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Vivek Kumar
Ph.D. Scholar, Rajasthan Agricultural Research Institute (RARI); Durgapura, Jaipur, S.K.N. Agriculture University, Jobner, Rajasthan, India

Priynka Kumari Jat
Ph.D. Scholar, Rajasthan Agricultural Research Institute RARI; Durgapura, Jaipur, S.K.N. Agriculture University, Jobner, Rajasthan, India

S Mukherjee
Professor, Division of Horticulture, Rajasthan Agricultural Research Institute, Durgapura, Jaipur, S.K.N. Agriculture University, Jobner, Rajasthan, India

Dr. SP Singh
Associate Professor, S.K.N College of Agriculture Jobner, S.K.N. Agriculture University, Jobner, Rajasthan, India

Correspondence
Vivek Kumar
Ph.D. Scholar, Rajasthan Agricultural Research Institute (RARI); Durgapura, Jaipur, S.K.N. Agriculture University, Jobner, Rajasthan, India

Role of plant growth regulator's in strawberry

Vivek Kumar, Priynka Kumari Jat, S Mukherjee, and Dr. SP Singh

Abstract
Strawberry is one of the most delicious fruits of the world, which is a rich source of vitamins and minerals, and has fabulous flavor and tantalizing aroma. It contains minerals, vitamins and also anti-cancer component called ellagic acid. Strawberry is a very rich source of bioactive compounds including vitamin C, E, b-carotene and phenolic compounds (phenol acids, flavan-3-ols, flavonols and anthocyanins). It is most widely distributed fruit crops due to its genotypic diversity, highly heterozygous nature and broad range of environmental adaptation. Plant growth regulators (PGRs) are effective means of improving fruit productivity as a result of their direct influence over the quantitative as well as qualitative aspects of fruit growth. There is significant consequence of plant growth regulator on vegetative growth, floral, yield and quality parameters of strawberry, the paper contains a number of reviews to conclude the result.

Keywords: role, plant growth, strawberry, tantalizing aroma

Introduction

The modern cultivated strawberry (*Fragaria x ananassa* Duch) is a monoecious octaploid hybrid of two largely dioecious octaploid species, *Fragaria chiloensis* and *Fragaria virginiana.* Fragaria species belong to the family Rosaceae, with basic chromosome number of x = 7. It is assumed that hybridization between *Fragaria chiloensis* and *Fragaria virginiana* had taken place spontaneously in Europe in early seventeen century when female plants of *Fragaria chiloensis* of Chilean origin were grown in proximity to male *Fragaria* virginiana plants of North American origin (Galletta and Bringhurst, 1990) [15]. Fruit is small, firm, and pink to red, aromatic and Non-climateric fruit. The edible portion of strawberry includes the ripened receptacle and achenes (true fruits and seeds) (Chaturvedi *et al.*, 2005 [9]; Kumar and Tripathi, 2009; Arora and Singh, 1970) [2, 24]. Strawberry is one of the most delicious fruits of the world, which is a rich source of vitamins and minerals, and has fabulous flavor and tantalizing aroma (Kher *et al.* 2010) [20]. Strawberry contains minerals, vitamins and also anti-cancer component called ellagic acid (Morgon 2005) [33]. Strawberry is basically a fruit plant of temperate climate, but during the recent years, there has been phenomenal increase in its area, production and cultivation in the non-traditional regions of India (Sharma and Sharma, 2004) [56]. It has happened because of standardization of modern agro-techniques and introduction of many subtropical cultivars which unprecedented returns higher capitals under subtropical conditions as well (Asrey and Jain, 2003) [5]. Strawberry is a very rich source of bioactive compounds including vitamin C, E, b-carotene and phenolic compounds (phenol acids, flavan-3-ols, flavonols and anthocyanins) (Oszmianski and Wojdylo, 2009) [36]. It is most widely distributed fruit crops due to its genotypic diversity, highly heterozygous nature and broad range of environmental adaptation (Larson, 1994: Childers *et al.*, 1995) [10].

Nutritional composition per 100g edible portion

Water (90%), Calories (37), Protein (1.4%), Carbohydrates (8%), Crude fibre (1.5%) (Mitra, 1991) The red colour of fruit is mainly due to the presence of anthocyanin. The most important aroma compounds are ethyl hexanoate, ethyl heptanoate, ethyl propionate, ethyl butanoate, methyl btanoate, furanone and linalool. Essential oils can be extracted from its leaves. The major constituents of oil are linalool and nonanal (Singh *et al.*, 1989; Rath *et al.*, 1980; Arora and Singh, 1970; Joon *et al.*, 1984) [2, 19, 48].

Plant growth regulators (PGRs) are effective means of improving fruit productivity as a result of their direct influence over the quantitative as well as qualitative aspects of fruit growth. These play an important role in controlling different growth and developmental processes of plants in conjunction with weather conditions. Recently, a synthetic cytokinin i.e. CPPU [N-(2-chloro-4-pyridyl)-N-phenyl-urea], GA_3, NAA and ethephon were found very effective in stimulating fruit growth in apple, grapes, cranberry and strawberry (Hamano *et al*. 2006) [16]. Therefore, an efforts has been made in this chapter to review the relevant literature on the effect of GA_3, CCC, NAA, CPPU, IAA, IBA, BA, CPPU and GA_3 combination on growth, yield and quality of strawberry in particular, under following heads.

Use of GA_3 in strawberry has been reported in early flowering, increased duration of flowering, harvesting and yield. It increases yield and quality of fruits, helps in cell elongation and cell enlargement, increases vegetative growth and minimizes time of maturity. Gibberellins increase growth in most plant species especially in rosette plants (Arteca, 1996) [3].

Application of NAA increases fruit size and delays ripening and increases anthocyanin accumulation in strawberry fruits. It also increases duration of flowering, improves yield and quality of fruits.

BA, as a plant growth regulator is used for different purposes in fruit production. It enhances the size and shape of fruits, lateral bud break and lateral shoot growth, leading to improved branching in fruit trees. It influences fruit size and weight by increasing the number of cells per fruit through the stimulation of cell division. Reports are there that thinning with BA had a positive effect on increasing return bloom. BA increases fruit size and delay chlorophyll breakdown and fruit ageing. BA also decreases loss in firmness, delay ethylene production, decreases respiration rate and induces mechanical resistance which reduces senescence rate after harvest.

Effect of plant growth regulators on vegetative parameters

In vegetative parameters plant height, number of leaves per plant, plant spread and petiole length. Mohammed *et al.* (1990) [32] found maximum plant height, number of leaves per plant and runner production with 100 ppm GA_3 application in strawberry cultivar Murree. Similar observations were also made by Tripathi and Shukla (2006) [68] that GA_3 at 100 ppm produced tallest plant with higher number of leaves. Sangwook *et al.* (1996) [53] GA_3 treatment and GA_3 + cold storage for 600 hour treatment promote runner production. Dwivedi *et al.* (2002) [13]. GA_3 at 50 or 100 ppm concentration which resulted in increased number of runners per m^2 and stem diameter. Dwivedi *et al.* (1999) [12] studied that GA_3 at 50 ppm resulted in maximum leaf number, petiole length, greater number of runners in both cultivars, while increased leaf area only in Senga Sengana. Mir *et al.* (2004) [30] observed that application of GA_3 significantly increased the number of runners as compared to NAA and control. Pipattanawong *et al.* (1996) [44] revealed that 50 ppm GA_3 + 50 ppm BA increase runner production and petiole length in three day-neutral strawberry cultivars (Summer Berry, Miyoshi and Enrai). Agafonov *et al.* (1978) [1] reported that CCC at 1 to 2 percent retarded runner's growth and increased the number of crowns per plant. Sharma and Singh (2009) [57] reported that 75 ppm of GA_3 treatment increased the leaf petiole, leaf area and leaf number significantly. Similar observations were also made by Kumar *et al.* (2011) [27] and Kumar *et al.* (2012b) [25] revealed that plants treated with 75ppm gibberellic acid showed an increase in all the vegetative characteristics of plants *viz*., plant height, petiole length, number of leaves and plant spread. Kumar *et al.* (2008) [28] studied the effect of GA_3, NAA and CCC and observed that GA_3 at 90 ppm gave the maximum vegetative growth and runner production. Sakila *et al.* (2007) [52] reported that the maximum frequency of rooting and highest number of roots was produced on medium containing 1.0 mg l 1 IBA. Singh and Singh (2009) [61] observed maximum number of leaves in strawberry plant treated with 100ppm BA. El-Shabasi *et al.,* (2009) [14] results showed that GA_3 at 10 ppm increased plant petiole length. Singh and Tripathi (2010) [65] studied that GA_3 at 100 ppm concentration sprayed on the plants before bud initiation (65 days after transplanting) increased plant height, number of leaves and runners per plant. Jamal *et al.* (2012) [18] found that GA_3 treated strawberry at 75 ppm resulted in tallest plant, maximum number of leaves and leaf area. Similar results were obtained by Kumar *et al.* (2012a) [26] reported that the plants treated with 75 ppm GA_3 showed an increase in all the vegetative characteristics of plants *viz*., plat height, petiole length, number of leaves, plant spread and leaf area index. ShouMing *et al.* (2007) [58] studied that treatments comprised of 50mg IAA/liter, 50mg 6-BA (benzyladenine)/liter and 25mg GA_3/liter showed that the plant growth regulators applied as a foliar spray significantly increased the dry mass of shoots and roots, as well as the root: shoot ratio in strawberry. Prasad *et al.* (2012) [45] revealed that the maximum plant height, plant spread, maximum number of flowers, maximum days taken to first flowering, first fruit set, early maturity of fruits, early harvesting was recorded on GA_3 100 ppm + Black polyethylene mulching. Similarly, Saied *et al.,* (2012) reported that the application of GA_3 at 100 ppm resulted in maximum leaf area in the strawberry cv. Merak. GA_3 50 ppm + Calcium chloride 0.4% radically increased the vegetative growth parameters by increasing plant height, crown diameter, canopy spread, fresh and dry weight of plant and leaves and leaf area Qureshi *et al.* (2013) [46]. 200 ppm GA_3 proved best in respect of plant height, number of leaves per plant, plant spread, petiole length and number of runners per plant Nishad *et al.* (2014) [34]. Saima *et al.* (2014) [51] result showed that plant height, maximum plant spread, number of leaves per plant, petiole length and leaf area of strawberry was obtained highest with the application of GA 75 mg/liter. Thakur *et al.* (2015) [67] studied that plant growth promoting rhizobacteria (PGPR) + GA_3 @ 75 ppm gave the best result in terms of plant growth of strawberry. Palei *et al.* (2016) [40] reported that GA_3 @ 100 ppm gave the best result in terms of vegetative characters like plant height, plant spread, petiole length, number of leaves per plant, runners per plant. Nishad *et al.* (2014) [34] studied that the 500 ppm cycocel proved best in respect of plant height, number of leaves per plant, plant spread, petiole length, number of runners per plant. Weidman and Stang (1983) [71] found that Number of blossoms, in Raritan cv. of strawberry increased by BA at 250 and 500ppm. Vishal *et al.* (2016) [70] revealed that maximum leaf area, leaf area index, absolute growth rate, crop growth rate was observed with the spraying of 125 ppm GA_3.

Effect of plant growth regulators on floral and yield parameters

Growth and fruiting behavior of strawberry cv. Pusa Early Dwarf was affected by cloching and Gibberellic acid treatments Lopez *et al.* (1989) [29]. 15ppm GA responded effectively as regard to the period of flower bud emission, floral stem elongation, fruit ripeness and the total yields D'Anna and Accardi (1990) [11]. Increase in individual fruit weight with 75 ppm GA_3 + clochicine Sharma and Singh

(1990) [55]. Will (1975) [72] reported that strawberry plants treated in September and October with cycocel (CCC) gave earlier and slightly higher yields. Application of GA_3 at 50 ppm resulted well advanced flowering in November Ozguven and Kaska (1991) [39]. The number of usable runners increased by 22 per cent in Yasna and Senga Sengana cultivars of strawberry with the pre-harvest application of GA_3 at 0.008 per cent Pankov (1992) [41]. CCC at 1000 to 2000 ppm sprayed on Gorilla cultivar of strawberry enhanced first flower opening and increased fruit set Barritt (1975) [8]. Saima *et al.* (2014) [51] reported that cycocel 750 mg / liter resulted in minimum days taken to first flowering and fruit formation. Solved and Sahira (1979) [66] observed that CCC at 0.5% to 1 percent concentration gave 28.4 percent increased yield in strawberry cultivars namely festival Naya, Senga Sengana, Taliswan and raunyaya Nekhe Vaukher. The cycocel @ 500 ppm enhanced the number of flowers, fruits per plant and yield Turemis and Kaska (1997) [69]. Similarly Paroussi *et al.* (2002) [42] studied that GA_3 at 50 ppm resulted in early inflorescence, accelerated flowering, earlier fruit setting and maturation in Seascape. Shan *et al.* (2007) [54] studied that the foliar spray of 50mg/L 6-BA increased the flower numbers. Ozguven and Yilmaz (2002) [37] reported that application of GA_3 at 5, 10 and 20 ppm in strawberry cv. Camarosa resulted in early flowering with increasing GA_3 doses and the highest yield was obtained using 5 and 10 ppm of GA_3. Banday *et al.* (2005) [7] reported that the application of 25 ppm GA_3 at the flower bud formation stage resulted in the maximum length, diameter and size of fruits, while application of 40 ppm GA_3 were required had minimized the number of days to maturation. Singh and Singh (2005) [59] studied that the effects of growth regulators like GA_3 at 50 and 100 ppm, NAA at 50 and 100 ppm and Benzyladenin (BA) at 50 and 100 ppm were applied on strawberry cv. Sweet Charlie. Plants treated with GA_3 at 100 ppm showed the earliest flowering, produced the maximum number of flowers per trusses, fruit set, better yield and yield attributing characters. Singh and Singh (2006) [60] reported that dual inoculation of *Azotobacter* and *Azospirillum* with 60 kg nitrogen/ha in conjunction with 100 ppm GA_3 proved most effective in increasing fruit set, early flowering and yield. Perez *et al.* (2009) [59] reported that the exogenous application of GA_3 at 20 ppm resulted maximum number of inflorescences and flowers in strawberry cv. Chandler. Roussos *et al.* (2009) [49] treated strawberry cv. Camarosa with different plant growth stimulators and reported that application of GA_3 + Auxin (Phenothiol) significantly increased marketable yield. Nishad *et al.* (2014) [34] studied that Strawberry plants treated with highest concentration of cycocel i.e. 1500 ppm took least number of days to produce first flower and fruit bud development after planting. Roussos *et al.* (2009) [49] studied the fruit quality attributes after application of plant growth stimulating compounds like Auxin (Phenothiol) + GA_3 on Strawberry cv. Camarosa which resulted in maximum fruit size and total anthocyanin content. Singh and Singh (2009) observed that plants treated with Azotobacter and Azospirillum along with 60 kg N ha^{-1} (50 % N of the standard dose) and 100 ppm GA_3. Asadi *et al.* (2013) [4] observed that GA_3 application at 50mg/l in Gaviota strawberry plants, increased number of flower on inflorescence. Lolaei *et al.* (2013) [28] results indicated that the treatment of GA_3 150 ppm have the greatest effect on fruit number in strawberry. Nuruzzaman *et al.* (2015) reported that GA_3 significantly influenced the flower bud, number of flower and berry. Kumar *et al.* (2012a) [26] reported that the plants treated with 900 ppm cycocel showed best result for fruit quality of strawberry. Kumar *et al.* (2012b) [25] revealed that application of 500 ppm CCC showed higher number of flowers, fruits per plant and yield. Shan *et al.* (2007) [54] studied that the foliar spray of 50mg/L 6-BA increased the flower numbers. Mir *et al.* (2004) [30] reported that yield of plant was observed with NAA 15ppm. Kirschbaum (1998) [22] found in Sweet Charlie' *cv.* of strawberry that the fruit weight was highest in the control plant without any significant difference with 6-BA or GA and the lowest weight in GA_3 only. Isam *et al.* (2012) [17] found that combined application of GA_3 + 6BA increased the fruit weight compared with the control plants.

Effect of plant growth regulators on quality parameters

Lopez *et al.* (1989) [29] recorded increase in acidity and TSS/acid ratio in strawberry with the application of GA_3 at 80 ppm. Application of 25, 50 and 75 ppm of GA_3 before flowering was reported to increase the per cent sugar content in strawberry cv. Magestic Singh and Phogat (1983) [62]. Highest fruit TSS and acidity in plants sprayed with 75 ppm GA_3 + clochicine Sharma and Singh (1990) [55]. The pre-harvest treatment with NAA 25ppm favored the higher vitamin C and pulp content during storage Asrey *et al.* (2004). Plants treated with 900 ppm cycocel showed the highest T.S.S., total sugar, vitamin-C content, juice content and lowest acidity Kumar *et al.* (2012a) [26]. GA_3 at 200 ppm before flowering in strawberry cv. Camarosa resulted in higher TSS and acidity Ozguven *et al.* (2000). Similarly Rana (2001) recorded higher TSS and total sugars contents, maximum number of berries per plant and berry yield with the application of GA_3 at 100 ppm in Chandler cv. of strawberry. Singh and Singh (2006) reported that 100 ppm GA_3 proved most effective in the maximum TTS, total sugar and ascorbic acid content were obtained with the same treatment combination. Roussos *et al.* (2009) [49] studied the fruit quality attributes after application of plant growth stimulating compounds like Auxin (Phenothiol) + GA_3 on Strawberry cv. Camarosa which resulted in maximum anthocyanin content. Singh and Tripathi (2010) studied that GA_3 at 100 ppm significantly increased berry length, breadth, total soluble solids and totals sugars as compared to control. Kumar *et al.* (2012b) [25] revealed that application of GA_3 @ 80 ppm gave the best result in ascorbic acid content. Palei *et al.* (2016) [40] reported that GA_3 @ 100 ppm gave the best result in terms of specific gravity, juice (%), TSS (˚brix), ascorbic acid (mg/100g). Kumar *et al.* (2012a) [26] reported that the plants treated with 900 ppm cycocel showed the highest T.S.S., total sugar, vitamin-C content, juice content and lowest acidity. Kumar *et al.* (2012b) [25] revealed that application of 500 ppm CCC showed higher total soluble solid and total sugar of strawberry. Khunte *et al.* (2014) [21] results revealed that maximum pH value and total soluble solid were obtained with the treatment 8.50 tonnes ha^{-1}, poultry manure + 1200 ppm CCC. Asrey *et al.* (2004) [6] reported that NAA 25ppm favored the higher vitamin C (49.30mg/100g) and pulp content during storage. Vishal *et al.* (2016) [70] revealed that total chlorophyll content was recorded in the treatment CCC @ 1000 ppm.

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