JARQ 39 (2), 135 – 138 (2005) http://www.jircas.affrc.go.jp

Reduction of High Temperature Inhibition in Tomato Fruit Set by Plant Growth Regulators

Hidekazu SASAKI[1]*, Takayoshi YANO and Atsushi YAMASAKI

Department of Vegetable and Floricultural Science, National Agricultural Research Center for Tohoku Region (Morioka, Iwate 020–0198, Japan)

Abstract

The effects of plant growth regulators on fruit set of tomato (*Lycopersicon esculentum* Mill.) under high temperature were examined in a controlled environment and a field under rain shelter. Tomato plants exposed to high temperature (34/20ºC) had reduced fruit set. Treatments of plant growth regulators reduced the fruit set inhibition by high temperature to some extent, especially treatment with mixtures of 4-chlorophenoxyacetic acid (4-CPA) and gibberellins (GAs). In the field experiment, tomatoes treated with a mixture of 4-CPA and GAs showed increased fruit set and the numbers of normal fruits (excluding abnormal types such as puffy fruit) were more than the plants treated with 4-CPA alone during summer.

Discipline: Horticulture
Additional key words: 4-chlorophenoxyacetic acid, gibberellin, rain shelter

Introduction

Tomato is one of the most important fruit vegetables that is cultivated throughout the year in Japan. During warm seasons, tomatoes cultivated in cool or highland areas are often planted under rain shelter. This enhances plant growth and improves fruit quality, thus the use of rain shelters became widespread in tomato production. On the other hand, the rain shelter with a plastic film exposes the plants to higher temperature than in an open field during summer. High temperatures reduce fruit set and fruit production in tomato[9], in eggplant[11] and also in bell pepper[2]. Plant growth regulators such as auxin and gibberellins are known to affect parthenocarpy[7] and fruiting[10]; therefore, synthesized auxin and gibberelins are often used for promotion of fruit set in some fruit vegetable production including tomatoes. Though tomatoes are usually treated with synthetic auxin during cool and mild seasons in Japan, the rate of fruit set under high temperature conditions is still low. The purpose of the present study was to characterize high temperature inhibition in fruit set and to understand the promotion of fruit set by plant growth regulators, so as to reduce high temperature damage in tomato production under rain shelters.

Materials and methods

Exp. 1. Effects of growth regulators and high temperature on fruit set of tomatoes in controlled environment

Seeds of tomato (*Lycopersicon esculentum* Mill. cv. Momotaro) were sown in a flat filled with a soil mixture. When the first leaves unfolded, seedlings were transplanted to plastic pots (12 cm in diameter) and were grown in a glasshouse. The seedlings with emerging first flower cluster were transferred to a growth chamber at 30/20ºC (day/night) and a 12 h photoperiod in which illumination was supplied by fluorescent lamp with a photosynthetic photon flux density (PPFD) of 230 µmol m^{-2} s^{-1}. Tomatoes before anthesis of the first flower of the first cluster were used for temperature and growth regulator treatments. The plants were exposed to 30/20 (12 h photoperiod), 34/20 (8 h photoperiod) or 34/20 (10 h photoperiod) ºC as temperature treatments until the determination of fruit set. As for the growth regulator treatments, the clusters were dipped in distilled water (control), 20 mg L^{-1} 4-

Present address:
[1] Biological Resources Division, Japan International Research Center for Agricultural Sciences (JIRCAS) (Tsukuba, Ibaraki 305–8686, Japan)
*Corresponding author: fax +81–29–838–6352; e-mail hsasaki@jircas.affrc.go.jp
Received 16 June 2004; accepted 29 November 2004.

chlorophenoxyacetic acid (4-CPA; Nissan Chemical Industries, Ltd. Tokyo, Japan), or a 20 mg L^{-1} mixture of 4-CPA and gibberellins (dominant GA_3 and a small amount of GA_1 compound; Meiji Seika Kaisha, Ltd. Tokyo, Japan) when the anthesis of second or third flower blooms occurred. Each treatment was conducted using 9 plants. The fruits were harvested 12 days after the growth regulator treatments. Fruit set ratio was calculated as a percentage of fruit number (diameter was over 10 mm) to flower number (including buds just before anthesis) of the growth regulator treatments.

Exp. 2. Effects of growth regulators on fruit set of tomatoes under high temperature condition

Experimental conditions were the same as Exp. 1, except for the temperature treatment which was 34/20 (8 h photoperiod) ºC and growth regulator treatments which were applied as follows. The plants were treated with growth regulators by dipping the cluster in distilled water (control), 5/20 (4-CPA / GAs), 20/5, 20/20, 20/ 50, or 50/20 mg L^{-1} growth regulators.

Exp. 3. Effect of growth regulators on fruit set of tomatoes under rain shelter in the field

Seeds of tomato (cv. Momotaro) were sown in a flat filled with a soil mixture on April 12, 2001. When the first leaves unfolded, seedlings were transplanted to plastic pots and were grown in a glasshouse. On May 31, the seedlings were planted in the experimental field of National Agricultural Research Center for Tohoku Region under a rain shelter (width 1.6 m, height 2 m) with a plastic film (Nouviace 0.1 mm in thickness; Mitsubishi Chemical MKV Co., Tokyo, Japan). Cultivation procedures were in accordance with the customary practices. The 5th clusters at anthesis were used. On August 15, the 5th clusters were dipped in distilled water (control), 20 mg L^{-1} 4-CPA (4-CPA), or a 20 mg L^{-1} mixture of 4-CPA and GAs (4-CPA+GA) as growth regulator treatments. Fruit set ratio was calculated on August 30 as a percentage of fruit number (diameter was over 20 mm) to flower number (including buds just before anthesis) when the growth regulator treatment was applied.

Exp. 4. Effect of growth regulators on fruit set and occurrence of abnormal fruit of tomatoes under rain shelter in the field

Seeds of tomato (cv. Momotaro) were sown in a flat filled with a soil mixture on April 21, 2002. When the first leaves unfolded, seedlings were transplanted to plastic pots and were grown in a glasshouse. On May 13, the seedlings were planted in the experimental field of National Agricultural Research Center for Tohoku Region under the rain shelter (width 1.6 m, height 2 m) with a plastic film. Cultivation procedures were in accordance with the customary practices. On August 16, the 5th and 6th clusters were treated with the same growth regulators as in Exp. 3. The numbers of plants used for the control, 4-CPA and 4-CPA+GA treatments were 35, 34 and 35, respectively. Fruit set ratio was calculated on August 30 as a percentage of fruit number (diameter was over 20 mm) to flower number (including buds just before anthesis) when the growth regulator treatment was applied. The mature fruits were harvested for assessing abnormal fruits on October 22.

Results and discussion

Exp. 1. Effects of growth regulators and high temperature on fruit set of tomatoes in controlled environment

Tomato plants exposed to high temperature (34/20ºC) had reduced fruit set (Table 1). The treatment

Table 1. Effects of growth regulators and high temperature on fruit set of tomatoes in controlled environment

Treatment	Fruit set ratio of first cluster (%)		
	30/20ºC a)	34/20ºC	34/20ºC
photoperiod	12 h	8 h	10 h
Control b)	42.9 x*	0.0 x	0.0 x
4-CPA c)	100.0 y	59.8 y	39.8 y
4-CPA/GA d)	91.7 y	88.0 y	75.9 z

a): Temperature of growth regulators treatment for determination of fruit set (day/night).
b): Clusters dipped in distilled water.
c): Clusters dipped in 20 mg·L^{-1} 4-chlorophenoxyacetic acid (4-CPA).
d): Clusters dipped in 20 mg·L^{-1} mixture of 4-CPA and gibberellins (dominant GA_3 and a small amount of GA_1 compound).
*: Means indicated by different letters within a column are significantly different at 0.05 level.

with 4-CPA induced fruit set; however, it was also affected by high temperature. For the condition at 34/20ºC with 10 h photoperiod (exposure to high temperature for a longer period), the fruit set ratio was reduced to 39.8%. Growth regulator treatments with the mixture of 4-CPA and GAs induced a greater fruit set ratio at 34/20ºC compared to 4-CPA treatment alone. The observation that high temperature reduced the fruit set coincides with the results of Iwahori and Takahashi[4] that the tomato flowers, one to three days after anthesis are especially sensitive to high temperature and fail to set fruits. Abdul-Baki and Stommel[1] reported that no fruit set occurred in the most heat-sensitive genotypes of tomato under high temperature (35/20ºC).

Results of the study showed that under high temperature the combination of 4-CPA and GAs induced fruit set to some extent. Early fruit growth was suppressed by uniconazole treatment and the application of GA_3 may reverse this action to some extent[5]. Nester and Zeevaart[8] observed that in tomatoes which are gibberellin-deficient mutants, completion of flower bud development and fruit set requires gibberellin. On the other hand, Kuo and Tsai[6] reported that high temperature treatment decreases the levels of auxin- and gibberellin-like substances, especially in floral buds and developing fruits of tomato. Therefore, shortage of auxin and gibberellins could cause the reduction of fruit set under high temperature. Then it is assumed that treatments of the combination of 4-CPA and GAs reduce the high temperature inhibition in tomato fruit set.

Exp. 2. Effects of growth regulators on fruit set of tomatoes under high temperature condition

Control plants had a lower fruit set ratio under high temperature (34/20ºC) (Fig. 1). In the conditions of the present experiment, 4-CPA with concentrations ranging from 5 to 20 mg L^{-1} induced fruit set. Addition of 20 mg L^{-1} GAs to 4-CPA induced the highest fruit set ratio under high temperature, except for the addition to 50 mg L^{-1} 4-CPA.

Exp. 3. Effect of growth regulators on fruit set of tomatoes under rain shelter in the field

From August 13 (2 days before treatment) to August 22, 2001 (7 days after treatment), the average daily maximum temperatures of the environment near the 5th clusters was about 31.5ºC and that of the air was about 29.5ºC. The control treatment showed a fruit set ratio of 54% while the 4-CPA treatment increased the ratio to 67% (Fig. 2). Moreover, treatment with the mixture of 4-CPA and GAs promoted the fruit set ratio to 88%. It is not clear if the temperature condition during the experiment was enough to induce the high temperature inhibition in tomato. The fruit set of the control treatment was lower than that of the 4-CPA treatment. This suggests that growth regulators could induce the fruit set in tomato under the rain shelter during the summer season.

Exp. 4. Effect of growth regulators on fruit set and occurrence of abnormal fruit of tomatoes under rain shelter in the field

The average daily maximum temperatures of the environment near the 5th clusters from 14 August 2002 (2 days before treatment) to 23 August (7 days after treatment) was about 29.6ºC and that of the air was about 26.8ºC. In this experiment, the growth regulator treat-

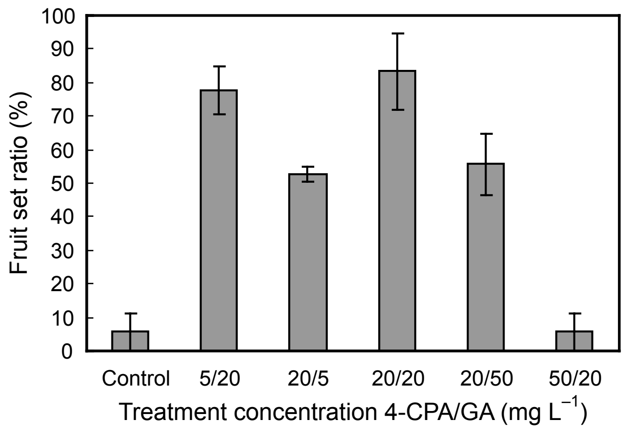

Fig. 1. Fruit set ratio in tomatoes affected by growth regulator treatments in controlled environment (34/20ºC)

Vertical bars indicate standard errors (n = 6).

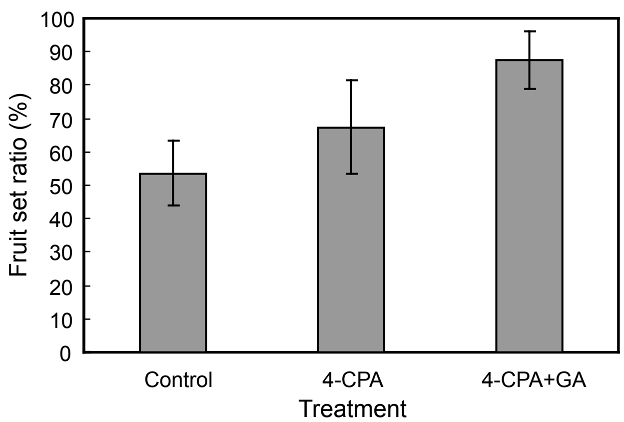

Fig. 2. Effect of growth regulators on fruit set of tomatoes under rain shelter in the field (2001)

The treatments are the same as those in Table 1. Vertical bars indicate standard errors (n = 11).

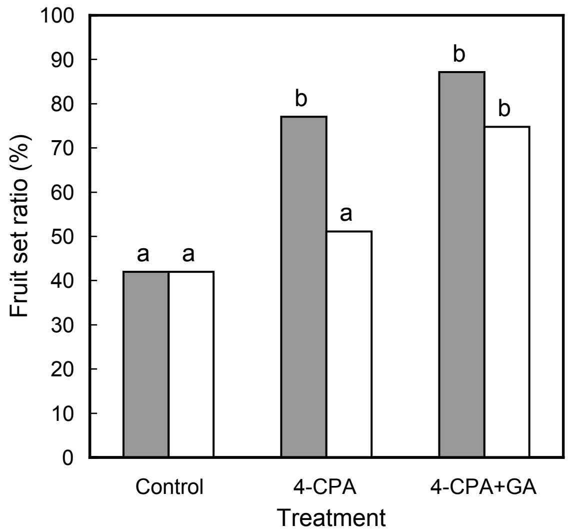

Fig. 3. Effect of growth regulators on fruit set and occurrence of abnormal fruit of tomatoes under rain shelter in the field (2002)

■: Fruit set. □: Normal fruit set.

The treatments are the same as those in Table 1. Different letters within same legend columns are significantly different at 0.05 level.

ments also showed an increased fruit set ratio as compared to the control treatment (Fig. 3). Assessment of the abnormal fruits showed that the 4-CPA treatment significantly included more abnormal fruits, especially puffy fruits than treatment with the mixture of 4-CPA and GAs. The increase of puffy fruit with the 4-CPA treatment agrees with the observation by Hosoki & Asahira[3] that *in vitro* cultured parthenocarpic fruits can be induced by auxin at higher temperatures promoting a degree of puffiness during the induction of parthenocarpy. Fruit-setting treatment with 4-CPA caused an increase in GA levels[12], but high temperature treatment decreased the levels of gibberellin-like substances in developing fruit of tomato[6]. Thus, application of GAs under high temperature would have a role in fruit set of tomatoes and might be interacting with 4-CPA.

These results suggest that treatment with the mixture of 4-CPA and GAs could induce the fruit set in normal fruits excluding the abnormal types such as puffy fruits of tomato under the rain shelter during the summer season.

Conclusion

In a controlled environment tomato plants exposed to high temperature (34/20ºC) reduced fruit set. Treatments of plant growth regulators reduced the inhibition of high temperature to some extent especially the treatment with the mixture of 4-chlorophenoxyacetic acid (4-CPA) and gibberellins (GAs). In the field experiment under a rain shelter, tomatoes treated with the mixture of 4-CPA and GAs showed an increased fruit set and number of normal fruits (excluding abnormal types such as puffy fruit) as compared to the plants treated with 4-CPA alone during the summer season. These results indicate that high temperature inhibition in fruit set could be reduced by a mixture of 4-CPA and GAs treatment in tomato production.

References

1. Abdul-Baki, A. A. & Stommel, J. R. (1995) Pollen viability and fruit set of tomato genotypes under optimum-and high-temperature regimes. *Hortscience*, **30**, 115–117.
2. Erickson, A. N. & Markhart, A. H. (2001) Flower production, fruit set, and physiology of bell pepper during elevated temperature and vapor pressure deficit. *J. Am. Soc. Hort. Sci.*, **126**, 697–702.
3. Hosoki, T. & Asahira, T. (1978) In vitro studies of controlling tomato puffiness enhanced by temperature, nitrogen source and sucrose concentration. *Sci. Hortic.*, **9**, 295–302.
4. Iwahori, S. & Takahashi, K. (1964) High temperature injuries in tomato. III. Effects of high temperature on flower buds and flowers of different stages of development. *Engei gakkai zasshi.* (*J. Jpn. Soc. Hort. Sci).*, **33**, 67–74 [In Japanese with English summary].
5. Kataoka, K., Uemachi, A. & Yazawa, S. (2003) Fruit growth and pseudoembryo development affected by uniconazole, an inhibitor of gibberellin biosynthesis, in pat-2 and auxin-induced parthenocarpic tomato fruits. *Sci. Hortic.*, **98**, 9–16.
6. Kuo, C. G. & Tsai, C. T. (1984) Alternation by high temperature of auxin and gibberellin concentrations in the floral buds, flowers, and young fruit of tomato. *Hortscience*, **19**, 870–872.
7. Matlob, A. N. & Kelly, W. C. (1975) Growth regulator activity and parthenocarpic fruit production in snake melon and cucumber grown at high temperature. *J. Am. Soc. Hort. Sci.*, **100**, 406–409.
8. Nester, J. E. & Zeevaart, J. A. D. (1988) Flower development in normal tomato and a gibberellin-deficient ga-2 mutant. *Am. J. Bot.*, **75**, 45–55.
9. Peet, M. M., Willits, D. H. & Gardner, R. (1997) Response of ovule development and post-pollen production processes in male-sterile tomatoes to chronic, subacute high temperature stress. *J. Exp. Bot.*, **48**, 101–111.
10. Rappaport, L. (1957) Effect of gibberellin on growth, flowering and fruiting of the Earlypak tomato, *Lycopersicum esculentum*. *Plant Physiol.*, **32**, 440–444.
11. Sanwal, S. K., Baswana, K. S. & Dhingra, H. R. (1997) High temperature tolerance in egg plant: Stigma, anther and pollen studies. *Ann. Biol.*, **13**, 123–125.
12. Sjut, V. & Bangerth, F. (1981) Effect of pollination or treatment with growth regulators on levels of extractable hormones in tomato ovaries and young fruits. *Physiol. Plant.*, **53**, 76–78.