The Pharma Innovation Journal 2018; 7(9): 301-305

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.03
TPI 2018; 7(9): 301-305

www.thepharmajournal.com
Received: 27-07-2018
Accepted: 29-08-2018

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Role of auxin and gibberellins growth, yield and quality of tomato: A review

Kartik Pramanik, Jyotsnarani Pradhan and Soumya Kumar Sahoo

Abstract
Increasing temperature, viral diseases and salinity are the major limiting factors in sustaining and increasing tomato productivity. To tackle the different biotic and abiotic stresses in tomato cultivation application growth regulators have been considered as right choice for scientists and farmers. Plant growth regulators (also called plant hormones) are numerous chemical substances that profoundly influence the growth and differentiation of plant cells, tissues and organs. Plant growth regulators function as chemical messengers for intercellular communication. In tomato, different growth regulators play a pivotal role in germination, root development, branching, flower initiation, fruiting, lycopene development, synchronization and early maturation, parthenocarpic fruit development, ripening, TSS, acidity, seed production etcetera. To boost the tomato production in India these versatile resources greatly help the professionals and researchers. Keeping the importance of growth regulator in tomato production in mind this review paper is scripted.

Keywords: Growth regulator, GA3, NAA, 4-CPA, 2, 4-d, TSS

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is worldwide known as “No. 1 processing vegetable” because of its demand not only in processing sector but also as a vegetable and protective food. It has been originated in tropical America (Salunkhe *et al*., 1987) [44] which includes Peru, Ecuador, Bolivia areas of Andes (Kallo, 1986) [25]. It is one of the most popular salad vegetables and is taken with great relish. It is widely employed in cannery and made into soups, conserves, pickles, ketchup, sauces, juices etc. Tomato juice has become an exceedingly popular appetizer and beverage. Food value of tomato is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990) [11]. Uddain *et al*., 2009 [49], Rashid, 1983 [42], Davies and Hobes, 1981 [14] reported that tomato adds flavor to the foods and it is also rich in medicinal value. Tomato has a significant role inhuman nutrition because of its rich source of lycopene, minerals and ß-carotene which are anti-oxidants and promote good health. The well ripe tomato (per 100 g of edible portion) contains water (94.1%), energy (23 calories), calcium (1.0 g), magnesium (7.0 mg), vitamin A (1000 IU), ascorbic acid (22 mg), thiamin (0.09 mg), riboflavin (0.03 mg) and niacin (0.8 mg). tomato contains organic acids like citric, malic and acetic acids which is found in fresh tomato fruit, promotes gastric secretion, acts as a blood purifier and works as intestinal antiseptic (Pruthi, 1993) [39]. Lycopene may help counteract the harmful effects of substances called free radicals, which are thought to contribute to age-related processes and a number of types of cancer, including, but not limited to, those of prostate, lung, stomach, pancreas, breast, cervix, colorectal, mouth and esophagus as reported by Masroor *et al*., 1988 [29].

Among vegetables, tomato occupies 4th position in area and 2nd position in production in India. It is amazing to note the quantum jump in the spread of tomato during the last four decades. In India crop was grown in area of 36000 ha during 1960 and present area and production in the country 8.82 lakh ha and 187.35 lakh tones respectively in 2010 (NHB, 2014) [33]. While in Andhra Pradesh, it is cultivated about an area of 1.67 lakh ha with a production of 33 lakh tones (NHB, 2014) [33].

Although tomato plants can grow under a wide range of climatic conditions, they are extremely sensitive to hot and wet growing conditions (Ahmad, 2002) [3]. Increasing temperature, viral diseases and salinity are the major limiting factors in sustaining and increasing tomato productivity (Fekadu and Dandena, 2006) [17]. There are generally various constraints resulting in low production of vegetables including tomato which includes poor soil fertility, water scarcity, poor cultivation skills, attack of pest and disease, poor availability of inputs and harsh climate (Baliyan & Kgathi, 2009) [8]. Lack of adoptive cultivars and poor fruit setting of existing varieties especially during the hot/dry season where the demand for tomato is very high is one challenge farmers are facing in tomato production even though there is potential land for cultivation. Breeding for heat tolerance in tomato crop has been difficult due to many factors like moderate heritability inheritance being complex or the cultivars becoming lower in yield (George *et al*., 1984) [20]. Tomato fruit set is very sensitive to environmental conditions, in particular, to too low or high temperatures that affect pollen development and anther dehiscence. Fruit set depends on the successful completion of pollination and fertilization (Gillaspy *et al*., 1993) [21]. Tomato requires day temperature of 21–28 °C and moderately cool night temperature of 15–20 °C for proper fruit setting. High temperature (both day and night), humidity, rainfall and light intensity are the limiting factors of tomato production (Abdulla and Verkerk, 1968) [1]. High day and night temperature above 32 °C and 21 °C, respectively, was reported as limiting factor to fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Picken, 1984) [37]. High temperatures reduces fruit set, fruit production and yield in tomato (Peet *et al*., 1997) [36]. For good fruit set and better yield, pollination, germination of pollen grains, pollen tubes growth, fertilization and fruit initiation must take place successfully (Kinet and Peet, 1997) [36]. Gelmesa *et al*., 2010 explained that high relative humidity of the air, low light intensity and extreme low and high temperature, and improper mineral nutrition seems to be involved in the control of those phenomena and result in low fruit set and quality. High day and night temperature above 32 °C and 21 °C, respectively, was reported as limiting factor to fruit-set due to an impaired complex of physiological process in the pistil, which results in floral or fruit abscission (Picken, 1984) [37]. Fruit setting and earliness of tomato were reported to be affected by environmental, cultural or genetic factors among which light, temperature, nutrition, hormonal imbalance and water supply play a significant role (Kinet and Peet, 1997) [36].

Plant growth regulators (PGRs) are used extensively in horticulture to enhance plant growth and improve yield by increasing fruit number, fruit set and size (Batlang, 2008 and Serrani *et al*, 2007a) [46]. Use of growth regulators had improved the production of tomato including other vegetables in respect of better growth and quality (Saha, 2009) [43]. Fruit set in tomato can be increased by applying plant growth regulators to compensate the deficiency of natural growth substances required for its development (Singh and Choudhury, 1966) [47]. Induction of artificial parthenocarpy through application of PGRs enables fertilization-independent fruit development that can reduce yield fluctuation in crops like tomato, pepper and likes (Heuvelink and Korner, 2001) [24]. Plant growth regulators such as auxins and gibberellins are known to affect parthenocarpy Matlob, A.N. and Kelly, W. C. (1975) [30], fruit setting Rappaport, L. (1957) and fruit size Osborne D.J., Went F.W. (1953) [35]; therefore synthesized auxins and gibberellins are often used for promotion of fruit set in some fruit vegetable production including tomatoes Kuo, C.G. and Tsai, C.T. (1984) [28] and yields can increase dramatically to four times Abdulla *et al*. (1978).Earlier reports indicated increased fruit size and setting in tomato due to application of 2, 4-dichlorophenoxy acetic acid (2,4-D), 4-chlorophenoxy acetic acid (4-CPA), and β-naphthoxyacetic acid (β-NAA) (Gemici *et al*., 2006) [19]. Similarly, gibberellic acid (GA3) at low concentration was reported to promote fruit setting in tomato (Sasaki *et al*., 2005; Khan *et al*., 2006) [45]. Tomato plants treated with a mixture of 4-CPA and GA_3 (Sasaki *et al*., 2005) [45] showed increased fruit set and proportion of normal fruits compared to plants of the same crop treated with 4-CPA alone. Similarly, sprays of NAA or β-NAA at the time of flowering resulted in reduced pre-harvest fruit drop and increased the number of fruits per plant (Alam and Khan, 2002) [4]. Synthetic auxin 4-CPA (4-chloro phenoxy acetic acid) reduced pre-harvest fruit drop with increased number of fruits per plant and yield (Sasaki *et al*, 2005) [45]. Application of 4-CPA is more effective during anthesis period than one week after anthesis (Poliquit *et al*, 2007) [38]. IAA stimulates cell elongation by stimulating wall-loosening factors, such as elastins, to loosen cell walls and the effect is stronger if gibberellins are also present (Bunger-Kibler and Bangerth, 1983) [12]. IAA also stimulates cell division if cytokinins are present (Zhao, 2008) [53]. IAA induces the formation and organization of phloem and xylem. When the plant is wounded, the IAA may induce the cell differentiation and regeneration of the vascular tissues (Ulmasov *et al*., 1999) [50]. As more native auxin is transported down the stem to the roots, the overall development of the roots is stimulated. The longer and branched root can uptake more nutrients from the soil which are accumulated to the plant sink and increase the yield (Wang *et al*., 2005) [51]. If the source of IAA is removed, such as by trimming the tips of stems, the roots are less stimulated accordingly. IAA induces shoot apical dominance and the axillary buds are inhibited by IAA (Woodward and Bartel, 2005) [52]. IAA is required for fruit growth and development and delays fruit senescence and plays also a minor role in the initiation of flowering and development of reproductive organs (Asahira *et al*., 1967) [6].

In general, full potential of high yielding varieties could only be realized under normal management practices, but under unfavorable conditions for tomato fruit setting, research results proved that the use of PGRs could increase both fruit setting and yield earliness. Fruit set in tomato was successfully improved by application of plant growth regulators and micronutrients. In fact the use of growth regulators had improved the production of tomato including other vegetables in respect of better growth and quality (Saha, 2009) [43].

In fact the use of growth regulators had improved the production of tomato including other vegetables in respect of better growth and quality which ultimately led to generate interest between the scientists and farmers for commercial application of growth regulators. Keeping in view, this review paper is enlisted to summarize the importance of growth regulators in tomato cultivation.

Role of Auxin and Gibberelin in Tomato

The most important Auxin produced by plants is indole-3-acetic acid (IAA). It plays important roles in a number of plant activities, including phototropism, gravitropism, apical dominance, fruit development, abscission androot initiation. A couple of synthetic auxins are 2, 4-D and 2, 4, 5-T.Gibberellins are a group of plant hormones responsible for growth and development. Chemically speaking, gibberellins are actually acids. They are produced in the plant cell's plastids, or the double membrane-bound organelles responsible for making food, and are eventually transferred to the endoplasmic reticulum of the cell, where they are modified and prepared for use.

Role of Auxin + Gibberilic Acid on growth of tomato

The main function of auxin is to help plants grow. Auxin stimulates plant cells to elongate, and the apical meristem of a plant is one of the main places that auxin is produced. This makes sense because the apical meristem is also the location that all the other parts of a plant grow from - the stem, leaves, and flowers. Gibberellins are growth hormones that stimulate cell elongation and cause plants to grow taller. Gibberellins also have a role in other plant processes, such as stem elongation and germination. Rahman *et al*., 2015 [40] revealed that maximum plant height was observed in BARI Hybrid Tomato-8 when treated with 4-CPA + GA3together. Gupta (1973) [23] found that tomato seed treated for 24 hour before sowing with GA, IAA and NAA each at 20 or 40 ppm enhanced germination, the higher concentration being more effective. Ginofegara (1981) [22] spayed tomato seedling with GA, NAA at 25-100 ppm. GA promoted flower primordial but there was no correlation between GA and NAA concentration at 25 ppm and 50 ppm promoted flowering and fruiting. Singh and LAl (2001) [48] observed reduction in plant height and branches per plant due to application of 40 ppm NAA and 10 ppm GA3 as compared to 20 ppm NAA and 5 ppm GA3 in tomato. Bhosle *et al*. (2002) [10] found the effects of NAA (25, 50 and 75 ppm), gibberellic acid (15, 30 and 45 ppm) and 4-CPA (25, 50 and 75 ppm). Treatment with 30 ppm gibberellic acid resulted in the tallest plants, whereas treatment with 25 ppm 4-CPA and 45 ppm gibberellic acid resulted in the highest number of primary branches of Dhanashree (4.16) and Rajashree (5.38), respectively. Butcher and Street (2002) [13] reported that application of both GA and NAA at appropriate concentrations enhanced the main axis growth excised tomato roots grown in culture media containing sucrose at concentrations below 1%. Lateral root extension growth is enhanced by GA at all sucrose concentrations tested, only at the lower sucrose concentration is this effect observed with NAA. Both GA and NAA increase the number of emergent lateral roots and this effect is most marked in media of low sucrose content. Both GA and NAA at higher concentrations inhibit root growth but NAA exhibits its full range of growth effects over a much narrower concentration range than GA. Nibhavanti *et al*. (2006) [34] reported plant height was greatest with GA3 at 25 and 50 ppm, and 4-CPA at 50 ppm. The number of primary branches per plant did not significantly vary among the treatments. GA3 at 50 ppm resulted in the lowest number of primary branches per plant. The number of fruits per plant was highest 50 ppm boron. Meena (2008) [31] reported that two foliar sprays at 50 ppm produced significantly more plant height and plant spread at 45 DAT and at harvest, leaf area per plant at harvest, number of flowers per plant and fruit set percentage GA3 at 75 ppm as foliar spray recorded significantly lower fruit drop percentage compared to the rest of the plant growth regulator treatments. Arvind (2012) [5] reported that foliar application of 15 ppm GA3 followed 25 ppm NAA produced superior growth attributing characters and ultimately fruit yield of tomato. Higher concentration of GA3 and NAA beyond 15 and 25 ppm were not found advantageous for tomato crop.

Role of Auxin + Gibberilic Acid on yield of tomato

Auxin is required for fruit growth and development and delays fruit senescence. Auxin plays also a minor role in the initiation of flowering and development of reproductive organs. In low concentrations, it can delay the senescence of flowers. A number of plant mutants have been described that affect flowering and have deficiencies in either auxin synthesis or transport. GAs stimulate vegetative to flowering, determines sex expression and seed development along with an interaction of different environmental factors viz., light, temperature and water. When there is difficulty with fruit set because of incomplete pollination, GA may be effectively used to increase fruit set. The resulting fruit maybe partially or entirely seedless. GA has increased the total yield in greenhouse tomato crops both as a result of increased fruit set and more rapid growth of the fruit. Gemici *et al* (2006) [19] reported that application of auxin and gibberellins are effective in increasing yield of tomato. Application of NAA and GA3 gives best results in fruit length, girth, pulp seed ratio, fruit weight, yield plant^{-1} and yield hectare^{-1} than micronutrients (Desai *et al*., 2012) [15]. Rahman *et al*., 2015 [40] revealed that maximum number of flowers and fruits plant^{-1}, individual fruit weight and fruit yield ha^{-1} were observed in BARI Hybrid Tomato-8 when treated with 4-CPA + GA3together. Aung (1976) supported Rahman *et al*., 2015 [40] that combine application of 4-CPA and GA3 increase the number of flower per plant in tomato. High temperature before and after the short winter season inhibits the flower and fruit development, use of plant growth regulators, viz. gibberellin and auxin has been reported to be very effective to overcome the problems of flower and fruit development in tomato (Adlakha and Verma, 1965; Groot *et al*., 1987). Sasaki *et al*. (2005) [45] reported that treatment of plant growth regulators reduced the fruit set inhibition by high temperature to some extent, especially treatment with mixtures of 4-chlorophenoxy acetic acid (4-CPA) and gibberellins (GA3). He revealed that tomato treated with a mixture of 4-CPA and GA3 showed increased fruit set and the number of normal fruits (Excluding abnormal types such as puffy fruit) were more than the plants treated with 4-CPA alone during summer. Singh and LAl (2001) [48] observed reduction in fruits per plant, fruit weight per plant and fruit yield due to application of 40 ppm NAA and 10 ppm GA3 as compared to 20 ppm NAA and 5 ppm GA3 in tomato. Bhosle *et al*. (2002) [10] found the effects of NAA (25, 50 and 75 ppm), gibberellic acid (15, 30 and 45 ppm) and 4-CPA (25, 50 and 75 ppm). The number of flowers per cluster, fruit weight and marketable yield increased with increasing rates of the plant growth regulators. The highest marketable yield of Dhanashree and Rajashree resulted from treatment with 75 ppm 4-CPA.Meena (2008) [31] reported that two foliar sprays at 50 ppm produced significantly more number of fruits per plant, fruit weight and yield. Saha (2009) [43] observed significant response of NAA (25 ppm) with respect to number of fruits/plant, fruit weight/plant and yield was obtained over the control. Similarly maximum yield was obtained with the application of 40 ppm GA3. Combined application of NAA (25 ppm) and GA3 (40 ppm) was more effective than their individual application in terms of yield. Arvind (2012) [5] reported that foliar application of 15 ppm GA3 followed 25 ppm NAA produced superior yield attributing characters and ultimately fruit yield of tomato. Higher concentration of GA3 and NAA beyond 15 and 25 ppm were not found advantageous for tomato crop. EI- Habbasha *et al*. (1999) [16] reported that the treatment of GA3 and 4-CPA significantly increased fruit set percentage and total fruit yield.

Role of Auxin + Gibberilic Acid on quality of tomato

Apart from improving the growth and development in plants, auxin and gibberellin have greater role in influencing the quality parameters in fruits like sugar content, acidity, sugar acid ratio, dry matter content etc. which have been described by many scientists. Application of GA3 also check many physiological disorder in tomato which further checks the quality loss in fruits. Gemici *et al*. (2006) [19] reported that application of auxin and gibberellins are effective in increasing quality of tomato. Singh and LAl (2001) [48] observed reduction in fruit dry mater and weight per fruit due to application of 40 ppm NAA and 10 ppm GA3 as compared to 20 ppm NAA and 5 ppm GA3 in tomato. Monteiro (2004) [32] applied auxin, gibberellin and an electric vibrator to the flowers of tomato plants grown in a polyethylene greenhouse without heating in spring, with minimum temperatures ranging from 9 To 15.4 ^{0}C. The vibrator produced high number of normal seeds per fruit, while auxin treated plants had mainly big fruit with aborted seeds and the control plants had small fruit some of them seed less. Meena (2008) [31] reported that two foliar sprays at 50 ppm produced significantly more TSS and ascorbic acid. There were significantly higher total soluble solids, ascorbic acid content and TSS/acid ratio and lower acidity percentage with application of GA3 at 50 ppm compared to 25 and 75 ppm GA3 and NAA. Saha (2009) [43] observed significant response of NAA (25 ppm) with respect to total soluble solid (TSS) and vitamin C was obtained over the control. Similarly maximum vitamin C was obtained with the application of 40 ppm GA3. Combined application of NAA (25 ppm) and GA3 (40 ppm) was more effective than their individual application in terms of TSS and vitamin C content, respectively. EI-Habbasha *et al*. (1999) [16] reported that the treatment of GA3 and 4-CPA significantly increased the percentages of puffy and parthenocarpicfruits compared to the controls in tomato cv. castel rock.

Conclusion

From this review it can be clearly inferred that combine application of 40 ppm GA3 with 25 ppm 4-CPA or 25 ppm NAA as foliar sprays had a stimulatory effect on plant growth, flowering and, fruit setting, yield and quality of fruit which was accompanied by increases in endogenous auxin, gibberellins and cytokinin contentsin tomato plant. So applying of both natural and synthetic auxinand gibberellin help farmer in cultivating tomato in adverse climatic condition which can give good fruit yield by increasing vegetative and reproductive growth and reducing the flower and fruit drop.

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