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SPRINGTIME FOLIAR APPLICATION OF PLANT BIO-REGULATORS ON OFF SEASON STRAWBERRY PRODUCTION UNDER MID HILL CONDITION

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ABSTRACT

To increase the strawberry production especially during offseason with the application of plant bio-regulators, the present study was conducted under subtropical mid-hill conditions of Arunachal Pradesh, India during spring-summer months of 2015-16. Effect of springtime foliar application of different plant bio-regulators viz., NAA, GA₃, and BA on plant growth, yield and quality attributes of strawberry cv. Chandler with the advantage of increasing strawberry production during the off-season was accessed during the current study. The experiment was laid out in a randomized block design with ten treatment combinations (NAA, GA₃, and BA at 50, 100, and 150 ppm each) replicated thrice considering water spray as control. The plant bio-regulators were sprayed at 25 days after transplanting and at the bud initiation stage. Results of the experiment revealed that the plants treated with GA₃ 150 ppm significantly influenced the plant height and number of leaves per plant at 30, 45, 60 and 75 days after transplanting. The minimum number of days taken to open the first flower (62.11 days) and the maximum number of runners per plant (9.17) were also recorded in the plants treated with GA₃ 150 ppm. While, GA₃ 50 ppm treated plants yielded fruits with maximum berry length (3.69 cm), berry width (2.74 cm), average berry weight (13.99 g), number of berries per plant (21.11) and yield per plant (209.11 g). Concerning the quality parameters of fruits, plants treated with NAA 100 ppm exhibited maximum TSS (9.00° B), total sugar (7.23 %), and ascorbic acid content (77.82 mg/100 g) whereas, GA₃ 100 ppm treatment significantly increased the contents of anthocyanin (122.18 mg/100 g), total phenols (69.42 mg/100 g) and β-carotene (3.96 µg/100 g).

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1 Introduction

Strawberry (*Fragaria x ananassa* Duch.) is an important berry fruit of temperate region which is also cultivated in subtropical and tropical regions. The cultivated octaploid strawberry, a surface feeder herbaceous perennial crop belongs to the family Rosaceae, is considered as one of the most delicious and nutritious soft fruits (Mitra, 1991). Apart from its fresh consumption, it has a demand in fruit processing industries for value addition viz. jam, ice-creams, syrups, dehydrated candy, etc. Hence, strawberry is one of the most favored fruit crops among the growers, especially in towns and cities due to its profitable remunerative prices. Therefore, increasing the productivity of strawberry by manipulation of flowering for increased fruit production is important key point research has proved that plant bio-regulators induce biochemical changes in fruit crops, which in turn induce both vegetative and reproductive responses (Saima et al., 2014; Baba et al., 2017). Some plant bio-regulators are synthesized endogenously, but occasionally need to be supplemented exogenously for additional stimulus in cases of short duration crops like strawberry, which require a quick response for increased growth, fruit set, and yield (Singh & Singh, 2009). The use of gibberellic acid (GA_3) and naphthalene acetic acid (NAA) alone or in combination has been reported to increase the plant height, the number of crowns, runners, and leaf area of strawberry (Kumar et al., 1990; Thakur et al., 1991) and the use of GA_3 75 ppm induce higher fruit set but reduced the average fruit weight (Sharma & Singh, 2009). Further, Banday et al. (2005) reported that the application of 25 ppm GA_3 at the flower bud formation stage in two strawberry cultivars 'Confitura' and 'Brighton' resulted in the maximum fruit size, while the application of 40 ppm GA_3 minimized the number of days to maturation. Based on the experiment conducted by Saima et al. (2014), it was concluded that GA_3 75 ppm applied at 30 and 45 days after transplanting was best in increasing the growth and yield of strawberry cv. Chandler. Further, many researchers have been reported that the GA_3 application in spring, after floral initiation increases the rate of open flower production (Hu et al., 2008; Gupta & Chakrabarty, 2013). Since strawberry is responsive to the application of plant growth regulators, it is imperative to assess the effect of plant bio-regulators which modifies various physiological processes with the advantage to increase the strawberry production, especially during off-season. Keeping in view the need to enhance and extend the production season under mid-hill conditions where spring-summer months are pleasant, a field experiment was conducted to understand and assess the effect of springtime foliar application of different plant bio-regulators on growth, yield, and quality of strawberry cv. Chandler during the off-season under the mid-hill conditions of Arunachal Pradesh, India.

2 Materials and methods

2.1 Experimental site and treatments

The present investigation was carried out at ICAR Research Farm, Gori, Basar, Arunachal Pradesh, India situated in the mid-hill zone at

the latitude of 27°59.537' N and longitude of 94°41.269' E with an altitude of 650 m above sea level during mid-February to June 2015-16, to study the effect of springtime foliar application of different plant bio-regulators on growth, yield and nutritional status of strawberry cv. Chandler. The location is under the sub-tropical hill zone characterized by high rainfall with humid subtropical wet summer (Mishra et al., 2004). The field experiment was laid out in RBD (Randomized Block Design) with three replications having ten treatments viz. three growth hormones (NAA, GA, and BA) at three concentrations (50 ppm, 100 ppm, and 150 ppm) and control. For further growth and development, well-decomposed farmyard manure with 40 kg/ha each of P_2O_5 and K_2O were applied at the time of bed preparation, whereas 80 kg N was applied in two split doses, the first half-dose after the establishment of transplanted runners and the second dose before blooming. Uniform and disease-free runners of cv. Chandler was transplanted in mid-February on raised bed maintaining a spacing of 25 cm x 50 cm followed by mulching with paddy straw. The growth regulators were sprayed at 25 days after transplanting and at the bud initiation stage. All necessary cultural practices and plant protection measures were followed uniformly for all the plots and treatments during the entire experimental period.

2.2 Physico-chemical quality traits of plants and fruits

Observations on plant height, number of leaves, days required for first flowering, number of runners per plant, fruit length, fruit breadth, fruit weight, and yield were recorded in randomly selected plants from each treatment with three replications. Total soluble solids (TSS) was determined with a digital Erma hand refractometer (0-32°Brix) where a drop of the juice was used on the calibrated refractometer. Titratable acidity was estimated by titrating against 0.1N sodium hydroxide using phenolphthalein as an indicator (AOAC, 2000) and ascorbic acid content by titrating sample filtrate with 4 % oxalic acid using 2, 6-dichlorophenol indophenol dye to the pink endpoint and expressed as mg/100 g (AOAC, 2005). Total sugar was estimated by the Anthrone method as described by Sadasivam & Manickam (2005) whereas total phenol by using Folin-Ciocalteu reagent (Singleton & Rossi, 1965). Ranganna (1986) method was followed for anthocyanin content and expressed as mg/100 g, whereas 10 g blended sample was mixed with 10 ml of ethanol-hydrochloric acid mixture (95% C_2H_5OH and 1.5 N HCl in the ratio 85:15) which was transferred into a 100 ml volumetric flask and kept overnight at 4°C, filtered through Whatman No. 1 and measured in a spectrophotometer at 535 nm. β -carotene was determined using the colorimetric method of Srivastava & Kumar (2002) where 5 g of fresh sample was crushed in acetone by adding crystals of anhydrous Na_2SO_4 , the supernatant thus collected was extracted in petroleum ether and OD was recorded at 452 nm.

2.3 Statistical Analysis

Data obtained for various parameters were performed as per standard procedure and mean comparison was performed using

Tukey's Honest Significant Difference (HSD) test with SAS 9.3 (TS1MO) software package developed by SAS Institute. A difference was considered statistically significant when $p < 0.05$.

3 Results and discussion

3.1 Vegetative growth attributes

The application of plant bio-regulators significantly influenced the plant height and number of leaves per plant. With the application

of GA₃ 150 ppm, maximum plant height (11.11, 18.78, 22.22 and 26.67 cm) and the maximum number of leaves per plant (8.78, 14.67, 20.11, 24.67) was attained at 30, 45, 60, and 75 days after transplanting (Figure 1 and 2). The maximum plant height and increase in the number of leaves per plant is the fact that gibberellins regulate the growth of strawberry plants by causing cell division, cell elongation, epidermal and parenchyma's cell length in the plant system (Prasad et al., 2015; Sood et al., 2018). These results conform with the works of Saravanan et al. (2013)

Figure 1 Effect of plant bio-regulators on plant height (cm) of strawberry

Figure 2 Effect of plant bio-regulators on number of leaves per plant of strawberry

and El-Shabasi et al. (2008), who reported that GA application increased petiole length. The maximum number of runners (9.17) per plant was produced with application of GA₃ 150 ppm (Table 1) which may be due to stimulated activity that redistributed the gibberellins in greater concentration in the crown region which later enhance the production of runners (Martinez et al., 1994; Palei et al., 2016).

3.2 Days to first flowering

Various plant bio-regulators showed a significant influence on the flowering and fruiting behavior of cv. Chandler (Table 1). Gibberellic acid aids in enhancing early flowering in all fruit crops in general and strawberry in particular, wherein with the GA₃ 150 ppm treatment, the minimum number of days was taken to open the first flower (62.11 days). These results are in concordance with Sharma & Singh (2009) those who suggested that GA positively influenced flower initiation and duration. A similar opinion was also put forwarded by Paroussi et al. (2002) and Ikram et al. (2016) whose report was on the reduced time of inflorescence emergence possibly due to the stimulation of hormone florigen by gibberellic acid. The maximum number of days (75.56 days) taken to produce the first flower was recorded under control.

3.3 Fruit growth, yield and yield attributes

The application of GA₃ 50 ppm exhibited a significant increase in berry length (3.69 cm), berry width (2.74 cm), yield (209.11 g), and yield attributing characteristics viz. berry weight (13.99 g) and the number of berries per plant (21.11) as

presented in Table 1. The increase in fruit size and weight during the study might be due to the increased photosynthetic ability of plants treated with GA₃ 50 ppm, which in turn might have favored and increased the accumulation of dry matter (Thakur, 2016). Plants treated with GA₃ 150 ppm was observed to attain first flowering in the least number of days (62.11 days) and maximum number of runners per plant (9.17) however, berry length (3.32 cm), berry width (2.39 cm), average berry weight (12.88 g), number of berries per plant (18.98) and fruit yield per plant (198.10 g) were significantly lower to GA₃ 50 ppm treated plants. Lopez et al. (1989) also recorded increased yield with an increase in GA concentration. Gibberellins enhance the production of flowers with rapid elongation of peduncle leading to the full development of flower buds having all reproductive parts functional which increases the fruit set and many berries per plant (Saima et al., 2014). The increase in berry yield per plant is representative of increased fruit set and larger berry size.

3.4 Fruit biochemical quality

It was observed that TSS, total sugars, titratable acidity and ascorbic acid contents of berries were significantly increased by application of plant growth regulators (Table 2). The highest TSS (9.00° Brix) and total sugars (7.23 %) were found in the berries produced from the plants treated with NAA 100 ppm concentration. The increased pattern of TSS and total sugars may be due to increased translocation of sugars from the leaves to the developing fruits as a result of starch and pectin transformation to soluble compounds (Brahamchari & Rani, 2001).

Table 1 Effect of different plant bio-regulators on the growth, yield and yield attributes of strawberry.

Treatments	Days required for first flowering	Berry Length (cm)	Berry Width (cm)	Average berry weight (g)	No. of berries per plant	Fruit yield per plant (g)	Number of runners per plant
NAA 50 ppm	71.89 ^b ± 1.567	3.15 ^{bc} ± 0.076	2.17 ^{ef} ± 0.044	12.31 ^c ± 0.235	17.83 ^{cde} ± 0.441	183.55 ^d ± 5.222	6.56 ^c ± 0.294
NAA 100 ppm	70.67 ^{bc} ± 0.882	3.08 ^{bc} ± 0.065	2.21 ^{de} ± 0.049	12.08 ^c ± 0.311	18.61 ^{bcd} ± 0.656	197.05 ^{bc} ± 1.868	6.89 ^c ± 0.110
NAA 150 ppm	70.67 ^{bc} ± 0.384	3.37 ^b ± 0.144	2.57 ^b ± 0.026	13.44 ^{ab} ± 0.249	18.50 ^{bcd} ± 0.764	188.85 ^{cd} ± 3.981	6.78 ^c ± 0.400
GA 50 ppm	63.89 ^d ± 0.950	3.69 ^a ± 0.052	2.74 ^a ± 0.081	13.99 ^a ± 0.453	21.11 ^a ± 0.936	209.12 ^a ± 2.610	8.78 ^{ab} ± 0.110
GA 100 ppm	62.89 ^d ± 1.458	3.36 ^b ± 0.058	2.45 ^{bc} ± 0.074	13.38 ^{ab} ± 0.232	20.17 ^{ab} ± 0.833	203.51 ^{ab} ± 2.628	8.89 ^{ab} ± 0.802
GA 150 ppm	62.11 ^d ± 0.294	3.32 ^b ± 0.073	2.39 ^c ± 0.074	12.88 ^{bc} ± 0.206	18.98 ^{bc} ± 0.290	198.10 ^b ± 3.018	9.17 ^a ± 0.441
BA 50 ppm	69.89 ^{bc} ± 0.890	3.10 ^{bc} ± 0.211	2.12 ^{ef} ± 0.111	12.10 ^c ± 0.274	16.72 ^{de} ± 0.546	169.48 ^c ± 0.999	7.67 ^{bc} ± 0.333
BA 100 ppm	71.89 ^b ± 1.567	3.23 ^b ± 0.123	2.37 ^{cd} ± 0.130	12.40 ^c ± 0.243	17.11 ^{cde} ± 0.675	180.48 ^d ± 3.194	8.33 ^{ab} ± 0.667
BA 150 ppm	68.22 ^c ± 0.619	3.26 ^b ± 0.087	2.35 ^{cd} ± 0.022	12.42 ^c ± 0.061	16.33 ^c ± 0.928	165.17 ^c ± 2.946	8.33 ^{ab} ± 0.333
Control	75.56 ^a ± 0.295	2.93 ^c ± 0.015	2.01 ^f ± 0.009	10.70 ^d ± 0.479	13.28 ^f ± 0.682	108.37 ^f ± 4.228	4.78 ^d ± 0.400
LSD (0.05)	2.69	0.29	0.17	0.88	2.11	8.76	1.28

*Values within the columns with similar superscripts are statistically identical and values with dissimilar superscripts differ significantly at $p < 0.05$ level of significance

Table 2 Quality attributes of strawberry fruits as influenced by application of different plant bio-regulators.

Treatments	TSS (°Brix)	Titrate acidity (%)	Ascorbic acid (mg/100 g)	Total sugar (%)	Phenols (mg/100 g)	Anthocyanin (mg/100 g)	β-carotene (µg/100 g)
NAA 50 ppm	8.89 ^a ± 0.110	0.65 ^b ± 0.020	76.38 ^a ± 1.840	7.10 ^a ± 0.473	56.17 ^d ± 0.338	91.63 ^c ± 8.883	1.26 ^d ± 0.015
NAA 100 ppm	9.00 ^a ± 0.191	0.64 ^b ± 0.059	77.82 ^a ± 0.935	7.23 ^a ± 0.306	61.29 ^c ± 1.232	100.84 ^{bc} ± 7.957	1.84 ^d ± 0.390
NAA 150 ppm	8.67 ^{ab} ± 0.193	0.63 ^b ± 0.027	76.69 ^a ± 2.729	7.17 ^a ± 0.276	61.43 ^c ± 1.951	116.50 ^{ab} ± 7.610	1.38 ^d ± 0.173
GA 50 ppm	8.11 ^{bc} ± 0.402	0.68 ^{ab} ± 0.040	68.99 ^b ± 2.828	6.50 ^{ab} ± 0.227	69.15 ^a ± 0.340	119.36 ^a ± 4.078	3.32 ^b ± 0.144
GA 100 ppm	7.67 ^c ± 0.193	0.69 ^{ab} ± 0.030	76.07 ^a ± 0.250	5.80 ^{bc} ± 0.573	69.42 ^a ± 2.176	122.18 ^a ± 4.676	3.96 ^a ± 0.274
GA 150 ppm	7.78 ^c ± 0.110	0.68 ^{ab} ± 0.020	76.23 ^a ± 2.295	6.35 ^{abc} ± 0.193	67.78 ^{ab} ± 0.592	93.07 ^c ± 1.920	3.52 ^{ab} ± 0.182
BA 50 ppm	7.56 ^c ± 0.294	0.71 ^{ab} ± 0.052	65.48 ^b ± 2.511	5.73 ^{bc} ± 0.537	63.80 ^{bc} ± 3.467	83.85 ^c ± 1.643	2.65 ^c ± 0.166
BA 100 ppm	7.45 ^c ± 0.223	0.74 ^{ab} ± 0.003	63.65 ^b ± 1.831	5.70 ^{bc} ± 0.186	60.49 ^c ± 0.193	91.41 ^c ± 0.860	3.01 ^{bc} ± 0.139
BA 150 ppm	7.89 ^{bc} ± 0.402	0.78 ^a ± 0.038	65.72 ^b ± 2.302	6.26 ^{abc} ± 0.594	66.28 ^{ab} ± 0.767	91.21 ^c ± 8.378	2.59 ^c ± 0.250
Control	7.33 ^c ± 0.193	0.71 ^{ab} ± 0.044	55.14 ^c ± 1.516	5.28 ^c ± 0.113	55.79 ^d ± 1.005	84.07 ^c ± 3.905	1.64 ^d ± 0.098
LSD _(0.05)	0.78	0.11	6.39	1.19	4.27	17.34	0.60

*Values within the columns with similar superscripts are statistically identical and values with dissimilar superscripts differ significantly at $p < 0.05$ level of significance

The minimum titratable acidity from NAA treatments might be attributed to the incitement occurring in the berries i.e. possibly due to the transformation of organic acids into sugars during the process of maturity and ripening (Gautam et al., 2018). Ascorbic acid content was found to be significantly higher (77.82 mg/100 g) in the berries treated with NAA 100 ppm followed by NAA at 150 ppm (76.69 mg/100 g) and NAA at 50 ppm (76.38 mg/100 g) which were statistically at par with treatments GA 150 ppm and GA 100 ppm with 76.23 mg/100 g and 76.07 mg/100 g respectively. This increase in ascorbic acid content might be due to the catalytic activity of auxins and gibberellins on its biosynthesis from its precursors (glucose-6-phosphate) or inhibition of its conversion into dehydro ascorbic acid by enzyme ascorbic acid oxidase or both (Brahamchari & Rani, 2001). Results showed that GA₃ 100 ppm treatment significantly influenced the secondary metabolites viz. anthocyanin (122.18 mg/100 g), total phenols (69.42 mg/100 g), and β-carotene (3.96 µg/100 g) contents in the strawberry fruits (Table 2). These results concur with the findings of Roussos et al. (2009) who observed that anthocyanin content in strawberry fruit increased significantly when the plants were treated with GA indicating that the hormone also plays a role in the accumulation of pigments in strawberry fruits. These findings were also consistent with the results of Klessig & Malamy (1994) who reported that GA significantly promoted the biosynthesis of secondary metabolites in the fruits.

Conclusions

To summarize, the study showed that the plant vegetative attributes were influenced by GA₃ 150 ppm meanwhile the fruit growth, yield and yield attributes were enhanced by the application of GA₃

50 ppm. In terms of quality attributes, the application of NAA 100 ppm was found to give higher TSS, total sugar, and ascorbic acid, while maximum phenols, anthocyanin, and β-carotene contents were influenced by the application of GA₃ 100 ppm. The result of the experiment concluded that exogenous application of plant bio-regulators enhances the production and quality of strawberry fruits during off-season under mid-hill conditions of Arunachal Pradesh in Eastern Himalayas, India.

Conflict of Interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise

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