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Effect of plant bio-regulators (PBRs) on quality and yield in litchi (*Litchi chinensis* Sonn.) cv. rose scented

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Abstract
The present investigation was carried out at Horticulture Research Centre, Patharchatta and Department of Horticulture, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during February, 2013 to July, 2013. The experiment was conducted to study the effect of Plant bio-regulators *viz*., Gibberellic Acid (GA_3), Naphthalene Acetic Acid (NAA) and Benzyl Adenine (BA) on fruit drop, cracking, fruit yield and physico-chemical properties of litchi cv. Rose Scented. The experiment was laid out in Randomized Block Design (RBD) with 10 treatments and 3 replications. The results indicated that among all treatments, GA_3 (50 ppm) and NAA (50 ppm) had significant effect on fruit drop, cracking, fruit yield and physico-chemical characters of litchi. The application of GA_3 @ 50 ppm was found to be more effective in minimizing fruit drop, fruit cracking and titratable acidity and increasing fruit retention, fruit size, fruit weight, fruit volume, ascorbic acid, total sugar, reducing sugar and yield.

Keywords: flowering, fruit yield, plant bio-regulators and fruit quality.

Introduction
Litchi (*Litchi chinensis* Sonn.) is one of the important subtropical fruits of India. It is a member of the family Sapindaceae (or soapberry family) and sub-family Nepheleae, which has about 150 genera and more than 2000 species. Litchi originated in Southern China and Northern Vietnam from wild populations recorded in these regions (Hai and Dung, 2002) [8]. India ranks second in the litchi production next to China and has undergone substantial expansion in cultivation in the past 50 years. India, occupies 83,000 ha area having the production of 580 thousand Mt with average productivity of 7.0 Mt/ha. In Uttarakhand, the area, production and productivity of litchi are 9.49 thousand ha, 19.16 thousand Mt/ha and 2.0 Mt/ha, respectively (Anonymous, 2014) [1]. The disturbance in the endogenous hormonal level is one of the major contributing factors responsible for fruit drop (Awasthi *et al*. 1975) [2]. Reduction in fruit drop with the application of growth substances was reported by many workers (Khan *et al.,* 1976; Barua and Mohan, 1984) [9]. Beneficial effect of growth substances and minor elements in reducing fruit drop in litchi cv Purbi was reported by Verma *et al.* (1980) [13].

Materials and Methods
The present study "Effect of Plant Bio-regulators (PBRs) on Quality and Yield in litchi (*Litchi chinensis* Sonn.) cv. Rose Scented" was conducted at Horticulture Research Centere, Patharchatta, Department of Horticulture, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, during the year 2013. The experiment was performed under Randomized Block Design (RBD) with control. All treatments with control were replicated thrice. Thus, 30 trees were marked for conducting the experiment. Selected trees were given uniform cultural operations.

Result and Discussion
The data presented in Table 1 showed that it varied significantly over control. All the treatments showed significantly higher fruit set than control. It was ranged from 52.20 per cent (minimum) in control to 65.08 per cent (maximum) in GA_3 (50 ppm).

GA_3 showed maximum fruit set which is statistically at par with NAA (50 ppm), BA (50 ppm) and NAA (30 ppm) followed by 61.12 per cent in GA_3 (10 ppm). In litchi, more flowers were produced but only few developed into fruits (primarily due to premature flower abscission). In present investigation, minimum fruit set was recorded in control and maximum fruit set was observed in GA_3 50 ppm (65.087%), NAA 50 ppm (62.493%) and BA 50 ppm (62.30%) followed by GA_3 10 ppm. The data represent that spray of GA_3 (50 ppm), NAA (50 ppm) and BA (50 ppm) significantly increased number of fruit set per panicle. The effects of various PBRs on fruit drop of litchi are presented in Table 1 and it is evident that all the treatments proved effective in controlling fruit drop over control. The minimum percentage of fruit drop 37.27 per cent and 39.62 per cent was observed in NAA (50 ppm) and GA_3 (50 ppm), respectively which were statistically at par with each other, while maximum fruit drop (66.91%) was obtained in control. It is evident from data presented in Table 1, that in litchi gradually decrease in fruit drop with increase in fruit maturity. The minimum fruit drop was obtained in T_5 (NAA 50 ppm) and T_8 (GA_3 50 ppm). The findings conclude that NAA and GA_3 play a positive role in reducing the extent of fruit drop in litchi. Thakur *et al*. (1990) and Rani and Brahmchari (2001) [4] observed the similar observations regarding the positive role of NAA and GA_3 in decreasing fruit drop in litchi.

Table 1: Effect of Plant Growth Regulators on fruit set (on per panicle basis), Fruit drop, Fruit retention, Fruit length, Fruit width, Fruit weight and Fruit volume.

Treatments	Fruit Set (%)	Fruit Drop (%)	Fruit Retention (%)	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	Fruit volume (ml)
T_1 (control)	52.203	66.905	33.093	3.287	2.087	19.440	19.163
T_2 (BA 50 ppm)	62.300	49.205	50.793	3.323	3.107	21.580	21.450
T_3 (BA 30 ppm)	59.820	53.845	46.153	3.533	3.213	22.027	21.577
T_4 (BA 10 ppm)	60.400	53.426	46.573	3.477	3.087	21.443	21.483
T_5 (NAA 50 ppm)	62.493	37.271	61.200	3.667	3.520	25.147	24.250
T_6 (NAA 30 ppm)	62.103	42.340	57.663	3.540	2.997	22.030	22.147
T_7 (NAA 10 ppm)	59.890	42.406	57.597	3.520	3.153	21.617	21.173
T_8 (GA_3 50 ppm)	65.087	39.620	61.950	3.573	3.427	22.297	22.697
T_9 (GA_3 30 ppm)	60.200	41.898	58.103	3.357	3.137	21.743	20.587
T_{10} (GA_3 10 ppm)	61.127	43.106	56.897	3.443	3.263	21.977	21.330
C.D. at 5%	3.101	3.215	3.183	0.136	0.276	1.404	1.351
SE(m)	1.036		1.063	0.045	0.092	0.469	0.451

The data presented in Table 1 showed that all the treatments significantly increased fruit retention in litchi fruits. The data regarding to fruit retention at the time of harvesting showed that maximum fruit retention (61.95% and 61.20%) was observed in GA_3 50 ppm and NAA 50 ppm respectively which were statistically at par with each other. Minimum fruit retention (33.09%) was found in control and all the treatments were statistically significant over control. The data pertaining to the influence of different concentrations of PBRs on fruit length are presented in Table 1 various chemicals had significant effect on fruit length. Maximum fruit length 3.66 cm, 3.57 cm, 3.54 cm and 3.53 cm was recorded in T_5 (NAA 50 ppm), T_8 (GA_3 50 ppm), T_6 (NAA 30 ppm) and T_3 (BA 30 ppm) which was statistically at par with each other followed by 3.52 cm in T_7 (NAA 10 ppm) and minimum fruit length 3.29 cm was observed in control. No significant difference was observed among T_1, T_2 and T_{10} treatments and among the treatments T_5, T_8, T_6 and T_3. It is interesting to note that all the PBRs significantly increased fruit length in comparison to control. It is obvious from data given in Table 1 that width also varied significantly. All treatments showed significantly higher fruit width than control. Higher width 3.52 cm was observed in T_5 (NAA 50 ppm) which was statistically at par with T_8 (GA_3 50 ppm) and T_{10} (GA_3 10 ppm), followed by 3.21 cm in T_3 (BA 30 ppm) and minimum fruit width 2.09 cm was obtained in control.

Maximum fruit length 3.66 cm was recorded in T_5 (NAA 50 ppm) which was statistically at par with 3.57 cm, 3.54 cm and 3.53 cm which was recorded in T_5 (NAA 50 ppm), T_8 (GA_3 50 ppm), T_6 (NAA 30 ppm) and T_3 (BA 50 ppm) respectively while minimum fruit length was observed in control. Maximum fruit length (3.52 cm) was recorded in T_6 (NAA 30 ppm) and minimum fruit width 2.91 cm was recorded in control. Higher fruit width 3.66 cm, 3.42 cm and 3.26 cm was recorded in T_5 (NAA 50 ppm), T_8 (GA_3 50 ppm) and T_{10} (GA_3 10 ppm) respectively which were statistically at par with each other while minimum fruit length (2.09 cm) was observed in T_1 (control).The data on average weight as represented in Table 1 one fruit also showed significant variations. The all treatments had significantly higher furit weight than control. Fruits of T_1 (control) showed minimum fruit weight of 19.44 g. With their maximum fruit weights of 25.14 g treatment T_5 (NAA 50 ppm) followed by 22.29 gm treatment T_8 (GA_3 50 ppm) were significantly superior to the fruit weights of all other treatments. The data showed in Table 1 volume of the fruit harvested from all the treatments including control varied between 19.16 to 24.25 ml. The all treatments showed maximum volume than control. The minimum volume 19.16 ml was recorded with T_1 (control), while maximum volume 24.25 ml was obtained with T_5 (NAA 50 ppm) followed by 22.69 ml with T_8 (GA_3 50 ppm) which was varied significantly from control 19.16 ml. In present study the maximum weight was found in NAA 50 ppm followed by GA_3 50 ppm.

Table 2: Effect of Plant Bio-regulators on fruit cracking, TSS, Acidity, Ascorbic acid, Total sugar, Reducing sugar, Sugar:Acid ratio, Fruit yield/tree and Fruit yield/ha.

Treatments	Fruit Cracking (%)	TSS (°Brix)	Acidity (%)	Ascorbic Acid(mg/100 g)	Total Sugar (%)	Reducing Sugar (%)	Sugar: Acid Ratio	Fruit Yield/tree (Kg)	Fruit Yield/ha (Ton)
T_1 (control)	18.203	16.523	0.707	23.923	11.403	12.380	16.133	70.973	7.097
T_2 (BA 50 ppm)	15.310	19.187	0.627	25.917	13.347	10.497	21.307	84.950	8.497
T_3 (BA 30 ppm)	15.090	19.527	0.640	26.783	13.293	10.307	20.770	84.770	8.477
T_4 (BA 10 ppm)	15.400	18.827	0.660	25.977	12.007	10.497	18.190	82.680	8.270
T_5 (NAA 50 ppm)	14.477	20.317	0.577	25.560	13.970	9.897	22.540	87.843	8.787
T_6 (NAA 30 ppm)	14.120	18.963	0.597	26.230	13.890	10.383	26.720	86.443	8.647
T_7 (NAA 10 ppm)	14.997	18.483	0.620	25.793	13.600	10.250	24.737	85.777	8.580
T_8 (GA_3 50 ppm)	11.033	19.883	0.470	31.233	15.660	7.797	33.347	92.377	9.240
T_9 (GA_3 30 ppm)	14.243	22.450	0.520	29.463	14.577	9.053	31.023	89.750	8.977
T_{10} (GA_3 10 ppm)	14.137	20.693	0.550	26.343	14.273	9.573	24.840	88.837	8.887
C.D. at 5%	2.636	1.696	0.028	1.449	1.304	1.427	2.751	2.834	0.283
SE(m)	0.880	0.567	0.009	0.484	0.436	0.476	0.919	0.946	0.094

The data represented in Table 2 showed maximum fruit cracking (18.20%) in T_1 (control) and minimum fruit cracking (11.03%) in T_8 (GA_3 50 ppm). Against maximum fruit cracking (18.20%) in control, the minimum fruit cracking (11.03%) was observed in trees treated with GA_3 50 ppm. The foliar spray of various concentrations of PBRs had pronounced effect on fruit cracking. Due to hot winds at the time of crop maturity fruit cracking is a serious problem in litchi. The data represented in Table 2 showed maximum fruit cracking (18.20%) in T_1 (control) and minimum fruit cracking (11.03%) in T_8 (GA_3 50 ppm). Against maximum fruit cracking (18.20%) in control, the minimum fruit cracking (11.03%) was observed in trees treated with GA_3 50 ppm. The foliar spray of various concentrations of PBRs had pronounced effect on fruit cracking. Due to hot winds at the time of crop maturity fruit cracking is a serious problem in litchi. Data presented in Table 2 showed that minimum TSS (16.52 ^{0}Brix) was recorded in control and maximum TSS (22.45 ^{0}Brix) was found in GA_3 (30 ppm) followed by GA_3 10 ppm (20.69 ^{0}Brix) and NAA 50 ppm (20.31 ^{0}Brix). Data regarding TSS revealed that although all the treatments improved the TSS in comparison to control which showed minimum TSS. High TSS was found in GA_3 30 ppm. Data showed in Table 2 revealed that all treatments including control differed significantly among themselves in terms of acidity content of fruits. Total acid content varied from 0.47 per cent in GA_3 50 ppm to 0.70 per cent in control.

Regarding the data all the treatments showed significantly lower acidity than control. Minimum acidity content 0.47 per cent was observed with GA_3 50 ppm and maximum acidity content (0.70%) was observed in control. The data regarding the influence of various levels of plant growth regulators on ascorbic acid content of litchi are presented in Table 2 all the treatments were significantly higher than control (23.92 mg/100 gm). The highest ascorbic acid content was recorded in GA_3 50 ppm (31.23 mg/100 gm) followed by GA_3 30 ppm (29.46 mg/100 gm) and BA 30 ppm (26.78 mg/100 gm). NAA 30 ppm also influence the ascorbic acid content with 26.23 mg/100 gm. Control showed minimum ascorbic acid content (23.92 mg/100 gm). All the treatments were significantly affect the ascorbic acid content of the fruit (Table 2). Maximum ascorbic acid content was recorded in GA_3 50 ppm and minimum in control. In the previous findings The data pertaining to influence of various PBRs on total sugar content of litchi are presented in Table 2 showed that minimum total sugar content was significantly lower in control and BA 10 ppm which are statistically at par with each other, rest treated fruits were significantly higher from those of the control fruits. Fruits obtained from control had minimum total sugar content (11.40%) and maximum total sugar content 15.66 per cent and 14.54 per cent were found under the treatment of GA_3 50 ppm and GA_3 30 ppm which were statistically at par with each other followed by GA_3 10 ppm (14.27%).

The maximum total sugar content was observed in the fruits under the treatment of GA_3 50 ppm and GA_3 30 ppm and minimum total sugar content was reported in control. Data in Table 2 that all the treatments showed significantly higher reducing sugar than control except BA 30 ppm. Maximum reducing sugar 12.38 per cent was observed in GA_3 50 ppm followed by 10.49 per cent with both GA_3 30 ppm and NAA 50 ppm. Minimum reducing sugar 7.79 per cent and 9.05 per cent was recorded in control and BA 30 ppm, respectively, which are statistically at par with each other. The maximum reducing sugar was recorded in GA_3 50 ppm and GA_3 30 ppm and NAA 50 ppm and minimum reducing sugar was recorded in control and BA 30 ppm. Data presented in Table 2 revealed that all treatment showed significantly higher sugar: acid ratio than control. Maximum sugar: acid ratio (33.34) was recorded with GA_3 50 ppm which is statistically at par with GA_3 30 ppm (31.02) followed by NAA 30 ppm (26.72). Minimum Sugar: acid ratio (16.13) was recorded in control and BA 10 ppm. Both treatments are statistically at par with each other. The maximum sugar: acid ratio (33.34) was recorded in GA_3 30 ppm and minimum sugar: acid ratio (16.13) was recorded in control. Rani and Brahmchari (2001) [4] conducted a field experiment in litchi and obtained maximum sugar: acid ratio in 50 ppm GA_3 which support the present study. Data in Table 2 regarding yield revealed that although all the treatments significantlly improved the yield in comparison to control which recorded minimum yield. Highest fruit yield 9.2 ton per hectare and 8.9 ton per hectare were recorded with the application of GA_3 50 ppm and GA_3 30 ppm which are statistically at par with each other, followed by 8.8 ton per hectare and 8.7 ton per hectare with GA_3 10 ppm and NAA 50 ppm, respectively. The average yield of fruit was ranged 7.09 ton per hectare to 9.24 ton per hectare, while maximum average fruit yield was 9.24 ton per hectare followed by 8.8 ton per hectare and minimum average yield was found in control. In the present study the plant growth regulators used may favour the yield promoting factors such as higher fruit set, higher fruit retention and higher fruit size which may promote the increase in yield. One of the other possible reasons for increased yield may be due to de novo biosynthesis of auxin and other growth regulating or

promoting chemicals at initial stage due to additional stimulus produced by external application of PBRs.

Conclusion

Application of three sprays of GA_3 50 ppm (after fruit set, 15 days after I^{st} spray and 15 days after II^{nd} spray) was proved to be most effective in minimizing fruit drop and fruit cracking and improving the physico-chemical properties and yield of litchi.

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