Protected Horticulture and Plant Factory, Vol. 24, No. 1:27-33, March (2015)
DOI http://dx.doi.org/10.12791/KSBEC.2015.24.1.027

pISSN 2288-0992
eISSN 2288-100X

Fruit Set and Yield Enhancement in Tomato (*Lycopersicon esculentum* Mill.) Using Gibberellic Acid and 2,4-Dichlorophenoxy Acetic Acid Spray

Binod Prasad Luitel, Taek Jong Lee and Won Hee Kang*

Department of Horticulture, Kangwon National University, Chuncheon 200-701, Korea

Abstract. High temperature stress in summer season at plastic house is a limiting factor for tomato fruit set and yield. This study was performed to assess the effects of gibberellic acid (GA_3) and 2,4-Dichlophenoxy acetic acid (2,4-D) spray on fruit set, yield, and quality of tomato cv. 'Adoration'(Enza Zaden Co., Ltd.) under the plastic house in Hwacheon, 2011. Four concentrations (0-, 5-, 10- and 15mg·L^{-1}) of GA_3, and three concentrations (0-, 5- and 10mg·L^{-1}) 2,4-D were sprayed in early flowering of tomato in the plastic house, and fruit set, yield and quality characters were observed. The results showed that spray of 10mg·L^{-1} GA_3 significantly increased the fruit set by 14.2% than unsprayed. The spray of GA_3 significantly increased the marketable fruit number, fruit weight, and yield. The spray of 2,4-D on blossoms significantly affected the fruit set percentage, fruit weight, marketable fruit weight and yield, and the highest fruit set observed as 62.5% in combined spray of GA_3 and 2,4-D at each 5mg·L^{-1}. Fruit size and total soluble solids significantly varied with the concentrations of GA_3 sprayed. The result indicates that the spray of 10mg·L^{-1} GA_3 and 5mg·L^{-1} 2,4-D can be more economic and effective to increase the fruit set, and yield in tomato under high temperature condition in plastic house.

Additional key word : blossoms, fruit set, gibberellic acid, 2,4-Dichlophenoxy acetic acid, total soluble solid

Introduction

Tomato is a high value vegetable crop and cultivated year round under protected condition in Korea. Tomato is rich source of lycopene, minerals and vitamins such as ascorbic acid and β-carotene which has an important role in human nutrition (Wilcox et al., 2003). Because of the lack of breeding to develop heat tolerant tomato cultivars in Korea, growers still rely on European hybrid (F_1) varieties for commercial production. In Korea, most of growers use plastic house as a rain shelter for tomato production rather than climate-control greenhouse. The plastic film increases the temperature inside the plastic house during the summer which is unfavorable for normal fruit production. High day temperature coupled with high night temperature during the summer under the plastic house causes the flower drop and poor fruit set in tomato. Pollination, germination of pollen grains, pollen tubes growth, fertilization and fruit initiation is necessary for good fruit set and better yield in tomato (Kinet and Peet, 1997). Reduced fruit set results from fewer pollen grains and reduced pollen viability with a threshold day temperature for pollen production and negative linear relation between pollen production and pollen viability at temperatures above 34°C (Vara Prasad et al., 1999). High temperatures reduce fruit set and fruit production in tomatoes (Peet et al., 1997), eggplant (Sanwal et al., 1997) and bell pepper (Erickson and Markhart, 2001).

Plant growth regulators (PGRs) have been used to mitigate the effect of high night temperature and to get higher yield with larger fruit size in tomato (Mullison and Mullison, 1948). In Korea, PGRs have been used to study the fruit quality of tomato (Soon et al., 1995) but the high temperature influence on poor fruit set and low yield in tomato under the plastic house has not been addressed. The application of synthetic auxin and gibberellins (GA_3) are effective in increasing yield and quality of tomato under the adverse weather condition (Gemici et al., 2006; Gelmesa et al., 2010). Likewise, these PGRs are widely used for fruit setting and yield enhancement in tomato (Batlang, 2008; Serrani et al., 2007). For example, application of 2,4-D increased the fruit yield of tomato (Anwar et al., 2010) and low concentration of GA_3 is promoted the fruit setting in tomato (Sasaki et al., 2005; Khan et al., 2006). The 2,4-D has herbicidal property which leads to flower bud abscission and poor fruit set (Pandolfini et al., 2002) but the GA_3 application promotes the reproductive organ

*Corresponding author: whkang@kangwon.ac.kr
Received December 22, 2014; Revised February 10, 2015; Accepted February 22, 2015

formation (Gemici et al., 2000) and extend the flowering, and fruit maturity with small fruit size (Graham and Ballesteros, 2006). The spray of GA_3 and 2,4-D on the tomato flower at high temperature condition under the plastic house would help to lessen the flower abscission as well as to increase the fruit set and yield of tomato. Therefore, this study was conducted to investigate the effect of GA_3 and 2,4-D on fruit set and tomato yield under the plastic house condition.

Materials and Methods

This study was conducted at Hwacheon (38º 6'N and 127º 31'E) Research Farm, South Korea and the seeds of tomato cv. 'Adoration' were received from Mifko Co., Ltd. Korea. The seeds were sown in plug trays containing horticultural soil (Seoul Bio. Co., Ltd.) on early April in 2011 and 35-days old seedlings were transplanted in the experimental plastic house at a spacing of 40 cm between the plants and 60 cm between the row and two rows were maintained at each planting bed. The mean monthly temperature in the plastic house was 32±4ºC day and 22±2ºC night during May-June. Plants were irrigated using drip irrigation through underground pipe and commercial fertilizers (Poly-Feed, Haifa Chemicals Co., Ltd.) mixed with water for supplying the nutrients and plants were grown with the recommended cultural practices of tomato. Four levels (0-, 5-, 10- and $15mg·L^{-1}$) of GA_3 and three levels (0-, 5- and $10mg·L^{-1}$) of 2,4-D were arranged in factorial randomized complete block design with three replications and each treatment consists of 15 plants. The stock solution was prepared by dissolving each hormone with ethanol and prepared in $1000mg·L^{-1}$. Then, working solution of each hormone was prepared according to the treatment levels. One to two drops of Tween-20 was added to the working solution before spraying. The PGRs were sprayed with hand held atomizer sprayer. and The hormones were sprayed to all the flower cluster of each plant 50 days after transplanting in the plastic house. The tomato plants in the experimental field are shown in Fig. 1A.

Observations were taken on five plants from each replication and fruit parameters including fruit set percentage, total fruit number per plant, marketable fruit number per plant, non-marketable fruit number per plant, fruit weight, marketable fruit weight, total yield per plant, fruit size (length and width, mm), total soluble soilds (ºBrix) and pericarp thickness (mm) were measured. Fruit set percentage was calculated based on the number of fruit set to the total number of flower per cluster. Based on the fruit weight, greater than 35g fruit with normal shape, defined as marketable, whereas lesser than 35g fruit weight with misshaped, disease fruits were considered as non-marketable (Luitel et al., 2012). Hand-held refractormeter PAL-1 (Atago, Japan) and vernier caliper were used to measure the sugar content and wall thickness, respectively. The data were analyzed using MSTATC software and significant mean was separated using Duncan's multiple range test (DMRT).

Results

1. Effect of GA_3 and 2,4-D on fruit set and yield

Highly significant ($P \leq 0.01$) effect of GA_3 was observed on fruit set percentage and total fruit number per plant. The

Fig. 1. The application of growth regulators on fruit set in tomato cv. 'Adoration' under the plastic house, Hwacheon. A, the tomato in experimental field; B, fruit set in unsprayed (control) plant, * indicates the abscised flower; C, fruit setting in tomato after the spray of $5mg·L^{-1}$ of GA_3 and $5mg·L^{-1}$ of 2,4-D.

highest (54.0%) fruit set was observed as 54.0% in 10mg·L^{-1} of GA_3, however, it was statistically similar to 5- and 15mg·L^{-1}GA_3 but the lowest fruit set recorded as 39.8% in control (Table 1). The unsprayed flower cluster tended to desiccate and had abscised flowers (Fig. 1B). The highest fruit number obtained as 17.2 at 15mg·L^{-1} but it was statistically similar with 5 and 10mg·L^{-1} GA_3. The significant variation observed in marketable fruit number within the levels of GA_3 applied. The marketable fruit number percentage was not significantly different with 5-, 10- and 15mg·L^{-1} of GA_3 applied. Highly significant ($P \leq 0.01$) difference observed among non-marketable fruit number per plant. The highest non-marketable fruit number percentage produced as 57.2% at unsprayed plant and percentage of non-marketable fruit decreased with the level of GA_3 increased. The highest fruit weight observed as 53.7g at 10mg·L^{-1} but it was not significantly different with 5- and 15mg·L^{-1} of GA_3 applied. Effect of GA_3 levels on marketable fruit weight and total fruit yield per plant was significant ($P \leq 0.05$). Marketable fruit weight per plant was not significantly different with the levels of GA application except control but the greatest fruit weight observed as 435.4g at 15mg·L^{-1} of GA_3 spray. With respect to total yield per plant, spraying 15mg·L^{-1} of GA_3 in tomato produced the highest yield as 574.3g; however, it was statistically similar with 5- and 10mg·L^{-1} of GA_3.

Highly significant ($P \leq 0.01$) effect on fruit set observed within the levels of 2,4-D spray (Table 1). The spray of 5mg·L^{-1} of 2,4-D on flowers gave the highest (55.0%) fruit set followed by 10mg·L^{-1} spray as 52.1%. Likewise, total fruit number produced the highest at 10mg·L^{-1} of 2,4-D spray as 14.8 followed by the spray of 5mg·L^{-1} 2,4-D as 13.9. The effect of 2,4-D spray on marketable fruit number and non-marketable fruit number was non-significant. But, the significant ($P \leq 0.05$) variation observed in fruit weight, marketable and total fruit yield within the 2,4-D levels. The highest (53.7g) fruit weight observed at 10mg·L^{-1} 2,4-D treatment; however it was not statistically different with the value obtained at 5mg·L^{-1} 2,4-D. The marketable fruit yield produced the maximum (469.5g) at 10mg·L^{-1} 2,4-D. However, it was statistically similar to 5mg·L^{-1} 2,4-D. Application 10mg·L^{-1} of 2,4-D yielded the highest (587.9g) yield per plant followed by the spray of 5mg·L^{-1} 2,4-D (515.6g).

The interaction effect of GA_3 and 2,4-D on fruit set was highly significant ($P \leq 0.01$) (Table 1 and 2). The spray of GA_3 and 2,4-D at each level of 5mg·L^{-1} gave the highest (62.5%) fruit set (Fig. 1C). However, this value was statistically similar to 15mg·L^{-1} of GA_3 spray without 2,4-D and 5 to 15mg·L^{-1} of GA_3 at each level of 5 to 10mg·L^{-1} of 2,4-D sprayed. Similarly, the interaction effect of GA_3 and 2,4-D on fruit number and yield per plant was significant.

Table 1. Analysis of variance (ANOVA) of the effects of GA_3 and 2,4-D spray on fruit set, yield components and yield of tomato (*Lycopersicon esculentum* Mill.)

Treatment	Fruit set (%)	Total fruit /plant (no.)	Marketable fruit no./plant (%)	Non-marketable fruit no./plant (%)	Fruit weight (g)	Marketable fruit weight/plant (g)	Fruit yield /plant (g)
GA_3 (mg·L^{-1})							
0	39.8 b^z	10.9 b	42.8 b	57.2 a	47.3 b	352.4 b	434.7 b
5	53.4 ab	14.2 ab	62.6 a	37.4 b	51.4 a	421.1 a	497.7 ab
10	54.0 a	14.7 ab	68.5 a	31.5 b	53.7 a	410.5 a	506.2 ab
15	53.8 a	17.2 a	68.2 a	31.8 b	50.9 a	435.4 a	574.3 a
2, 4-D (mg·L^{-1})							
0	43.7 b	12.2 b	59.5	40.2	45.6 b	342.6 b	436.2 b
5	55.0 a	13.9 a	64.9	35.0	47.6 ab	390.9 ab	515.6 a
10	52.1 a	14.8 a	62.4	37.5	53.7 a	469.5 a	587.9 a
GA	**	**	*	**	*	*	*
2, 4-D	**	*	NS	NS	*	*	*
GA3 × 2, 4-D	**	*	NS	NS	NS	NS	*

NS, *, ** Non-significant or significant at $P \leq 0.05$ or $P \leq 0.01$.
[Z]Means in a column followed by the same letter are not significantly different ($P \leq 0.05$); Duncan's Multiple Range Test (DMRT).

Table 2. Interaction effects of GA_3 and 2,4-D spray on fruit set, fruit number and yield of tomato (*Lycopersicon esculentum* Mill.).

GA_3 levels ($mg \cdot L^{-1}$)	2,4-D levels ($mg \cdot L^{-1}$)	Percentage of fruit set (%)	No. of fruit (ea/plant)	Fruit yield (g/plant)
0	0	17.6 d^z	8.7 e	349.5 c
	5	47.9 bc	11.4 cde	427.6 bc
	10	53.9 abc	12.5 b-e	527.1 abc
5	0	42.8 c	13.0 b-e	409.7 bc
	5	62.5 a	12.5 b-e	514.5 abc
	10	54.7 abc	17.0 ab	588.8 ab
10	0	47.0 bc	13.0 b-e	428.7 bc
	5	53.3 abc	10.5 de	527.9 abc
	10	51.6 abc	14.8 bcd	568.8 ab
15	0	54.3 ab	15.6 bc	556.9 ab
	5	56.2 abc	21.2 a	599.1 a
	10	52.9 ab	14.8 bcd	567.1 ab

^{Z}Means within a column followed by the same letter are not significantly different ($P \leq 0.05$); Duncan's Multiple Range Test (DMRT).

Table 3. Effect of GA_3 and 2,4-D spray on fruit quality characters of tomato (*Lycopersicon esculentum* Mill.).

Treatment	Fruit length (mm)	Fruit width (mm)	Total soluble solid (°Brix)	Pericarp thickness (mm)
GA_3($mg \cdot L^{-1}$)				
0	39.0 c^z	44.7 a	5.5 a	5.8
5	40.6 b	46.9 a	5.7 a	5.6
10	41.8 a	47.7 a	5.7 a	5.6
15	41.2 ab	45.5 a	6.1 a	5.7
2,4-D($mg \cdot L^{-1}$)				
0	40.4	46.0	5.7	5.9
5	39.2	45.5	5.9	5.6
10	39.6	47.1	5.8	5.5
GA	**	*	*	NS
2, 4-D	NS	NS	NS	NS
GA3 × 2,4-D	NS	NS	*	NS

NS, *, ** Non-significant or significant at $P \leq 0.05$ or $P \leq 0.01$.
^{Z}Means in a column followed by the same letter are not significantly different ($P \leq 0.05$); Duncan's Multiple Range Test (DMRT).

The highest (21.2) fruit number per plant was produced at 15mg·L^{-1} of GA_3 spray in combination with the spray of 5mg·L^{-1} of 2,4-D followed by the spray of 5mg·L^{-1} of GA_3 with 10mg·L^{-1} of 2,4-D. The highest (599.1g) fruit yield obtained in 15mg·L^{-1} of GA_3 spray in combination with 5mg·L^{-1} of 2,4-D. The interaction effect in other studied traits was found to be non-significant.

Table 4. Interaction effect of GA and 2, 4-D on TSS (°Brix) of tomato (*Lycopersicon esculentum* Mill.)

GA levels ($mg \cdot L^{-1}$)	2,4-D levels ($mg \cdot L^{-1}$)		
	0	5	10
0	5.1 d^z	5.5 bcd	5.8abcd
5	5.3 cd	5.6 bcd	6.1 ab
10	5.8 abcd	5.9 abc	5.5 bcd
15	6.4 a	6.4 a	5.6 bcd

^{Z}Means in a row and column followed by the same letter are not significantly different (P=0.05); Duncan's Multiple Range Test (DMRT).

2. Effect of GA_3 and 2, 4-D on fruit size and quality

The different concentrations of GA_3 application significantly affected the fruit size (Table 3). The highest (41.8mm) fruit length measured at 10mg·L^{-1} but it was statistically similar with 15mg·L^{-1} GA_3 spray. The fruit width showed statistically similar values in all the concentrations of GA_3 applied. Likewise, a total soluble solid was significantly different with the level of GA_3 applied. Application 15mg·L^{-1} of GA_3 exhibited the highest (6.1 °Brix) TSS but it was not statistically different with values obtained at other treatments. The effect of GA_3 spray on fruit pericarp thickness was non-significant. Similarly, 2,4-D effect on all studied fruit quality characters was non-significant. The interaction effect of GA_3 and 2,4-D in fruit size and pericarp thickness was non-significant, but it was significant in total soluble solid content of the fruit. The 15mg·L^{-1} of GA_3 spray with 5mg·L^{-1} or without 2,4-D showed the highest (6.4 °Brix) total soluble solids (Table 4).

Discussion

Plant hormones are organic substances that are produced naturally in the plants and regulate the growth phenomena such as bud development, root growth and fruit setting (Minges and Mann, 1949). Khan et al. (2006) reported that marketable fruit number per plant increased in tomato due to GA_3 application. In the study of Taiz and Zeiger (2002), they reported that application of GA_3 caused the fruit set and fruit growth. Our result showed that spray of GA_3 on flower cluster improved the fruit set in tomato by 13-14.2% than unsprayed flower. Gelmesa et al. (2010) reported that the spray of GA_3 on blossom increased the fruit set of tomato. The unsprayed flowers tended to flower drop that caused the poor fruit setting in tomato. Kuo and Tsai (1984) reported that the high temperature decreases the levels of auxin and gibberellins-like substances particularly in flower bud that tend to reduce the fruit set in tomato. The shortage of auxin and gibberellins due to high temperature stress in unsprayed flower might be the cause of poor fruit set. The increased marketable fruit number per plant, reduced fruit drop and increased fruit weight and fruit yield due to GA_3 spray have been reported by Naeem et al. (2001). In this study, we observed the increased fruit weight due to single GA_3 spray. In contrast, Gelmesa et al. (2010) observed increased marketable fruit number per plant and reduced fruit weight due to GA_3 spray on flower. Sasaki et al. (2005) found that the mixture of 4-chlorophenoxyacetic acid and gibberellins in tomato increased fruit set and fruit number. They reported that control treatment showed a fruit set ratio of 54% and 4-chlorophenoxyacetic acid increased the fruit set ratio up to 67% but the mixture of GA_3 and 4-CPA promoted the fruit set ratio to 88%. However, in our study, the single spray of $10mg{\cdot}L^{-1}$ 2,4-D showed 55% fruit set but the interaction effect of GA_3 and 2,4-D at each $5mg{\cdot}L^{-1}$ increased the fruit set up to 62.5%. Gemici et al. (2006) reported that high concentration of 2,4-D at $10mg{\cdot}L^{-1}$ produced fewer fruits per plant due to increased rate of flower bud abscission but in this result, no significant differences were observed in fruit number per plant between 5 and $10mg{\cdot}L^{-1}$ 2,4-D spray. This result showed similar yield in the spray of 5 to $15mg{\cdot}L^{-1}$ of GA_3 in combination with each level of 5 to $10mg{\cdot}L^{-1}$ of 2,4-D sprayed. Pudir and Yadav (2001) reported that low concentration ($5mg{\cdot}L^{-1}$) of 2,4-D improved the fruit yield whereas Mullision and Mullison (1948) found 2,4-D at $10mg{\cdot}L^{-1}$ was effective for higher yield in tomato. They also observed the enlargement of fruit develop from the growth regulators sprayed blossoms. Cell division followed by cell expansion is the major phenomenon involved in the fruit growth and cell volume increase due to cell expansion which contribute to final size of the fruits (Gillaspy et al., 1993). This results show that fruit developed from GA_3 sprayed flowers showed larger size than control. Higher total soluble solid was found in $15mg{\cdot}L^{-1}$ GA_3 sprayed treatment. Graham and Ballesteros (2006) reported that GA_3 increased protein, soluble carbohydrates, ascorbic acid, starch and B-carotene in tomato. In the study of Kataoka et al. (2009), they reported that higher sugar content of tomato fruits obtained from $50mg{\cdot}L^{-1}$ GA3 treated plants. 2,4-D is the most responsive synthetic auxin which involves in the cell division and cell enlargement of the fruits. Rasul et al. (2008) observed 2,4-D at 25, 50 and $100mg{\cdot}L^{-1}$ produced longer fruits as compared to Fulmet (forchlorophenuron) and CPPU: N-(2-chloro-4 pyridyl)-N' phenyl urea) in Teasle Gourd. Gelmesa et al. (2010) mentioned longer fruits with bigger size in 2,4-D treated plants. Similarly, Gimici et al. (2006) also reported that 2,4-D increased thetomato fruit sizebut in this study, we did not observe significant difference in fruit size in response to the different concentrations of 2,4-D sprayed. Serrani et al. (2007a) reported that tomato fruits induced by GA_3 and 2,4-D had thicker pericarp but in this result, 2,4-D did not any significant effect on pericarp thickness. To conclude, the growth regulators like GA_3 and 2,4-D spray in flower increased the fruit set, yield and quality characters under high temperature condition. The combined spray of $10mg{\cdot}L^{-1}$ GA_3 and $5mg{\cdot}L^{-1}$ 2,4-D can increase the fruit set and yield in tomato during the summer inside the plastic house. Thus, both plant growth regulators are found to be important to increase the fruit set and yield under unfavorable condition of high temperature.

Literature cited

Anwar, W., T. Aziz, F. Naveed, and S.T. Sahi. 2010. Foliar applied 2, 4-Dichlorophenoxyacetic acid improved tomato growth and yield. Soil Environ. 29:77-81.

Batlang, U. 2008. Benzyladenine plus gibberellins (GA_{4+7}) increase fruit size and yield in greenhouse-grown hot pepper (*Capsicum annuum* L.). J. Biol. Sci. 8:659-662.

Erickson, A.N. and A.H. Markhart. 2001. Flower production, fruit set and physiology of bell pepper during elevated temperature and vapor pressure deficit. J. Amer. Soc. Hort. Sci. 126:697-702.

Gelmesa, D., B. Abebie, and L. Desalegn. 2010. Effects of gibberellic acid and 2, 4-dichlorophenoxyacetic acid spray on fruit yield and quality of tomato (*Lycopersicon esculentum* Mill.). J. Plant Breed Crop Sci. 10:316-324.

Gemici, M., A. Guve, and A. K. Yurekli. 2000. Effect of some growth regulators and commercial preparations on the chlorophyll content and mineral nutrition of *Lycopersicon esculentum* Mill. Turk. J. Bot. 24:215-219.

Gemici, M., B. Turkyilmaz, and K. Tan. 2006. Effect of 2,4-D and 4-CPA on yield and quality of the tomato, *Lycopersicon esculentum* Mill. J. Food Sci. 29:24-32.

Gillaspy, G., H. Ben-David, and W. Gruissem. 1993. Fruits: a developmental perspective. The Plant Cell 5(10): 1439-1451.

Graham, H.D. and M. Ballesteros. 2006. Effect of plant growth regulators on plant nutrients. J. Food Sci. 45:502-505.

Kataoka, K., Y. Yashiro, T. Habu, K. Sunamoto, and A. Kitajima. 2009. The addition of gibberellic acid to auxin solutions increases sugar accumulation and sink strength in developing auxin-induced parthenocarpic tomato fruits. Sci. Hort. 123:228-233.

Khan, M.M.A., A.C. Gautam, F. Mohammad, M.H. Siddiqui, M. Naeem, M.N. Khan. 2006. Effect of gibberellic acid spray on performance of tomato. Turk. J. Biol. 30:11-16.

Kinet, J.M. and M.M. 1997. Tomato, p. 207-248. In: H.C. Wien (ed.). The Physiology of Vegetable Crops. CAB International.

Kuo, C.G. and C.T. Tsai. 1984. Alternation by high temperature of auxin and gibberellin concentration in the floral buds, flowers and young fruit of tomato. HortScience. 19:870-872.

Luitel, B.P., P.B. Adhikari, C.S. Yoon, and W.H. Kang. 2012. Yield and fruit quality of tomato (*Lycopersicon esculentum* Mill.) cultivars established at different planting bed size and growing substrates. Hort. Environ. Biotechnol. 53:102-107.

Minges, P.A. and L.K. Mann. 1949. Improving tomato fruit set: Use of hormone spray treatment for improvement of fruit set for spring and early summer harvest. California Agriculture, p. 8.

Mullison, W.R. and E. Mullsion. 1948. Effects of several plant growth-regulators on fruit set, yield and blossom-end rot of six tomato varieties grown under high temperatures. Botanical Gazette, 109:501-506.

Naeem, N., M. Ishtiaq, P. Khan, N. Mohammad, J. Khan and B. Jamiher. 2001. Effect of gibberellic acid on growth and yield of tomato cv. Roma. J. Biol. Sci. 6:448-450.

Pandolfini, T., G.L. Rotino, S. Camerini, R. Defez, and A. Spena. 2002. Optimization of transgene action at the post-transcriptional level: High quality parthenocarpic fruits in industrial tomatoes. BMC Biol. 2:1-11.

Peet, M.M., D.H. Willits, and R. Gardner. 1997. Response of ovule development and post-pollen production processes in male-sterile tomatoes to chronic, acute high temperature stress. J. Exp. Bot. 48:101-111.

Pudir, J.P.S. and P.K. Yadav. 2001. Note on the effect of GA_3, NAA and 2,4-D on growth, yield and quality of tomato var. Punjab Chuhara. Curr. Agric. 25:137-138.

Rasul, M.G., M.A.K. Mian, Y. Cho, Y. Ozaki, and H. Okubo. 2008. Application of plant growth regulators on the parthenocarpic fruit development in Teasle Gourd (Kakrol, *Momordica diocia* Roxb). J. Fac. Agr., Kyushu Univ. 53:39-42.

Sanwal, S.K., K.S. Baswana, and H.R. Dhingra. 1997. High temperature tolerance in egg plant: Stigma, anther and pollen studies. Ann. Biol. 13:123-125.

Sasaki, H., T. Yano, and A. Yamasaki. 2005. Reduction of high temperature inhibition in fruit set by plant growth regulators. Japan Agr. Res. Q. 39:135-138.

Serrani, J.C., M. Fos, A. Atare's, and J.L. Garcia-martinez. 2007. Effect of gibberellins and auxin on parthenocarpic fruit growth induction in the cv. Micro-Tom of tomato. J. Plant Growth Regul. 26:211-221.

Soon, J.C., I.S. Kim, and Y.K. Chang. 1995. Effect of several growth regulators on inhibition of puffy-fruit, sugar and organic acid in tomatoes. Kor. Soc. Hort. Sci. 13:100-101.

Taiz, L. and E. Zeiger. 2002. Plant physiology, 3rd ed. Sinaure. Associates, Inc. USA, p. 690.

Vara Prasad, P.V., P.Q. Craufurd, and R.J. 1999. Fruit number in relation to pollen production and viability in groundnut exposed to short episodes of heat stress. Ann. Bot. 84:381-386.

Wilcox, J., G. Catignani, and C. Lazarus. 2003. Tomatoes and cardiovascular health. Crit. Rev. Food Sci. Nutr. 43:1-18.

지베렐린과 2,4-D 처리를 이용한 토마토 착과율 및 수확량 증가

루이텔 비노드 · 이택종 · 강원희
강원대학교 원예학과

토마토의 착과와 수확량은 여름철 비닐하우스내 고온스트레스로 인하여 감소하게 된다. 본 연구는 여름철 화천지역에 위치한 비닐하우스에서 지베렐린(GA_3)과 2,4-Dichlorophenoxy Acetic Acid(2,4-D) 처리가 토마토의 수확량, 착과율, 착과 후 과실품질에 미치는 영향을 알아보기 위해 'Adoration' 품종을 이용하여 실험하였다. GA_3 0-, 5-, 10-, 15mg·L^{-1}와 2,4-D 0-, 5-, 10mg·L^{-1}를 개화 초기에 처리한 후 착과율, 수확량, 과실품질과 관련된 형질을 관찰한 결과, GA_3 10mg·L^{-1}처리구에서 대조구에 비해 14.2%의 착과율 증가를 보였다. GA_3처리구에서는 수확량, 과중, 상품과실 수에 유의한 차이가 있었다. 2,4-D를 개화기에 처리했을 경우 착과율, 수확량, 상품과의 과중에 영향을 미쳤으며 GA_3과 2,4-D를 각각 5mg·L^{-1} 농도로 혼합처리 하였을 때 가장 높은(62.5%) 착과율을 나타내었다. 과실크기와 고형물함량은 GA_3처리구에서만 유의성 있는 차이를 보였다. 따라서 여름철 비닐하우스의 고온조건에서 GA_3 0mg·L^{-1}처리구와 2,4-D 5mg·L^{-1}를 처리했을 때 착과율이 가장 높아 많은 수확량을 기대할 수 있을 것으로 판단된다.

추가 주제어 : 개화기, 착과, 지베렐린, 2,4-D, 고형물