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Influence of plant bioregulators on growth, yield and physico-chemical characteristics of strawberry

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ABSTRACT

The present investigation was carried out to study the influence of plant bioregulators on growth, yield and quality of strawberry cv. Festival. The study indicates that growth, yield attributing characters, yield and quality of strawberry fruits were significantly influenced by various bioregulators. Among different plant bioregulators, GA_3 150 ppm recorded the significantly the highest yield of 116.18 q ha^{-1}. It also recorded the highest value with respect to different growth parameters, *viz.* plant height (22.27 cm), spread (26.35 cm), number of runners (9.27) and flowering and fruiting duration (83.02 days). Among different yield attributing characters like berry set (87.93%), berry length (46.74 mm), berry diameter (29.75 mm), berry weight (18.62 g), berries $plant^{-1}$ (32.37), GA_3 150 ppm showed superiority than other plant bioregulators. Regarding various physico-chemical parameters, *viz.* TSS, acidity, total, reducing and non-reducing sugars of fruits, ethrel 250 ppm exhibited significantly the maximum values. The treatment GA_3 150 ppm was the best plant bio-regulator treatment for improving growth, and yield. However, with respect to physico-chemical characteristics of fruits, ethrel 250 ppm was found best.

Key words: Bioregulators, growth, quality, strawberry, yield.

INTRODUCTION

The strawberry (*Fragaria* × *ananassa* Duch.) is one of the most important soft fruits acclaimed for its refreshing characteristics, aroma, lucrative appearance and good nutritive value (Singh *et al.*, 12). Delicacy in flavour and richness in vitamins and minerals, makes strawberry a highly favoured food in the diet of millions of people around the globe (Bhat *et al.*, 3). Among the fruits, strawberry is one containing good amount of anti-oxidants. In addition, the presence of ellagic acid prevents many diseases and has made it a more valuable fruit.

In strawberry, among the various factors, which contribute to the growth and yield, plant bioregulators are important aspect of crop production. Because of its diverse effect, it is possible to use certain growth regulating chemicals at particular stages of fruit growth and development to have its maximum effect. Occasionally they are needed to be supplemented exogenously for additional stimulus for strawberry, which require quick response for increased growth, fruit set and yield (Singh and Singh, 11). Being bestowed with a wide range of agro-climatic conditions, north-eastern hill region of India offers immense potentiality for growing strawberry. However, the productivity of strawberry in this region is not comparable to other parts of India due to traditional systems of cultivation. Considering these facts, there is a pressing need to lay out the field experiment to study the influence of plant bioregulatorss on growth, yield, physico-chemical characteristics and economics of strawberry cv. Festival.

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MATERIALS AND METHODS

The present investigation was conducted at Experimental Orchard, Dept. of Horticulture, Aromatic and Medicinal Plants, Mizoram University, Aizawl during 2011-13. The experimental site was situated at an elevation of 779 m above msl and lies between 23°44´15.1´´ N latitudes and 092°39´36.5´´ E longitudes. The soil of the experimental plot was sandy loam, acidic in reaction with soil pH 5.27; the available N, P and K were 278.65, 27.25 and 123.78 kg ha^{-1} with 0.65% organic carbon. The experiment was laid out in Randomized Block Design (RBD) with 13 treatments and three replications. Recommended dose of FYM was applied before planting of strawberry runners in the respective plots. Plant bioregulators, *viz.*, GA_3, BA, TIBA and ethrel were applied as foliar application at 30, 45 and 60 days after planting. The recommended dose of P_2O_5 and K_2O @ 80 and 100 kg ha^{-1} were applied at the time of field preparation. The recommended N @120 kg ha^{-1} was applied in two splits, half one month after planting and second half after flowering. The various treatments followed for the investigation were as follows: T_0 = control (water spray), T_1 = BA 50 ppm, T_2 = BA 100 ppm, T_3 = BA 150 ppm, T_4 = GA_3 50 ppm, T_5 = GA_3 100 ppm, T_6 = GA_3

150 ppm, T_7 = TIBA 50 ppm, T_8 = TIBA 100 ppm, T_9 = TIBA 150 ppm, T_{10} = Ethrel 150 ppm, T_{11} = Ethrel 200 ppm and T_{12} = Ethrel 250 ppm.

Observations on various growth and yield characters were recorded by using standard methods. Five plants from the middle of each plot were selected randomly and tagged for observation of plant growth characters. The leaf area was recorded with leaf area meter and expressed in cm^2. Twenty berries from each treatment were randomly selected to record the data on physico-chemical characters. Fruit size was recorded by measuring length and breadth using the digital Vernier calipers, whereas fruit weight was taken using top pan digital balance. Total soluble solids were determined with Zeiss hand Brix refractometer (0-32°B). The titratable acidity, sugars and ascorbic acid were determined by method as suggested in AOAC (2). Pooled data were subjected to ANOVA (Gomez and Gomez, 5), where appropriate means were separated with least significant difference analysis.

RESULTS AND DISCUSSION

Different bio-regulators exhibit significant to highly significant influence on growth and yield of strawberry plants (Table 1). The maximum growth in terms of plant height (22.27 cm) and plant spread (26.35 cm) was observed with GA_3 150 ppm. The increased plant height and spread might be attributed due to more cell division and cell elongation, thereby enhanced vegetative growth in strawberry by overcoming genetic dwarfism (Singh and Singh, 11). Earlier, Syamal *et al.* (13) also reported increased growth of rough lemon and papaya with the application of GA_3.

The maximum number of leaves (35.50), leaf area per plant (136.12 cm^2) and No. of crowns $plant^{-1}$ (7.27) were observed in BA 150 ppm. BA application causes higher cell division and thus there will be higher supply of assimilates (Dwivedi *et al.*, 4). Our finding is in close conformity with those of Singh and Singh (11), who also reported increase in leaf number, leaf area and number of crowns in strawberry cv. Sweet Charlie with BA application. The data furnished in Table 1 showed that variation in number of runners $plant^{-1}$ among the treatments was significant. Among the treatments, GA_3 150 ppm recorded the highest runners $plant^{-1}$ (9.27), while the lowest (5.27) was recorded in the control. It is well known that gibberellic acid has been used to stimulate runner production consistently in ever bearing varieties (Moore and Scott, 7). Al-Madhagi *et al.* (1) also reported a consistent positive response in runner production due to GA application in strawberry.

Plants treated with TIBA required minimum days to first flowering (62.33 days), and first fruiting (70.33 days). Syamal *et al.* (13) reported that TIBA promotes formation and translocation of flowering stimulus as hormones from leaf to axil of leaves and thus produces early flowering as compared to other treatments. The early fruiting might be due to the effect of TIBA to produce the flower early, which might have resulted early fruiting. Similarly, GA_3 150 ppm recorded the maximum flowering and fruiting duration (83.02 days). Sharma and Singh (9) also reported maximum

Table 1. Effect of bioregulators on growth characteristics of strawberry.

Treatment	Plant height (cm)	Plant spread (cm)	Leaves/ plant (cm)	Leaf area/ plant (cm^2)	Crowns/ plant	Runners/ plant	Days to first flowering	Duration of flowering (days)	Days to first fruiting	Duration of fruiting (days)
T_0	15.87	21.82	26.78	111.08	4.77	5.27	79.33	58.62	85.67	60.96
T_1	20.65	24.89	33.37	130.72	6.58	5.42	74.67	59.40	82.00	63.08
T_2	20.67	24.92	34.35	132.49	6.73	6.45	74.33	60.63	80.67	64.62
T_3	20.87	24.42	35.50	136.12	7.27	6.88	73.67	60.83	81.33	64.72
T_4	21.35	26.03	33.05	123.87	5.07	7.97	72.33	75.85	79.33	78.52
T_5	21.72	26.06	32.56	122.80	5.52	8.23	75.33	76.51	83.00	78.71
T_6	22.27	26.46	31.85	123.45	5.58	9.27	71.33	83.02	79.33	83.02
T_7	20.75	24.17	31.32	129.75	6.20	7.87	65.67	73.77	72.33	74.10
T_8	20.95	24.75	31.98	127.61	6.30	7.30	63.33	75.38	72.00	74.05
T_9	20.87	24.83	32.43	125.37	6.35	7.35	62.33	75.52	70.33	74.87
T_{10}	17.23	22.82	29.05	115.63	6.38	7.15	77.33	75.33	82.67	76.63
T_{11}	17.12	22.93	28.62	113.92	6.33	7.13	77.67	73.37	85.33	72.67
T_{12}	16.27	22.45	28.22	116.43	6.37	7.12	78.33	73.10	84.67	74.10
$CD_{0.05}$	1.40	1.15	3.07	5.21	0.79	1.09	4.31	4.39	4.68	5.40

flowering and fruiting duration in 'Chandler' strawberry with different GA_3 concentrations.

Various bio-regulators significantly influenced the yield and yield attributing characters of strawberry. It is revealed from the Table 2 that, the maximum berry set was obtained in GA_3 150 ppm (87.93%), while minimum in control (68.67%). The increased berry set in GA_3 treated plants might be due to the fact that GA_3 induced the production of enzymes attributed to improved fruit set by playing a role in the post fertilization stage. In addition, exogenous application of GA_3 shifted the endogenous balance between promoters and inhibitors in favour of fruit forming metabolic processes (Sharma and Sharma, 10). Berry length (46.74 mm), berry diameter (29.75 mm) and berry weight (18.62 cm) were also influenced significantly by GA_3 150 ppm over other treatments. The increase in fresh weight and size may also be explained by the fact that hormones play a regulatory role in the mobilization of metabolites within the plant and it is a well established fact that developing fruits are the extremely active metabolites 'sink', which mobilizes metabolites and their flow from vegetative parts (Weaver, 14). Sharma and Singh (9) reported higher fruit weight in strawberry by spraying GA_3. It is revealed from the data that the variation in number of berries plant^{-1} was significant. The highest number of berries per plant was recorded in GA_3 150 ppm (32.37), while, control recorded the lowest (19.40). The marked influence of GA_3 on number of berries may be attributed to its effect on better pollen germination and fruit set (Sharma and Singh, 9).

Among all the treatments, GA_3 150 ppm recorded the highest yield (116.18 q ha^{-1}). The lowest yield of 86.73 q ha^{-1} was recorded in control. The increase in yield with gibberellic acid might be is due to increase in flower number, better fruit set and production of more number of fruits with maximum weight besides better vegetative growth. In fact, the enlargement of the strawberry fruit is dependent on the auxin produced by the developing achenes, and if the flowers remain un-pollinated, the cells fail to elongate. GA might have helped in the elongation of cells in the un-pollinated region of the fruit, as well, affected the auxin metabolism, which might have indirectly helped in the fruit enlargement, and also higher number, which ultimately increases the yield (Kappel and MacDonald, 6). Similar increase in strawberry yield following GA application has also been reported by Paroussi *et al.* (8).

An inquisition of data presented in Table 3 revealed that different plant bioregulators have significant role on physico-chemical characteristics of berries. The highest TSS (12.43%), lowest titrable acidity (0.823%), highest value of total, reducing and non-reducing sugars (8.96, 4.74 and 4.22%) were recorded in ethrel 250 ppm. The improved TSS with ethrel treated plants can be attributed to the fact that stress might have caused cell elongation accompanied by considerable increase in sugar content (Syamal *et al.*, 13). Similarly, the reduction in pulp acidity with ethrel might be due to the metabolic changes with fast conversion of organic acids and starch into sugars and their derivatives through higher respiration and carbon assimilation activity (Yadav *et al.*, 15). The increase in sugar content in ethrel treated plants might be due to better ripening of fruits,

Table 2. Effect of bioregulators on yield attributing characters and yield of strawberry.

Treatment	Berry set (%)	Berry length (mm)	Berry dia. (mm)	Berry wt. (g)	Berries/ plant	Yield (q/ha)
T_0	68.67	33.18	23.37	11.15	19.40	86.73
T_1	76.07	38.38	24.18	11.25	21.48	101.90
T_2	77.45	39.79	24.68	12.33	23.00	101.94
T_3	79.19	41.17	24.76	12.68	25.37	103.30
T_4	85.67	44.38	27.73	16.87	28.67	111.27
T_5	86.68	45.03	28.60	17.28	30.57	113.45
T_6	87.93	46.74	29.75	18.62	32.37	116.18
T_7	82.40	43.72	26.79	15.50	24.73	107.02
T_8	83.73	42.98	26.92	15.96	24.93	107.72
T_9	84.25	42.85	26.55	16.39	24.88	104.82
T_{10}	81.90	42.33	25.97	16.43	24.60	107.52
T_{11}	79.87	42.08	25.52	16.26	25.03	109.07
T_{12}	79.83	43.26	25.95	15.73	26.55	110.40
$CD_{0.05}$	5.57	1.84	1.23	0.95	6.38	6.82

Table 3. Effect of bioregulators on quality parameters of strawberry.

Treatment	TSS (°Brix)	Acidity (%)	Total sugars (%)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid (mg/100 g)
T_0	7.82	0.903	7.72	4.06	3.66	63.28
T_1	8.23	0.843	8.23	4.17	4.06	72.07
T_2	8.28	0.840	8.53	4.37	4.16	74.51
T_3	8.47	0.847	8.68	4.56	4.12	70.78
T_4	8.88	0.837	8.23	4.58	3.65	92.47
T_5	9.20	0.838	8.39	4.55	3.84	95.41
T_6	9.59	0.838	8.52	4.52	4.00	98.28
T_7	8.75	0.832	8.39	4.45	3.94	73.70
T_8	8.69	0.833	8.38	4.57	3.82	85.06
T_9	9.81	0.837	8.47	4.52	3.95	82.18
T_{10}	10.43	0.825	8.86	4.68	4.18	82.97
T_{11}	11.01	0.824	8.92	4.72	4.2	84.28
T_{12}	12.43	0.823	8.96	4.74	4.22	84.88
$CD_{0.05}$	0.61	0.01	0.43	0.12	0.27	8.72

which is associated with high metabolic changes and conversion of complex polysaccharides into simplest sugars through higher respiration and carbon assimilation activity, conversion of organic acids into sugars (Yadav *et al.*, 15). The data presented in Table 3 revealed that, the highest ascorbic acid (98.28 mg/100 g) was recorded with GA_3 150 ppm. The perceptive increase in ascorbic acid content with gibberellic acid might be due to catalytic influence of gibberellic acids on its biosynthesis from its precursor glucose-6-phosphate or inhibition of its conversion to dehydro-ascorbic acid by enzyme ascorbic acid oxidase or both.

Data presented in Tables 4 and 5 revealed the correlation among the growth parameters with yield. The estimates for correlation co-efficient for plant height, plant spread, leaf No., leaf area, crowns plant^{-1} and yield in all possible combination are presented in Table 4. All the growth and yield attributing characters were shown to be significant to highly significant positive correlation with yield. Highly significant positive association with yield was shown by plant spread (r = 0.565**), while other traits, *viz.* plant height (r = 0.450), leaf No. (r = 0.237), leaf area (r = 0.109), and crowns plant^{-1} (r = 0.088) showed positive correlation with yield. Similarly, the yield was positively correlated with yield attributing characters of berries, *viz.* per cent berry set, berries plant^{-1}, berry weight, berry length and berry diameter (Table 5). The per cent berry set (r = 0.750**), berries plant^{-1} (r = 0.887**), berry weight (r = 0.851**), berry length (r = 0.967**) and berry diameter (r = 0.847**) were positively correlated with yield and effect was found to be highly significant for all the parameters.

From the results of the present investigation, it can be concluded that the 150 ppm GA_3 (T_6) was the most efficient plant bio-regulator for improving growth and yield of 'Festival' strawberry. The physico-chemical characteristics of fruits were improved with application of ethrel 250 ppm (T_{12}). Hence,

Table 4. Correlation coefficient values of growth characters on yield of strawberry.

Trait	Plant height	Plant spread	Leaf No.	Leaf area	Crowns/ plant	Yield
Plant height	1.00	0.953**	0.856**	0.773**	0.095**	0.450
Plant spread		1.00	0.769**	0.602**	-0.069	0.565**
Leaf No.			1.00	0.929**	0.436	0.237
Leaf area				1.00	0.565**	0.109
Crowns/ plant					1.00	0.088
Yield						1.00

Table 5. Correlation coefficient values of yield attributing berry traits with yield in strawberry.

Trait	Berry set	Berries/ plant	Berry weight	Berry length	Berry dia.	Yield
Berry set	1.00	0.613**	0.780**	0.859**	0.750**	0.750**
Berries/ plant		1.00	0.834**	0.895**	0.930**	0.887**
Berry weight			1.00	0.890**	0.903**	0.851**
Berry length				1.00	0.898**	0.967**
Berry dia.					1.00	0.847**
Yield						1.00

these two plant bioregulators can be recommended for increasing the growth, yield and quality of strawberry.

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