l) could remarkably reduce the contents of IAA and GA_3 in Jizui litchi while ABA was increased resulting in improved flower formation. Similar results were reported by Mitra and Sanyal (2000). Sharma *et al.*, (1986) reported the hastening of maturation by ethrel treatment 3 weeks before harvesting in litchi cv Shashi.

Abscissic acid

Chen (1990) observed an increase in ABA level 30 days before bud formation in litchi cv Heh Yeh and concluded that the decrease in shoot growth was associated with high ABA content. Pre-harvest exogenous application of ABA @ 150 ppm and 300 ppm at colour break stage in litchi cv Calcuttia significantly increased the accumulation of anthocyanins in litchi pericarp without adversely affecting the post harvest quality (Singh *et al.*, 2014). Wang *et al.*, (2007) investigated changes in endogenous abscissic acid levels during the course of fruit development and maturation in litchi cvs. Feizixiao and Nuomici and found that ABA concentration in aril as well as pericarp of litchi went on increasing with the fruit maturation and it was critical for sugar accumulation in the fruit while its exogenous application promoted the anthocyanin synthesis. Exogenous ABA treatment @ 100 µmol/l to the fruits of litchi cv Guiwei and then storage at 0±2ºC effectively, delayed colour change to red, decreased the anthocyanin content of the fruit and reduced the activity of polyphenol oxidase and hence retarded the development of pericarp browning resulting in more chilling tolerance of the fruits (Hu *et al.*, 2010).

CCC: A dose of 2000 ppm resulted in maximum pulp weight, pulp/stone ratio, TSS and minimum acidity whereas CCC 500 ppm was found to be sig

nificantly effective in decreasing seed weight as well as peel weight in Calcuttia cv of litchi (Singh *et al.*, 2012). Fruits of litchi cv China sprayed with CCC 500 ppm resulted in highest TSS, total sugars, ascorbic acid and least acidity (Rani and Brahmachari, 2001b). According to Thakur *et al.*, (1990), CCC @ 2000 ppm significantly improved the fruit set, fruit size and retention in litchi cvs. Purbi and DeshiIn experiments on litchi cv Purbi, the spray of CCC @ 300 ppm at pea stage and again 21 days later resulted in minimizing the fruit drop as compared to other treatments (Brahmachari *et al.*, 1996).

Paclobutrazol

Singh *et al.*, (2012) found that PBZ @ 7.5 g per tree was the most effective treatment for suppressing shoot growth, panicle size, male flower percentage, fruit drop and increased the hermaphrodite percentage, sugars, fruit size and fruit yield per tree in litchi cv Calcuttia. Singh *et al.*, (2017) applied PBZ @ 1, 2, 3 and 4 g a.i. per meter tree canopy as soil drenching along with combination of two levels of potassium nitrate @ 100 and 200 mg/l respectively as triple application starting from 3 months after harvesting of the fruit at 15 days interval on trees of litchi cv China and observed the significant reduction in vegetative winter flushing and more floral shoots as compared to control. In 'Bengal' litchi trees, Pires and Yamanishi (2014) applied PBZ at 500, 1000 and 2000 mg a i/m of canopy diameter of the tree in May soon after girdling of main trunk, and branches. They concluded that tree trunk girdling combined with the application of PBZ @ 1000 mg ai /m of canopy diameter significantly increased the average yield by 4 to 6 folds as compared to control. Singh *et al.*, (2017) found that the trees treated with PBZ @ 4 g a i/ m canopy of tree proved to be the most significant as the number of vegetative flushing in winter was significantly reduced with 66 per cent emergence of floral branches. Hung and Nghi (2006) observed that in litchi cv Binhkhe PBZ applied @ 20 gm a i/tree in late Aug-early Sept at mature bud stage resulted in the inhibition of winter bud emergence, reduced inflorescence size but increased female flowers, fruit set and yield by 61.5-85.2 per cent than control.

Maleic hydrazide

Biao and Fang (1998) tried many growth regulators for inducing kernellessness or mini kernels in litchi cv Huaizhi and found 1 mm MH sprayed twice to be the most effective in obtaining mini kernelled/ aborted kernel fruits with 100% success. Liang and Qiu (1998) applied Maleic Hydrazide @ 1000 mg/l about 2 weeks from full bloom in litchi cv. Huaizhi and concluded that fruit weight was same as non- sprayed fruits, but had shriveled seeds and about 10% more aril than untreated controls. Spraying PP333 or ethrel + MH to litchi flower clusters could extend the flowering period by 10-14 ultimately increasing the fruit production (Win *et al.*, 1998).

In conclusion, important future perspective with researchers has been to test new formulations and adjuvants to increase the efficacy of the PGRs. The knowledge of application of specific hormones at proper phenological stage for effective manipulation of key physiological processes can result in more efficient management strategies and achieving the desired goals.

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