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.

Method: 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 GA₃ (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 GA₃. 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, GA₃, 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 grown 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 field cultivation of strawberry requires special care and judicious
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$_2$O$_5$ (as SSP) and K$_2$O (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 (Missshapen) 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 ≤ 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). Such

**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 ≤0.05 | 3.99             | 5.23                | 11.68             | 1.39                   | 0.53                | 0.78                 | NS                        | 2.55                |
activities in the meristematic tissue of leaf primordial in GA3 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 GA3 increases the above mechanisms many folds. Earlier findings also suggested that exogenous application of GA3 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 GA3 (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 GA3 was also reported earlier in strawberry (Paroussi et al., 2002). More number of leaves in GA3 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 GA1 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 GA3 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 GA3. 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 (284.27 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 GA3 [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 GA3 treated plants might able to produce more metabolites through the activity of photosynthesis which ultimately sink in to the developing fruits and resulting berries with maximum weight. Increase in berry weight with the application of GA3 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 GA3 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 GA3 (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 unpollinated ovaries of strawberry flowers might be elongated through the foliar application of GA3 and produced fruits of marketable size (Sharma and Singh, 2009). Additionally, the exogenous application of GA3 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 GA3 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 hardest fruit. The TSS and sugar content of strawberry fruits

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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 GA3 | 11.50 | 3.14 | 13.20 | 3.20 | 16.40 | 80.53 (63.94) |
| 75 mg l⁻¹ GA3 | 12.76 | 3.35 | 14.20 | 3.07 | 17.27 | 82.18 (65.02) |
| 100 mg l⁻¹ GA3 | 15.37 | 3.98 | 16.00 | 2.67 | 18.67 | 85.73 (67.88) |
| 125 mg l⁻¹ GA3 | 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 ≤ 0.05 | 1.59 | 0.37 | 1.66 | 0.76 | 1.65 | 3.34 |

*Figures in parentheses indicate transformed values.
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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 GA₃    | 0.80                    | 7.55     | 0.84        | 76.28                     | 4.55              | 3.68                   | 8.24            |
| 75 mg l⁻¹ GA₃    | 0.80                    | 8.40     | 0.79        | 77.07                     | 4.63              | 3.91                   | 8.54            |
| 100 mg l⁻¹ GA₃   | 0.83                    | 8.82     | 0.78        | 82.65                     | 4.73              | 4.08                   | 8.81            |
| 125 mg l⁻¹ GA₃   | 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 ≤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).

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 GA₃ and 125 mg l⁻¹ NAA at 30 and 60 days after planting, respectively.

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