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Effect of Plant Growth Regulators on Growth, Yield and Quality of Strawberry (*Fragaria* × *ananassa* Duch.) Cv. Winter Dawn under Open Field Conditions of South Gujarat

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ABSTRACT

Background: The South Gujarat hilly part is considered to be a non-traditional area of strawberry cultivation in India. The poor farmers of this region are cultivating strawberries under open field condition. Both, the yield and quality of strawberry fruits of this region are not up-to-the-mark as there in other parts of the country. Hence, a low-cost improved production technology is required to maximize yield as well as improve the quality of strawberry fruits.

Methods: Uniform runners of strawberry cv. Winter Dawn were grown in open field under paddy straw as bedding material. Foliar spraying of plant growth regulators *viz.* NAA (50, 75, 100 and 125 mg l^{-1}) and GA_3 (50, 75, 100 and 125 mg l^{-1}) were done at 30 and 60 days after planting. The experiment was laid out in randomized block design with control plants receiving no spray treatments and replicated thrice.

Result: The plant growth parameters like plant spread, number of leaves, number of crowns, leaf area, length of petiole, number of runners were recorded maximum with the application of 100 mg l^{-1} GA_3. This treatment was also found to be the best in respect of number of flowers, number of fruits, fruit weight, marketable and total fruit yield of strawberry. Strawberry fruits with the highest total soluble solid, ascorbic acid, reducing sugar, non-reducing sugar and total sugar content were recorded in the plants which received 125 mg l^{-1} NAA. However, the plant growth regulator treatments failed to influence any significant effect on days taken to 50.0 % flowering, fruit firmness and acidity content of strawberry fruits.

Key words: Foliar spraying, GA_3, NAA, Plant growth regulators, Strawberry.

INTRODUCTION

Strawberry (*Fragaria* × *ananassa* Duch.) is an important fruit crop of the family Rosaceae. The attractive red colour, pleasant aroma and high nutritional value in terms of vitamins (A and C) and minerals (Fe and K) make this fruit highly prized in global markets. Beside the fresh consumption, strawberry fruits are also being used to prepare jam and jellies due to presence of high amount of pectin. Strawberry fruits have a fair amount of natural antioxidants which are found to be useful for relieving the oxidative stresses (Sharma and Thakur, 2008). Consumption of strawberry helps in prevention of various types of cancers and heart related diseases. This fruit is also reported to be beneficial in reduction of inflammation and obesity related disorders (Arfin *et al*., 2016). For these reasons the demand of strawberries in the markets is increasing gradually and the growers are also encouraged to cultivate this crop to gain higher income.

Strawberries can be cultivated successfully in temperate or subtropical climate under open field condition. However, it could be gown anywhere under protected condition (Sharma and Sharma, 2004). In India, this fruit crop is still cultivated under open field conditions in paddy straw mulching system by poor or marginal farmers and covers a major portion of total cultivated area of strawberry in this country. The South Gujarat hilly part offers immense potentiality for strawberry cultivation (Bhagariya and Prajapati, 2019). Unlike other parts of the country, its cultivation has also been initiated here in open fields under paddy straw mulch. However, the productivity is not comparable as obtained in other parts of country. Therefore, a cost effective and sustainable technological advancement regarding the cultivation of this crop is required. Open filed cultivation of strawberry requires special care and judicious

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management practices, otherwise satisfactory return is difficult to achieve. The plant growth regulators have quick stimulative effects on plant growth responses like growth, flowering and fruiting (Krishnamoorthy, 1981). Scientific evidences have also suggested that the strawberry plant responded well to growth regulator application (Sharma and Sharma, 2004). Among the plant growth regulators, naphthalene acetic acid (NAA) and gibberellins (GA_3) have been widely tested in modern agricultural system due to their suitability of application at cheaper rate. The role of these plant growth regulators has been investigated in several fruits (Bisht *et al.*, 2018). Therefore, the present experiment was undertaken to investigate the effects of NAA and GA_3 on growth, yield and quality of strawberry in Southern Gujarat region.

MATERIALS AND METHODS

The present investigation was carried out at Rambhas Farm (20°77′ N and 73°50′ E), Hill Millet Research Station, Navsari Agricultural University, Waghai, India during the year 2017-18. The experimental site was sandy loam and neutral in reaction with pH 6.7. The available N, P and K of the field soil were 313.6, 60.7 and 230.8 kg ha^{-1}, respectively with 1.20 % organic C. The recommended dose of FYM 10 t ha^{-1} and fertilizers [N (as Urea), P_2O_5 (as SSP) and K_2O (as MOP) @ 120:80:100 kg ha^{-1}] were applied at the time of field preparation. Healthy, well developed, almost uniform, pest and disease-free runner plantlets of strawberry cv. Winter Dawn were planted at second week of October at a spacing of 60 cm × 30 cm under paddy straw mulching. Each experimental bed (3 m × 1.8 m) comprised of 30 plants with 12 plants in a net plot area (1.8 m × 1.2 m). Foliar spraying of plant growth regulators (NAA and GA_3) was carried out at 30 and 60 days after planting. The experiment was laid out in Randomized Block Design (RBD) with nine treatments *viz.* T_1 = 50 mg l^{-1} NAA, T_2 = 75 mg l^{-1} NAA, T_3 = 100 mg l^{-1} NAA, T_4 = 125 mg l^{-1} NAA, T_5 = 50 mg l^{-1} GA_3, T_6 = 75 mg l^{-1} GA_3, T_7 = 100 mg l^{-1} GA_3, T_8 = 125 mg l^{-1} GA_3, T_9 = No spray (Control) and replicated thrice.

Five plants from the net plot area were selected randomly and tagged to record the plant growth and ancillary observations. The leaf area was measured using leaf area meter (Biovis PSM-L2000) and expressed in cm^2. Ten berries from the harvested fruit lot of each treatment were randomly selected to record the observations on physico-chemical properties. Digital fruit firmness tester (LTLUTRON-FR-5120) and digital refractometer (ATAGO Pocket 3810, PAL-1) were used to measure the fruit firmness and total soluble solid (TSS) content of the fruits, respectively. The fruits having weight < 10 g or malformed (Misshapen) or disease infected were considered as non-marketable fruits. The titratable acidity, sugar content and ascorbic acid of fruits were determined following the standard procedures (AOAC, 1980). The data were analysed for the variance and least significant differences (LSD) were calculated to compare significant effects at $p \le 0.05$ (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Effect on growth and flowering of strawberry plant

The foliar spraying of plant growth regulators significantly influenced the plant growth of strawberry (Table 1). The plant growth in terms of plant spread (27.72 cm) was noted maximum in the plants which received foliar spraying of 100 mg l^{-1} GA_3. The leaf with larger leaf lamina (122.75 cm^2) and maximum length of petiole (11.50 cm) were also recorded from the same set of plants. This treatment had also found to be the best for producing the highest number of leaves (28.53), crowns (2.93) and runners (3.93) in strawberry. All the above parameters were recorded minimum in control plants. The exogenous application of plant growth regulators failed to influence any significant effect on days taken to 50 per cent flowering in strawberry. However, the plants received 100 mg l^{-1} GA_3 exhibited earliest flowering with significantly maximum number of flowers in strawberry (Table 1).

The ability of gibberellins to stimulate the process of cell division and expansion in epidermal and parenchyma cells has been well documented (Bisht *et al.*, 2018).

Table 1: Effect of plant growth regulators on growth and flowering of strawberry cv. Winter Dawn.

Treatments	Plant spread (cm)	Leaves plant^{-1}	Leaf area (cm^2)	Length of petiole (cm)	Crowns plant^{-1}	Runners plant^{-1}	Days taken to 50% flowering	Flowers plant^{-1}
50 mg l^{-1} NAA	21.21	20.07	105.38	9.00	2.07	2.67	45.67	27.27
75 mg l^{-1} NAA	21.52	21.87	106.08	9.51	2.27	2.80	42.67	27.33
100 mg l^{-1} NAA	24.28	22.73	108.09	10.47	2.33	3.53	42.00	28.07
125 mg l^{-1} NAA	24.56	24.07	109.17	11.00	2.67	3.80	41.67	29.47
50 mg l^{-1} GA_3	20.92	20.73	107.70	9.13	2.13	2.33	43.67	27.47
75 mg l^{-1} GA_3	23.04	24.87	110.19	10.44	2.40	3.40	41.33	29.00
100 mg l^{-1} GA_3	27.72	28.53	122.75	11.50	2.93	3.93	41.00	31.20
125 mg l^{-1} GA_3	25.64	26.53	117.04	11.30	2.80	3.67	41.67	31.00
Control	19.15	19.87	101.95	8.50	2.00	2.67	46.67	27.20
LSD at $p \le 0.05$	3.99	5.23	11.68	1.39	0.53	0.78	NS	2.55

Such activities in the meristematic tissue of leaf primordial in GA_3 treated plants might be higher and perhaps resulted a greater number of leaves with broader leaf lamina and petiole of longer length. Higher concentration of GA_3 increases the above mechanisms many folds. Earlier findings also suggested that exogenous application of GA_3 induced higher number of leaves (Kaur *et al*., 2009) with large leaves and petioles (Sharma and Singh, 2009) in strawberries. However, very high concentration of GA_3 (125 mg l^{-1}) resulted slightly stunted growth in strawberry plants. Since, application of GA at high concentrations is reported to have an inhibitory action in plants (Hedden and Sponsel, 2015). The trifoliate leaves of strawberry are arranged in rosette at crowns and hence, the length of petiole determines the relative plant spread (Massetani and Neri, 2016). Therefore, the highest plant spread was recorded in plants that had boarder leaf lamina with longest petiole. Increased plant spread with the application of GA_3 was also reported earlier in strawberry (Paroussi *et al*., 2002). More number of leaves in GA_3 treated plants facilitates the synthesis of more photosynthates leading to formation of maximum number of crowns and runners. Similar results were reported in strawberry cv. Sujatha (Vishal *et al*., 2016). Paroussi *et al.* (2002) reported that application of GA_3 to strawberry plants was able to reduce the time required for emergence of inflorescence with increased number of flower buds.

Effect on fruiting and yield of strawberry

The plant growth regulator treatments significantly influenced the fruiting of strawberry (Table 2). The plants received foliar spraying of 100 mg l^{-1} GA_3 produced fruits of maximum weight (15.37 g) and length (3.98 cm). The maximum number of fruits (18.67) and marketable fruits [16.00 (85.73 %)] plant^{-1} were also recorded in the plants sprayed with 100 mg l^{-1} GA_3. This treatment also registered the best for producing the highest marketable fruit yield (245.40 g plant^{-1}, 108.95 q ha^{-1}) and total fruit yield (264.27 g plant^{-1}, 117.15 q ha^{-1}). The lowest number of fruits (total and marketable) plant^{-1} and yield were produced by control plants. Similarly, the lowest non-marketable fruit yield (18.87 g plant^{-1}, 8.19 q ha^{-1}) was recorded in the plants which received foliar application of 100 mg l^{-1} GA_3 [Fig 1(a) and (b)].

Gibberellic acid plays a regulatory role in the mobilization of metabolites from source (foliage) to sink (developing fruits) (Iqbal *et al*., 2011). Excessive biomass in GA_3 treated plants might able to produce more metabolites through the activity of photosynthesis which ultimately sank in to the developing fruits and resulting berries with maximum weight. Increase in berry weight with the application of GA_3 is also reported in strawberry (Sharma and Singh, 2009). The fruit setting in plants is largely depended on the endogenous level of promoters and inhibitors. The exogenous application of GA_3 might regulate this balance in favour of fruit forming metabolic processes by inducing enzymes required during post fertilization stage and thus improve the fruit setting which finally resulted the maximum number of fruits plant^{-1} (Sharma and Sharma, 2004). Further, better pollen germination in strawberry flowers is reported with the application of GA_3 (Paroussi *et al*., 2002). A major portion of non-marketable fruit in strawberries includes the malformed and underweight fruits (Kirschbaum *et al*., 2014). The aggregate nature of strawberry fruit requires pollination each and every ovary to form a healthy compact fruit. Usually, a malformed (misshapen) fruit is developed when ovaries fail to elongate due to poor pollination or partial pollination of strawberry flowers (Zaitoun *et al*., 2006**)**. The unpollianted ovaries of strawberry flowers might be elongated through the foliar application of GA_3 and produced fruits of marketable size (Sharma and Singh, 2009). Additionally, the exogenous application of GA_3 had an indirect effect on the auxin metabolism and resulted higher number of marketable fruits and thereby increased the fruit yield (Kappel and McDonald, 2007). Enhancement of fruit yield with the application of GA_3 is also reported earlier in strawberry (Paroussi *et al*., 2002).

Effect on fruit quality of strawberry

The firmness and acidity of the strawberry fruits were not influenced by foliar application of plant growth regulators. However, the plants receiving 125 mg l^{-1}NAA produced the hardiest fruit. The TSS and sugar content of strawberry fruits

Table 2: Effect of plant growth regulators on fruiting of strawberry cv. Winter Dawn.

Treatments	Fruit weight (g)	Fruit length (cm)	Marketable fruits plant^{-1}	Non-marketable fruits plant^{-1}	Total fruits plant^{-1}	Marketable fruits (%)
50 mg l^{-1} NAA	12.18	3.29	12.67	3.60	16.27	77.79 (61.89)*
75 mg l^{-1} NAA	12.37	3.30	13.33	3.20	16.53	80.64 (63.87)
100 mg l^{-1} NAA	12.89	3.42	14.60	2.60	17.20	84.92 (67.13)
125 mg l^{-1} NAA	13.70	3.60	15.13	2.87	18.00	84.06 (66.48)
50 mg l^{-1} GA_3	11.50	3.14	13.20	3.20	16.40	80.53 (63.94)
75 mg l^{-1} GA_3	12.76	3.35	14.20	3.07	17.27	82.18 (65.02)
100 mg l^{-1} GA_3	15.37	3.98	16.00	2.67	18.67	85.73 (67.88)
125 mg l^{-1} GA_3	14.48	3.66	15.00	3.33	18.33	81.73 (64.69)
Control	11.44	2.98	12.33	3.87	16.20	76.16 (60.76)
LSD at $p \leq 0.05$	1.59	0.37	1.66	0.76	1.65	3.34

*Figures in parentheses indicate transformed values.

Table 3: Effect of plant growth regulators on physico-chemical properties of strawberry cv. Winter Dawn.

Treatments	Fruit firmness (kg cm^{-2})	TSS (°B)	Acidity (%)	Ascorbic acid (mg 100 g^{-1})	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
50 mg l^{-1} NAA	0.81	8.07	0.82	76.28	4.81	4.15	8.96
75 mg l^{-1} NAA	0.85	8.32	0.80	83.48	4.83	4.17	9.00
100 mg l^{-1} NAA	0.91	8.63	0.78	91.56	4.84	4.37	9.21
125 mg l^{-1} NAA	0.97	8.98	0.74	97.18	5.14	4.57	9.72
50 mg l^{-1} GA_3	0.80	7.55	0.84	76.28	4.55	3.68	8.24
75 mg l^{-1} GA_3	0.80	8.40	0.79	77.07	4.63	3.91	8.54
100 mg l^{-1} GA_3	0.83	8.82	0.78	82.65	4.73	4.08	8.81
125 mg l^{-1} GA_3	0.84	8.92	0.76	95.59	4.69	4.00	8.69
Control	0.79	7.32	0.84	70.60	4.45	3.63	8.09
LSD at $p \leq 0.05$	NS	1.07	NS	6.36	0.34	0.33	0.44

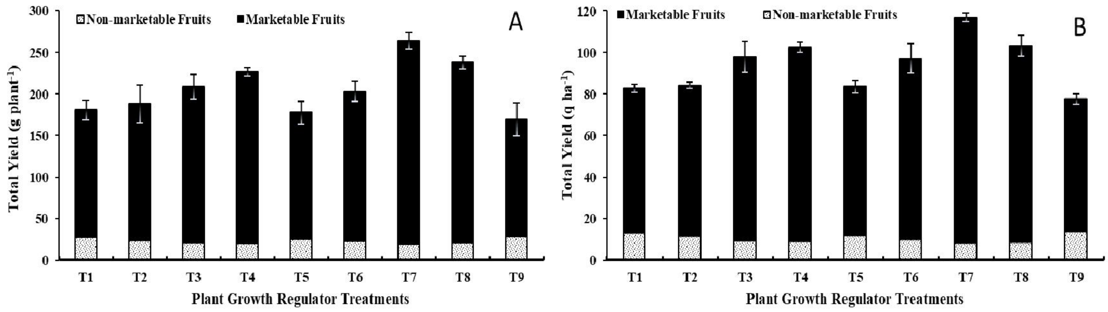

Fig 1: Effect of plant growth regulators on total yield plant^{-1} (A) and total yield ha^{-1} (B). The vertical bars denote the standard error (n=3).

were the maximum with the foliar application of 125 mg l^{-1} NAA. The plant received no sprays produced fruit with lowest TSS and sugar content. Fruits with the highest ascorbic acid (Vitamin C) content were produced in plants treated with 125 mg l^{-1} NAA (Table 3).

Both skin toughness and the hardiness of the underlying flesh determine the firmness of strawberry fruit (Hietaranta and Linna, 1999). In strawberry, the skin toughness is directly linked to hard achene development and auxin is known to regulate the process of achene development and perhaps resulted in hardiest fruit in NAA treated plants (Archbold and Dennis, 1984).The application of NAA in strawberry plants might have increased the concentration of volatile compounds along with hydrolysis of starchy compounds which ultimately raised the TSS level (Krishnamoorthy, 1981). Palei *et al*. (2016) also recorded higher TSS of strawberry fruits with the application 50 ppm NAA. The total sugars content which account for more than 60 per cent of TSS percentage. The higher enzymatic activity like α-amylase and invertage with the application of NAA might be responsible for higher total sugar content and non-reducing sugar content of strawberry fruits. Singh *et al*. (1989) obtained the maximum sugar content in ber with application of 50 ppm NAA. The improvement in the ascorbic acid content of strawberry fruits might be due to increase level of metabolites that stimulate the precursor of ascorbic acid biosynthesis in plants which received NAA. Increased level of ascorbic acid with the application of 200 ppm NAA has also been reported in guava (Singh *et al*., 2017).

CONCLUSION

The modern era has witnessed a rapid progress in popularity of strawberries both among the consumers as well as growers. This study was undertaken to boost up the strawberry production by harnessing the beneficial effects of comparatively less priced plant growth regulators sold in the markets. The outcome of the aforesaid experiment suggests that the yield and quality strawberry could be improved by foliar spraying of 100 mg l^{-1} GA_3 and 125 mg l^{-1} NAA at 30 and 60 days after planting, respectively.

REFERENCES

Afrin, S., Gasparrini, M., Forbes-Hernandez, T.Y., Reboredo-Rodriguez, P., Mezzetti, B., Varela-López, A., Giampieri, F. and Battino, M. (2016). Promising health benefits of the strawberry: a focus on clinical studies. Journal of Agricultural and Food Chemistry. 64(22): 4435-4449.

AOAC (1980). Official Method of Analysis. Association of Official Analytical Chemist, AOAC, Benjaminn Franklin Station, Washinton DC.

Archbold, D.D. and Dennis, F.G. (1984). Quantification of free ABA and free and conjugated IAA in strawberry achene and receptacle tissue during fruit development. Journal of the American Society of Horticultural Science. 109: 330-335.

Bhagariya, D.A. and Prajapati, V.P. (2019). First report of *Pestalotiopsis clavispora* (G.F. Atk.) Steyaert causing crown rot disease on strawberry in India. International Journal of Economic Plants. 6(3): 140-142.

Bisht, T.S., Rawat, L., Chakraborty, B. and Yadav, V. (2018). A recent advances in use of plant growth regulators (PGRs) in fruit crops - A review. International Journal of Current Microbiology and Applied Sciences. 7(5): 1307-1336.

Hedden, P. and Sponsel, V. (2015). A century of gibberellin research. Journal of Plant Growth Regulation. 34(4): 740-760.

Hietaranta, T. and Linna, M.M. (1999). Penetrometric measurement of strawberry fruit firmness: Device testing. Hortechnology. 9(1): 103-105.

Iqbal, N., Nazar, R., Khan, M.I.R., Masood, A. and Khan, N.A. (2011). Role of gibberellins in regulation of source-sink relations under optimal and limiting environmental conditions. Current Science. 100(7): 998-1007.

Kappel, F. and MacDonald, R. (2007). Early gibberellic acid spray increase fruiting and fruit size of Sweet Heart sweet cherry. Journal of the American Pomological Society. 61(1): 38-43.

Kaur, A., Singh, S. and Singh, B. (2009). Influence of planting time and GA_3 concentrations on growth, yield and fruit quality of strawberry cv. Chandler. Haryana Journal of Horticultural Science. 38(1/2): 14-15.

Kirschbaum, D.S., Jerez, E.F., Salazar, S.M., Borquez, A.M., Meneguzzi, N.G., Agüero, J.J., Conci, V.C., Conci, L.R., Salame, T.P. and Santos, B.M. (2014). Causes of non-marketable fruit production throughout the strawberry harvest season in subtropical environments. Acta Horticulturae. 1049: 887-892.

Krishnamoorthy, H.N. (1981). Plant Growth Substances. Tata McGraw-Hill Publishing Company Ltd., New Delhi, India, 169-175.

Massetani, F. and Neri, D. (2016). Plant Architecture in Different Cultivation System. In; Strawberry Growth, Development and Diseases. [Husaini, A.M., Neri, D. (Eds.)], CABI, 99-118.

Palei, S., Das, A.K., Sahoo, A.K., Dash, D.K. and Swain, S. (2016). Influence of plant growth regulators on strawberry (*Fragaria* × *ananassa*) cv. Chandler under Odisha condition. International Journal of Recent Scientific Research. 7(4): 9945-9948.

Paroussi, G., Voyiatzis, D.G., Paroussis, E. and Drogoudi, P.D. (2002). Growth, flowering and yield responses to GA_3 of strawberry grown under different environmental conditions. Scientia Horticulturae. 96(1-4): 103-113.

Sharma, G. and Thakur, M.S. (2008). Evaluation of different strawberry cultivars for yield and quality characters in Himachal Pradesh. Agricultural Science Digest. 28(3): 213-215.

Sharma, R.R. and Singh, R. (2009). Gibberellic acid influences the production of malformed and button berries and fruit yield and quality in strawberry (*Fragaria x ananassa* Duch.). Scientia Horticulturae. 119: 430-433.

Sharma, V.P. and Sharma, R.R. (2004). The strawberry. Indian Council of Agricultural Research, New Delhi, India. 162.

Singh, A.R., Shukla, P.K. and Singh, K. (1989). Effect of boron, zinc and NAA on chemical composition and metabolites of ber (*Z. mauritiana* Lamk.). Haryana Journal of Horticultural Science. 18(1-2): 23-28.

Singh, K., Sharma, M. and Singh, S.K. (2017). Effect of plant growth regulators on fruit yield and quality of guava (*Psidium guajava*) cv. Allahabad Safeda. Journal of Pure Applied Microbiology. 11(2): 1149-1154.

Snedecor, G.W. and Cochran, W.G. (1967). Statistical methods (6^{th} Edn.) Oxford and IBH Publ. Co., New Delhi, India 593.

Vishal, V.C., Thippesha, D., Chethana, K., Maheshgowda, B.M., Veeresha, B.G. and Basavraj, A.K. (2016). Effect of various growth regulators on vegetative parameters of strawberry (*Fragaria x ananassa* Duch.) cv. Sujatha. Research Journal of Chemical and Environmental Science. 4(4): 68-71.

Zaitoun, S.T., Al-Ghzawi, A.A., Shannag, H.K. and Al-Tawaha, A.R.M. (2006). Comparative study on the pollination of strawberry by bumble bees and honey bees under plastic house conditions in Jordan valley. Journal of Food Agriculture and Environment. 4(2): 237-240.