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Kartik Pramanik
Assistant Professor (Hort.), M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha, India

Shubhashree Priyadarshinee Das
Reseacrh Scholar, Department of Vegetable Science, BCKV, West Bengal, India

Licon Kumar Acharya
Assistant Professor (Plant Pathology), M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha, India

Debasis Jayapuria
Assistant Professor (Agriculture Extension), M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha, India

Correspondence
Kartik Pramanik
Assistant Professor (Hort.), M. S. Swaminathan School of Agriculture, CUTM, Paralakhemundi, Odisha, India

Role of gibberellic acid on growth, yield and quality of tomato: A Review

Kartik Pramanik, Shubhashree Priyadarshinee Das, Licon Kumar Acharya and Debasis Jayapuria

Abstract
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. By keeping the importance of growth regulator in tomato production this review paper is scripted.

Keywords: growth regulator, GA_3, TSS, parthenocarpy, MFN, ascorbic acid

1. Introduction

Tomato (*Solanum lycopersicum* L.) 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) [43] which includes Peru, Ecuador, Bolivia areas of Andes (Kallo, 1986) [20]. 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) [9]. 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. 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) [37]. 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 [26].

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) [32]. While in Andhra Pradesh, it is cultivated about an area of 1.67 lakh ha with a production of 33 lakh tones (NHB, 2014) [32].

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.*, 2007) [6, 45]. 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) [19]. Plant growth regulators such as auxins and gibberellins are known to affect parthenocarpy Matlob and Kelly (1975) [27], fruit setting Rappaport (1957) [41] and fruit size Osborne and Went (1953) [35]; therefore synthesized auxins and gibberellins are often used for promotion of fruit set in some fruit vegetable production including tomatoes and yields can increase dramatically to four times Abdulla *et al.* (1968). 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 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.

2. Role of gibberellic acid in tomato

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.

2.1 Role of gibberellic acid on growth of tomato

Gibberellins stimulate cell elongation and cause plants to grow taller. Gibberellins also have a role in other plant processes, such as stem elongation, germination, flowering, and fruit ripening. Once a plant releases gibberellins, its cells begin a process of elongation. Since plants are composed of single cells stacked on top of one another, this elongation of thousands of individual cells results in the overall growth of the plant. GA3 application in tomato plant helps in synthesis of protein including various enzymes increases rate of shoot elongation and photosynthetic capacity leading to total leaf area and leaf dry weight (Ballantyine, 1995; Mostafa and Saleh 2006) [5, 30]. Bokode *et al.* 2006 reported the tomato treatment with GA_3 50ppm concentration gave maximum height of plant. Application of GA_3 at 50 ppm was found it be more effective in earliness to 50% flowering. Bora and Selman (1969) [8] demonstrated that four foliar sprays of GA_3 increased the leaf area, weight and height of tomato plants. Gibberellin induces cell division, cell elongation and cell enlargement as reported by Chaudhary *et al.*, 2004; Shittu and Adeleke (1999) [46] and Sanyal *et al.* (1995) [44]. Gabal *et al.*, 1999 [11] revealed that number of leaves plant^{-1} increased with the application of plant growth regulators in tomato especially GA at 15, 30 and 45 DAT. This might be due to that plant growth regulators enhanced cell division with considerable stem elongation. GA3 applications seem to promote vegetative growth (Gelmesa *et al.*, 2012) [12]. Gemici *et al.* (2000) [13] indicated that 10 ppm GA3 treated tomato plants showed a 17% increase in stem length when compared to the control and it is quite effective in increasing fruit size. Ghulam *et al.* (2006) [14] reported that the tomato cv. Roma parasitized by Orobanche was treated with different concentrations of gibberellic acid (GA3; at 10-1 M) as foliar spray. Grunwald and Lockared (1973) [16] reported Gibberellic A4 & 7 was more effective than Gibberellic acid in increasing shoot elongation when applied to the apex of dwarf cultivar and wins all a tall cultivar. After 14 days Gibberellic acid, Gibberellic A4 & 7 stimulated growth of the dwarf more than the tall tomato. Hasanuzzaman *et al.*, 2015 [18] revealed that application of GA3 @ 125 ppm showed an increased Plant height, number of leaves, branches per plant, Dry matter content of stem and root in tomato. Kumar *et al.*, 2014 [23] observed the highest plant height and number of leaves treated with GA3 50 ppm. Leonard *et al.* (1983) [24] reported that inflorescence development in tomato plants grown under low light regimes was promoted by GA3 application directly on the inflorescence. Malash (1998) [25] observed that in the field, growth promoters i.e., GA3 and B-NOA increased plant height and plant fresh weight. Ethrel treatment at low concentration increased branching and subsequent number treatment but its response was less than vegetative growth. Effect GA3 treatment, all other plant growth regulators failed to produce fruit under cold weather conditions. Muzzucato *et al.*, 1998 [28] reported that application of GA3 increasesplant height in tomato.

GA_3 significantly increases growth characters of tomato. Pundir and yadav (2001) [38] reported that the treatment GA_3 50 ppm and recorded the highest plant height. Similar result was also found by Shittu and Adeleke, 1999 [46] and Wu *et al.*, 1983 [55]. This might be due to the effect of GA_3 on cell enlargement and cell division in sub-apical meristem. Rai *et al.*, 2006 [40] and Nibhavanti *et al.*, 2006 [33] reported that GA3 at 25 and 50 ppm and Wu *et al.*, 1983 [55] reported that 100 ppm GA_3 increased plant height in tomato. Sanyal *et al.* (1995) [44] found that foliar application of GA_3 is more effective than root soaking of seedlings on tomato. Shittu and Adeleke (1999) [46] investigated plant height and number of leaves were significantly enhanced by GA3 treatment in tomatoes cv, 158-3. Plants treated With GA3 with 250 ppm were the tallest plant the highest number of leaves in tomatoes cv, 158-3.Singh and Singh (2005) [48] revealed that number of branches plant^{-1} of tomatoincreased with the application of plant growth regulatorsin tomato especially GA at 15, 30 and 45 DAT. Application of GA_3 at50 ppm increasesplant height (Khan *et al.*, 2006) [22] in tomato. Tomar and Ramgiry (1997) [52] found that plants treated with GA3 showed significantly greater number of fruits per plant and greater yield per plant than untreated controls. Uddain *et al.*, 2009 [53] observed that GA gives the maximum plant height, number of leaves plant^{-1} and number of branches plant^{-1} all days after transplanting (DAT) than other plant growth regulators.

2.2 Role of gibberelic acid on yield of tomato

Adlakha and Verma (1964) [3] observed that when the first four clusters of tomato plants were sprayed with GA_3 at 50 and 100 ppm three times at unspecified intervals, the fruit setting increased by 5% with higher concentration and GA_3 at 100 ppm could appreciably increase fruit size. Gibberelic acid plays role on controlling fruit setting, pre-harvest fruit drop and increasing fruit yield (Adlakha and Verma, 1965 and Mehta *et al.*, 1975) [2, 29]. It might be due to that Gibberelic acid (GA_3) enhanced fruit setting in tomato. Gibberellin induces cell division, cell elongation, cell enlargement and ultimately leads to significantly increases the fruit length, girth and pulp-seed ratio as reported by Shittu and Adeleke, 1999 [46] and Sanyal *et al.*, 1995 [44]. GA_3 applications help in improvement in number of fruits per cluster, fruit set, and marketable fruit number per plant and extended maturity time and harvest (Gelmesa *et al.*, 2012) [12]. Hasanuzzaman *et al.*, 2015 [18] revealed that application of GA_3 @ 125 ppm showed an increased fruit, number of flowers, fruit clusters, and fruits per plant, length and diameter of fruit, yield per plant, yield per plot and yield per hectare. Ghulam *et al.*, 2006 [14] reported that the tomato cv. Roma parasitized by Orobanche was treated with different concentrations of gibberellic acid (GA_3; at 10-1 M) as foliar spray. The application of growth regulators minimized the detrimental effect of parasite on the host. Habbasha *et al.* (1999) [17] found that application of GA_3 increased fruit set percentage and total fruit yield as well as percentage of puffy and parthanocarpic fruit and compared to

control. Khan *et al.* (2006) [22] indicated the significant role of GA_3 in tomato plant to increase fruit set that leads to larger number of fruits per plant and increased fruit size and final yield. They also observed an increase in leaf phosphorous, nitrogen, and potassium content in addition to increased lycopene content of tomato fruit when treated with GA_3. Even after the end of GA3 treatment there was a positive effect on petal elongation and inflorescence stalk length both in wild type and pat mutants of tomato plants. Naeem *et al.*, 2001 revealed GA_3 spray on tomato plant reduces fruit drop and contributes better number of fruits per plant. Naeem *et al*., 2001 indicated increased MFN per plant, reduced fruit drop, increased fruit weight due to GA3 spray and also recorded maximum days to flowering, fruit per plant, plant height, fruit weight, number of branches, per plant and total yield in the plant sprayed with 60 mg/lit of gibberellic acid 10 days before transplantation, while minimum value were noted in controlled treatment. Maximum fruit drop per plant was found for control treatment and minimum for the plant treated with gibberellic acid at 60mg/lit. GA_3 gave the higher number of flowers cluster^{-1}, number of flower per plant^{-1} (Saleh and Abdul, 1980) [42] and number of flower cluster plant^{-1} this caused that GA_3 promoted flower primodia production. Orzlek and Kaplan (2006) [34] observed that the combination treatment of GA3 and Nutra-Phos 3-15 appeared antagonistic and resulted in significantly lower fruit yield and delayed maturity. However, GA3 and Nutra-Phos 3-15 treatment alone produced higher fruit yield than the combination with no effect on fruit maturity compared to the control.

GA3 significantly increases growth characters, yield of tomato (Pundir and Yadav, 2001) [38]. Gibberellic acid is an important growth regulator that may have many uses to modify the yield and yield contributing characters of plant (Rafeekher *et al*., 2002) [39]. It is observed that highest yield was recorded due to application of 30 ppm gibberellic acid which was 26% higher than control (Singh and Rajodia, 2001) [47]. Application of GAs can cause fruit set and growth of some fruits, in case where auxinmay have no effect (Taiz and Zeiger, 2002) [50]. Uddain *et al*., 2009 [53] observed that GA gives the highest number of flowers cluster plant^{-1}, number of flower cluster plant^{-1}, number of flowers plant^{-1}, number of fruits cluster plant^{-1}, number of fruits plant^{-1}, average weight of individual fruit yield hectare^{-1} than other plant growth regulators. Application of GA_3 at 50 ppm increases number of fruitsin tomato (Uddain *et al*., 2009; Adlakha and Verma, 1964) [53, 3]. Verma *et al*., 2014 revealed that gibberelic acid plays role on controlling fruit setting, pre harvest fruit drop, increasing fruit yield and extending shelf life in tomato. Sultana (2013) [49] concluded that application of GA 50 ppm increases the plant height, number of leaves, number of flower clusters per plant, number of flowers per cluster, number of fruit clusters per plant, fruit diameter, weight of fruits per plant and yield of tomato.

2.3 Role of gibberelic acid on quality of tomato

Gibberelic acid (GA) plays important role on increasing fruit yield and extending self-life (Adlakhaand Verma, 1965 and Mehta *et al.*, 1975) [2, 29]. Afaf *et al.*, 2007 [4] indicated that GA_3 application increased phosphorous accumulation in leaves and stems of tomato plants that was also responsible for required lycopene content in the fruit. Application of GA_3 at 50 ppm increases ascorbic acid (Chaudhary *et al.*, 2006 and Ouzounidou *et al.*, 2010) [10, 36] and TSS in tomato (Gelmesa *et al.*, 2012) [12]. Graham and Ballesteros (2006) [15] reported that GA3 increased proteins, soluble carbohydrates, ascorbic acid, starch and β-carotene in the tomato. Kumar *et al.*, 2014 [23] observed the highest ascorbic acid and total soluble solid (TSS) treated with GA3 50 ppm. Masroor *et al.*, 2006 also reported that foliar application of gibberelic acid significantly increased lycopene content of tomato fruits. Serrani *et al*., 2007 [45] reported that, tomato fruits induced by GA_3 had thicker pericarp than pollinated fruits throughout its development and more in response to 2,4-D than GA3. Saleh and Abdul (1980) [42] reported that GA3 improved tomato fruit quality. Thakur *et al*., 1996 [51] indicated that acidity of tomato fruits was reduced when the whole plant was sprayed with GA_3 and 2,4-D. Higher sugar content in tomato fruits was obtained from plants treated with 50 mg l^{-1} GA3 (Kataoka *et al.*, 2009) [21].

3. Conclusion

From this review it can be clearly inferred that application of GA3 @ 50 ppm and 100 ppm have positive effect on seed germination, earliness, number of leaves, leaf area, number of branches, plant height, number of flowers, cluster fruit setting, number of fruits cluster, fresh fruit weight reducing pre-harvest fruit drop, increasing fruit yield, ascorbic acid TSS and dry matter in tomato plant.So spraying of gibberelic acid helps 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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