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Rakesh Kumra
Junior Scientist, Rainfed Research Station for Subtropical Fruits, SKUAST-Jammu, India

Reena
Assoc Professor ACRA, Dhiansar, SKUAST- Jammu, India

S Saravanan
Professor, A.A.I.D.U, Allahabad, Uttar Pradesh, India

Parshant Bakshi
Senior Scientist and Head, ACHR, SKUAST-Jammu, India

Anil Kumar
Associate Director, ACRA Dhiansar, SKUAST-Jammu, India

Manpreet Singh
PhD Scholar G.B.P.U.A.T Pantnagar Uttarakhand, India

Vijay Kumar
Junior Scientist, Rainfed Research Station for Subtropical Fruits, SKUAST- Jammu, India

Correspondence
Rakesh Kumra
Junior Scientist, Rainfed Research Station for Subtropical Fruits, SKUAST-Jammu, India

Influence of plant growth regulators on strawberry: A review

Rakesh Kumra, Reena, S Saravanan, Parshant Bakshi, Anil Kumar, Manpreet Singh and Vijay Kumar

Abstract
Strawberry (*Fragaria spp.*); genus *Fragaria*; family Rosaceae and sub –family Rosaceae (Staudt, 1989) is native to Europe, Asia and some other to North and South America and has 20 recognized species. The cultivated strawberry is a hybrid plant crossed between two species, *Fragaria chiloensis* and *Fragaria virginiana*. The botanical name of the common cultivated strawberry is *Fragaria* × *ananassa*. Strawberry (*Fragaria* × *ananassa*) is commercially grown in temperate regions, but there are varieties, that can be cultivated in subtropical climate (Suga *et al.*, 2013). The strawberry is an attractive, luscious, tasty, aggregate, nutritious fruit. Plant growth regulators or phytohormones are organic substances produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts. Apart from it, they also regulate expression of intrinsic genetic potential of plants. Control of genetic expression has been demonstrated for the phytohormones at both transcriptional and translational levels. The paper reviews the influence of various phytohormones on strawberry growth, development and fruit yield. Plant growth regulators were found to be very effective in increasing the vegetative growth, flowering and yield of berry fruits in temperate, tropical as well as subtropical regions. In most of the studies, high concentration of gibbereliic acid increased vegetative growth and runner production in strawberry whereas cycocel, a growth retardant was very effective in improving fruit quality.

Keywords: Strawberry, PGRs, Phytohormones

Introduction
Strawberry (*Fragaria* × *annanassa*) is one of the most popular and early paying back fruit in the world. Though strawberry is a short day plant but it has limited vegetative growth during this short day period that caused less production with low quality (Asrey *et al.* 2004) [4]. Its cultivars are significantly influenced by plant growth regulators (Jamal Uddin *et al*. 2012) [18] which may affect directly the floral induction, fruit size, quality and production. In the world, the high demand on organic berry fruit plants has increased in last decades. Which make strawberry cultivation very demanding enterprise (Asad, 1997) [3]. It is a unique and one of the over ripe fruit among temperate fruits in spring season (Behnamian and Masiha 2005) [6] and is a very profitable fruit crop (Bhat *et al.*, 2005) [8]. Strawberry contains minerals, vitamins and also anti-cancer component called ellagic acid (Morgan 2005) [27]. Strawberry fruit is a good source of Vitamin-C (40-120mg/100g of fruit), protein and minerals like potassium, phosphorus, calcium and iron (Kanupriya, 2002) [19] as well as foliate and photochemical compound such as the elligic acid. As compared to other berry fruits, strawberries contain a higher percentage of vitamin C, phenolics and flavonoids. It was estimated that the strawberry production in Indian 8.50 tons, according to national horticulture board (NHB, 2004-15). Application of growth regulators has been practiced commercially to increase the production and quality of crops. Gibberellic acid has a significant role in plant heights, number of runners, number of flowers, fruit set percentage, number of fruits, fruit size, fruit weight and fruit quality (Sharma and Singh, 2009; Kasim *et al.* 2007; Usenik *et al.* 2005) [8, 20, 40]. Chlorocholine Chloride (CCC) is gibberellins biosynthesis inhibitor involved in the inhibition of cyclization of geranylgeranyl pyrophosphate to copyallyl pyrophosphate. Chlormequat [CCC, Cycocel] chlormequat chloride was discovered during a screening program of quaternary ammonium compound for growth retardant activity. Chlormequat chloride is highly mobile in both xylem and phloem tissue and rapidly absorbed and translocated. It is highly

water soluble and passively absorbed by all plant tissues, allowing it to be effectively applied as a spray or drench. Application of chlormequate chloride to crops results in plants with shorter internodes and thicker, darker green leaves. The chemical control of the plant growth to reduce the size through the use of plant growth regulators is a common practice to make a plant more compact and commercially more acceptable. A review is presented on the influence of different phytohormones on strawberry growth, development and yield. Though the work on this aspect is limited, it has been tried to compile it in a comprehensive manner in this review.

1. Influence of gibberellic on strawberry

Growing fruits are very active metabolically and act as strong sinks for nutrients with hormones possibly modulating the process. Among the plant growth regulators, plant growth promoter gibberellins control plant growth and fruit development in various ways and at different developmental stages. Fruit development is a complex and tightly regulated process, the development of a fruit can be separated into phases that include pre-pollination, pollination, fertilization and fruit set, post fruit set, ripening and senescence.

1.1 Influence on vegetative growth and runners production

Bower and Cutting (1992) [9] reported that GA_3 applied in strawberries stimulated the growth of the vegetative shoot apex of indeterminate vegetative growth. Brian, *et al.*, (1958) [10] observed that increased shoot length after GA_3 treatment may be due to the increased length of certain internodes which were either in the process of elongation at the time of treatment or were differentiated soon thereafter. Nanda and Purohit (1965) [28] explained the enhancement of growth by GA_3 in relation to the mobilization of reserve starch, due to enhanced mobilization by GA_3, large amounts of food material are available over a shorter period, causing a spurt in the growth processes. Dennis and Bennet (1969) [12] reported that GA_3 50 ppm was applied on new and one year old plants in June or July can inhibit flowering and promote runner development. Spraying of GA_3 at 8 weeks after planting reduced the number of inflorescence. Guttridge and Thompson (1964) [16] observed that gibberellins treated plants increased runner's growth and plant growth. Perez de Camacaro *et al.* (2008) [30] reported that applied gibberellic acid promoted blooming and growth. However it was observed that the highest effect on leave, runner, crown, inflorescence and flower production. Luangprasert (1994**)** [25] applied GA for one a week during 4 leave stage in Tioga species, showed in all treatments runner production increased with no effects on leave and branch crown production. Also with high amount at GA_3 application, fruit production decreased. Eshghi *et al.* (2012) [15] noticed that GA_3 did not increase fruit weight and production, but 100 ppm GA_3 decreased inflorescence and increased runners per plants. El-Shabasi *et al.* (2008) [14] reported that 100 ppm GA_3 treated plants increased flower production. Sharma and Singh (2009) [8] registered that 75 ppm GA treated plants in Chandler variety affected growth pattern and decreased the fruit weight. Paroussi *et al.* (2002) [29] reported GA increased bud flower in 3 variety of strawberry (Seascape, Laguna, Camarosa) especially in Seascape species. Runner number significantly increased in GA_3 applied plants. Highest number runner was reported in GA_3 at 50 ppm treated per plants.

1.2 Influence of GA_3 on flowering

Paroussi *et al.* (2002) [29] reported that application of GA_3 has effect significantly on number flower on inflorescence increased. Kumar *et al.*, (2014) [24] reported that high concentration GA_3 took minimum days to initiate flowering. Stuart and Cathey (1961) [35] observed that Gibberellins have huge impact on flowering and inflorescence production. Adams *et al.*, (1975) [1] reported that the gibberellins are known to influence both cell division and cell enlargement. Moreover the successful fertilization of the ovule is followed by cell division and cell expansion resulting in the growth of the fruit.

1.3 Effect of GA_3 on yield and fruit quality of strawberry

Ingle *et al*. (2001) [17] revealed that foliar application of GA_3 @ 25 ppm increased the fruit weight, volume, TSS, ascorbic acid, peel and yield over control. Chao and Lovatt (2006) [9] found that application of 10 ppm GA_3 at 60 per cent full bloom, 75 per cent petal fall and in early July or 25ppm at 60 per cent and 90 per cent full bloom, 75 per cent petal fall and 10 days after 75 per cent petal fall reduced total yield relative to the untreated control.. Moneruzzaman *et al*., (2011) [26] found that application of GA_3 increased fruit length and diameter. Kumar *et al.,* (2012) [21] observed that the application of GA_3 in strawberry at 80 ppm improved vegetative growth, runner production, ascorbic acid and acidity. Application of 75 ppm GA_3 provided maximum number of fruit in strawberry and increased the number of strawberry fruits. Kumar *et al*. (2013) [23] reported the partially deblossoming with application of 50 ppm GA_3 treated plants improved fruit quality of strawberry in subtropical area. Singh and Singh (1979) observed that the effect of GA 75 ppm and with FYM 50 t ha^{-1} supplemented with superphosphate (1122 kg ha^{-1}) before planting, ammonium sulphate (421 kg ha^{-1}) and muriate of potash (175 kg ha^{-1}) the main treatment being alone or together. The fruit weight (g) and size was greatest with maturing alone and were depressed by GA but TSS content and acidity were increased by GA. GA_3 spray @ 50 – 200ppm increased bunch and fruit weight and fruit size but decreased total soluble solids and total sugars and delayed ripening. Davis, (2004) reported that application of gibberellic acid increased cell size and/or cell numbers. Dwivedi *et al.*, (2002) [13] the effect of photoperiods i.e. short, normal and long days, and plant growth regulators, i.e. gibberellic acid (GA_3) at 50 ppm shown the maximum in leaf number and area was observed when plants of senga sengana were kept under short day condition the treated with 50 ppm GA. In Tioga, in 1966 maximum leaf number and area was obtained under long day condition + 50 ppm GA. In 1995 maximum leaf area was recorded under short day while + 50 ppm GA. Wang (1989) [41] were also significantly showed that increased in maximum number of leaves per plant with GA_3 @ 200 ppm.

2. Influence of Chlormequat and triacontanol on growth, yield and quality

Plant growth retardants are commonly used in fruit crop to modify the trees vegetative growth and enhance the flowering, fruit setting and yield. It is observed that plant growth regulators exercise an indirect influence on flowering through their restricting vegetative growth. Will (1975) [44] reported that in three year trials of strawberry plants treated in September and/or October with cycocel gave earlier and slightly higher yields. Barritt *et al*., (1975) [5] found that CCC at 100 to 200 ppm sprayed on Gorella cultivar strawberry between 8th and 23th march enhanced first flower opening and increased fruit set. Thakur *et al.*, (1991) [38] reported that triacontanol at 10, 25 or 50 ppm, Activol (GA_3 BA and GA + 7 mixture at 50, 100 or 200 ppm) and NAA at 5, 10 or 20 ppm observation were made on vegetative growth and flowering 15 days after spraying. Physical and chemical characteristics of fruits were determined at harvest. The use of Cycocel (CCC) was reported to reduce plant height by which fruit yield is positively increased (Benoit and Aerts, 1975) [7].

3. Influence of Triacontanol and NAA on growth, yield and quality

Triacontanol, a natural component of the epicuticular waxes (Chibnall *et al*. 1933; Crosby and Vlitos 1959) [10, 11] has been shown to increase the vegetative growth, chlorophyll content and dry weight of various plants when applied in field conditions (Ries 1985) [31]. Triacontanol, Activol and NAA resulted in increased vegetative growth of strawberry as compared control. Highest crown height (7.2cm) was obtained with 100 ppm Activol and highest leaf number/plant (7.2) and leaf area (49.4m^2) were obtained with 50ppm tricontanol treated plants. Kumar *et al*., (1996) [23] reported that the highest yield of strawberry cv. Tioga when treated with triacontanol 5 ppm just before flower emergence. Tiwari *et al.*, (2017) [39] reported that tricontanol treated plants increased plant height, plant spread, number of leaves and averages fruit weight (g). The highest fruit diameter, weight, volume, acidity per cent (as citric acid equivalent) and the lowest sugar: acid ratio was reported with 400 ppm NAA treated strawberry plant (Techawongstein, 1989) [37].

Conclusion

From these results, it can be concluded that GA_3 and Triacontanol are very effect to increase vegetative growth, quality and runners production of strawberry. Whereas growth retardant cycocel increase number of flowers, improve fruit quality and yield of strawberry.

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