British Biotechnology Journal
4(7): 794-800, 2014

SCIENCEDOMAIN ***international***
www.sciencedomain.org

Effect of Abscisic Acid on Soluble Sugar Contents in Tomato Fruits under Condition of Short-Term Night Sub-Low Temperature[1]

Nan Wang[1], Kaiyue Zhang[1], Na Cui[1,2*], Haiyan Fan[1], Yang Yu[1] and Tianlai Li[2]

[1]Biological Science and Technology College, Shenyang Agricultural University, Shenyang 110866, China.
[2]Key Laboratory of Protected Horticulture, Ministry of Education, Shenyang Agricultural University, Shenyang 110866, China.

Authors' contributions

This work was carried out in collaboration between all authors. Authors NW and KZ are co-first authors with equal contributions. Authors NC and TL designed the study. Authors NW and KZ performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors NW and YY managed the analyses of the study. Author HF managed the literature searches. All authors read and approved the final manuscript.

Short Research Article

Received 8th May 2014
Accepted 19th June 2014
Published 7th July 2014

ABSTRACT

Aims: This research explored the effect of ABA treatment before short-term night sub-low temperature on the sugar composition and contents, and provided theoretical basis for temperature management in tomato protected cultivation.
Study Design: The whole tomato was treated by spraying with 50mmol/L and 100mmol/L ABA respectively before short-tern night sub-low temperature. Spraying distilled water was as the control. The lower temperature treatment was as the lower temperature control group.
Place and Duration of Study: Biological Science and Technology College, between February 2013 and March 2014.
Methodology: The sugar composition and contents were determined using High Performance Liquid Chromatography (HPLC).
Results: The pectinic tissues, pericarp and dissepiments after sub-low temperature treatment had high contents of three soluble sugars at the early fruit development stage.

**Corresponding author: Email: wannan1988@126.com;*

The fructose and glucose contents were reduced by the 50mmol/L ABA treatment under condition of lower temperature. At the fruit mature stage, contents of three soluble sugars in the pericarp and dissepiments after sub-low temperature treatment had less than those in control group and had higher accumulation than the other two groups by 50mmol/L ABA treatment, but the soluble sugars contents were reduced by ABA treatment in the pectinic tissues.

Conclusion: 50mmol/L ABA was the optimum concentration on improving the ability of resisting sub-low temperature in tomato fruits at the early development stage, improving the tomato fruit quality at the fruit mature stage, promoting transfer of soluble sugars to structure matter or storage matter. However, the effects of ABA on sugar accumulation were different in the pectinic tissues or pericarp and dissepiments.

Keywords: Tomato fruit; sub-low night temperature; content of sugar.

1. INTRODUCTION

Temperature is the most important factor that affecting dry matter distribution in plant, especially at the night temperature. It can directly affect the sink strength of plant organs and further affect dry matter distribution [1,2].

During the winter cultivation, the protected tomato often suffers from the low temperature stress, which causes poor plant growth and ultimately leads to fruit yield and quality reduction. There are some reports about physiological study of protected vegetables under low temperature stress conditions [3,4]. The most of them are concentrated on extreme low temperature or low temperature day and night. The studies still lack about the effects of normal day-temperature and low night-temperature on the plant growth in northern China. The plant hormones ABA, which is the initiator of the express of cold resistance genes [5], plays an important role in regulating the cold resistance of plants, and promotes resistance of low temperature stress in plant [6]. The soluble sugar is not only the main substance for plant growth and fruit quality formation, but also the protective substance of cell under cold damage and freeze damage [7]. Its content is positively correlated with the cold resistance in the most plants [8,9].

Thus, this study applied exogenous abscisic acid under condition of short-term night sub-low temperature. We assayed the soluble sugar contents of different parts at different fruit development stages, and try to find out the optimum exogenous ABA concentration which can promote the cold resistance of plants under low night temperature.

2 MATERIALS AND METHODS

2.1 Plant Materials

Liaoyuanduoli tomato (*Solanum lycopersicum*) seeds were sown on 28th February, 2013 and seeds were transplanted to a solar greenhouse of Shenyang Agricultural University with array pitch of 50 cm and row spacing 35cm. The plants were pruned to one branch and growing points were removed above the first cluster fruits. Other management was the same as the field management [10].

When the second flower of the first flower inflorescence was blossoming, the plants were labeled to mark the date. The whole tomato plants were treated with 50 or 100mmol/L ABA at six days before 20d，40d and 60d (mature stage) after fruit development. Spraying the plants with distilled water used as the control. Then the treated plants were subjected to low-temperature treatment for 3 days in phytotron. The day temperature was maintained at 25±1ºC, which 15ºC was used as control temperature in the night, and 12ºC for 11 hours every day was used as the treatment temperature (the treatment of short-term night sub-low temperature). There was one hour transition time and buffer time before pre-and-post treatment. The photoperiod was 12h. The light intensity was fifty to sixty thousand Lux. The relative humidity was 60%. Pericarp and dissepiments, pectinic were harvested at 20d, 40d and 60d after anthesis, frozen in liquid nitrogen, and stored at -80ºC for analysis of sugar concentration. Three repetition samples were collected.

2.2 Sugar Concentration and Content Determination

Approximately 2g fresh weight of frozen plant tissue was extracted three times in 80% ethanol (v:v). Soluble sugars were separated by Agilent1100 high-performance liquid chromatograph (HPLC) system. An amino column (Dikma) and a model 1100 refractive index monitor were used. The mobile phase was 80% acetonitrile and ultrapure water (80:20, v:v), the flow rate was 1.0mL/min and the temperature of the column was 35ºC. Sucrose, glucose and fructose were identified by their retention times and quantified according to standards. Angelient software was used for data analysis. The contents were assayed as described by Wang [11].

3. RESULTS

3.1 Effect of ABA on the Sugar Contents of Pericarp and Dissepiments under Condition of Short-Term Night Sub-Low Temperature

An increasing trend in fructose and glucose contents of pectinic and dissepiments tissues was observed during fruit development. At the early fruit development stage, T0 treatment group had the highest contents of fructose and glucose and was significantly higher than other groups, but no significant difference among other groups was found. At the middle fruit development stage, the fructose and glucose contents of each group showed no significant difference but were higher than the normal temperature control group. At fruit mature stage, low temperature treatment groups had lower contents of fructose and glucose than the normal temperature control group. TA2 treatment group had the lowest contents of fructose and glucose (Fig. 1).

A downward trend in sucrose content of pectinic and dissepiments tissues was observed during fruit development and the content was the lowest in ripening fruit. At the earlier fruit development stage, the sucrose content of TA1 and T0 treatment groups were significantly higher than TA2 and C0 treatment groups ($P<0.01$). At the middle fruit development stage, the sucrose content of T0 treatment group was significantly higher than other groups ($P<0.01$).

3.2 Effect of ABA on the Sugar Contents of Pectinic Tissues under Condition of Short-Term Night Sub-Low Temperature

An increasing trend in fructose and glucose contents of pectinic was observed in the normal temperature control group during fruit development. A falling first then increasing trend was observed in T0 treatment group. A smooth trend at the same level was observed in TA1 and TA2 treatment groups. At the earlier fruit development stage, T0 treatment group had the highest contents of fructose and glucose and was significantly higher than other groups (P<0.01), but no significant difference among other groups was found. At the middle fruit development stage, TA2 treatment group was slightly higher than other groups. At fruit mature stage, the low treatment groups were lower than the normal temperature control group, and the groups by ABA treatment under short-term night sub-low temperature were the lowest (Fig. 2).

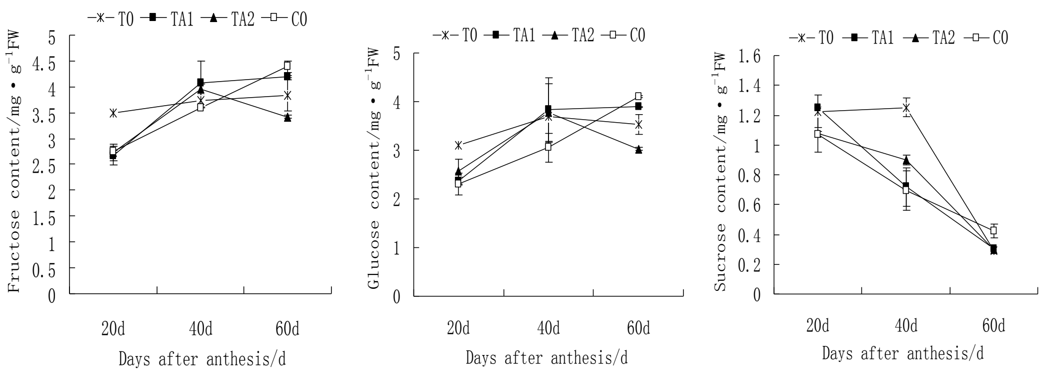

Fig. 1. Effect of ABA on the sugar contents of pericarp and dissepiments under condition of short-term night sub-low temperature

Note: T0-The lower temperature control group; C0-The normal temperature control group; TA1-50 mmol/L ABA treatment before short-tern night lower temperature group; TA2-100mmol/L ABA treatment before short-tern night lower temperature group

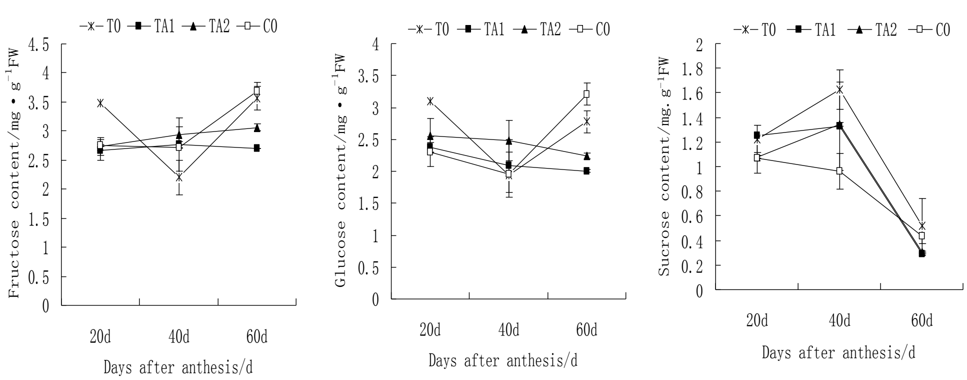

Fig. 2. Effect of ABA on the sugar contents of pectinic under condition of short-term night sub-low temperature

Note: T0-The lower temperature control group; C0-The normal temperature control group; TA1-50 mmol/L ABA treatment before short-tern night lower temperature group; TA2-100mmol/L ABA treatment before short-tern night lower temperature group

A downward trend in sucrose contents of pectinic was observed during fruit development in the normal temperature control group. An increasing first then falling trend was observed in lower temperature groups. The contents of sucrose in all groups were the lowest in ripening fruit. At the early fruit development stage, no significant difference among each group was found. At the middle fruit development stage, T0 treatment group had the highest content of sucrose, followed by TA1 and TA2 treatment groups. The normal temperature control group had the lowest content of sucrose. At fruit mature stage, all treatment groups were down to the lowest level and had no significant difference among each group.

4. DISCUSSION

During the cultivation, the protected tomato often suffers from the normal day-temperature and low night-temperature in northern China. The low temperature stress can cause poor plant growth and ultimately lead to fruit yield and quality reduction. Recent studies suggest that ABA can promote the cold resistance by protecting the membrane structure, maintaining the membrane function [12] and inducing cold resistance genes expression [13], thus avoiding the influence of the climate conditions on tomato fruits yield and quality. The studies also show that application of exogenous ABA could enhance the cold resistance in rice [14] and other plants [15]. Furthermore, Jian found that the optimum exogenous concentration of ABA can enhance the cold resistance but not inhibit growth [16]. Therefore, this research used ABA spraying the whole tomato on the sixth day before the treatment of lower temperature. When the ABA was completely absorbed, using the short-term night sub-low temperature to treat tomato.

The results showed that the fructose and glucose contents were an upward trend in the pectinic, pericarp and dissepiments and reached to the highest value at fruit mature stage. The sucrose content was a downward trend and reached to the lowest value at fruit mature stage. This suggested that the sucrose existed as the intermediates between photosynthetic products and quality products at fruit development stage. The fructose and glucose can determine fruit quality at fruit maturation stage. This result was consistent with Yu [17].

At the early fruit development stage, the contents of sucrose, fructose and glucose under short-term night lower temperature (without ABA treatment) were more than under normal temperature group in the pectinic, pericarp and dissepiments tissues. But through ABA treatment before short-term night lower temperature, the contents of three sugars were relatively low as the normal temperature group. Results indicated that lower temperature treatment without ABA could enhance the cold resistance by accumulating the soluble sugars. However, the resistance had been promoted by ABA treatment before short-term night lower temperature. It could fully ensure the normal growth and development of fruits at this point of lower temperature stress. The consumption of the soluble sugars is faster than normal temperature. So the contents of ABA treatment before short-tern night lower temperature groups were similar to the normal temperature control group. The contents of fructose and glucose were the predominant sugars at fruit mature stage，and the 50mmol/L ABA could enhance the accumulation of soluble sugars under the lower temperature.

The data also showed that the fructose content was relatively high in all fruit tissues. ABA treatment before short-term night sub-low temperature could increase the content of fructose. This result suggested that the application of exogenous ABA could not only ensure the normal growth and development, but also increase the contents of soluble sugar to improve the quality of ripening tomato fruits. The essential function and mechanism of action of exogenous ABA on fructose metabolism are still unclear and require further investigation.

5. CONCLUSION

In summary, this study explored the effect of the 50mmol/L or 100mmol/L ABA treatments before short-term night sub-low temperature on the sugar composition and contents. The results showed that application of ABA at 50mM consider the optimum concentration on improving the ability of resisting lower temperature in tomato fruits at the early development stage, improving the tomato fruit quality at mature stage, promoting transfer of soluble sugars to structure matter or storage matter.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Wang LJ, Li TL, Qi HY, Zhao MX, Hao WH. Effects of long-tern sub-low temperature on growth, development and dry matter distribution in tomato. Journal of Shenyang Agricultural University. 2006;37(3):300-303.
2. Yamauchi H, Kanayamay S. Changes in the amounts of the NAD-dependent sorbitol dehydrogenase and its involvement in the development of apple fruit. American Society for Horticultural Science. 1996;121(5):848-852.
3. Simona P, Stefano M, Franco F, Alberto B. Increase of ascorbic acid content and nutritional quality in spinach leaves during physiological acclimation to low temperature. 2009;47(8):717-23.
4. Zhao B, Pang SQ, Chen K, Fan XM. The chilling tolerance of processing tomato varieties during seed germination and seedling stage. China Cucurbits and Vegetables. 2007;(3):7-9.
5. Aryadeep R, Saikat P, Supratim B. Cross-talk between abscisic acid-dependent and abscisic acid-independent pathways during abiotic stress. Plant Cell Rep. 2013;32(7):985-1006.
6. Liu L, Cang J, Yu J, Wang X, Huang R, Wang J, et al. Effects of exogenous abscisic acid on carbohydrate metabolism and the expression levels of correlative key enzymes in winter wheat under low temperature. Bioscience, Biotechnology, and Biochemistry. 2013;77(3):516-525.
7. Ma YY, Zhang YL, Lu J, Shao HB. Roles of plant sugars and their responses to plant cold stress. African Journal of Biotechnology. 2009;8(10):2004-2010.
8. Rutten D, Santarius KA. Relationship between frost tolerance and sugar concentration of various bryophytes in summer and winter. Oecologia. 1992;91:260-265.
9. Sauter JJ, Wisniewski M, Witt W. Interrelationships between ultrastructure, sugar levels, and frost hardiness of ray parenchyma cells during frost acclimation and deacclimation in poplar (Populus Canadensis Moench robusta) wood. Journal of Plant Physiology. 1996;149:451-461.
10. Ding WJ. The field management technology of planting tomato. Yuan Yi Te Chan. 2013;48.
11. Wang L, Cui N, Zhao XC, Fan HY and Li TL. Accumulations of carbohydrate and the preliminary study of regulation of 14-3-3 protein on sucrose phosphate synthase (SPS) activity in two tomato species. Journal of Integrative Agriculture. 2014;13(2):358-364.

12. Bin L, Daisuke T, Yukio K and Matsuo U. Comparison of plasma membrane proteomic changes of Arabidopsis suspension-cultured cells (T87 Line) after cold and ABA treatment in association with freezing tolerance development. Plant and Cell Physiol. 2012;53(3):543-54.
13. Hossain MA, Lee YJ, Cho JI, Ahn CH, Lee Sk, Jeon JS. The bZIP transcription factor OsABF1 is an ABA responsive element binding factor that enhances abiotic stress signaling in rice. Plant Molecular Biology. 2010;72(4-5):557-566.
14. Chen SN, Guo ZH, Shen YG, Chen ZQ, Liu JM, Luo YL. The effect of exogenous ANA on the scavenging systems of oxygen free radical of plateau rice seedlings in chilling stress. Journal of Yun Nan University. 1996;18(2):167-172.
15. Ren XQ, Liu MQ, Chen GL, Wang R. Effect of exogenous ABA on chilling resistance in pepper. Journal of Chang Jiang Vegetables. 2009;8:30-32.
16. Jian LC, Sun LH, Sun DL. Changs in ATPase activity at plasmallemma and tonoplast during cold hardening of wheat seedlings. Acta Biologica Experimentalis Sinica. 1983;16:133-144.
17. Yu ZH, Cui N, Dong XF, Wang L, Zhao XC and Li TL. Effect of para-chlorophenoxyacetic acid on acid invertase gene expression and sucrose metabolism in tomato (*Solanum lycopersicum*) fruit. African Journal of Biotechnology. 2011;10(32):5950-5958.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history.php?iid=573&id=11&aid=5195