Image analysis as a tool for understanding tomato fruit growth under water deficit

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Keywords

Tomato fruit, cell number, cell size, pericarp cell layer, partial root-zone drying, deficit irrigation

Introduction

Water deficit is the main limiting factor affecting worldwide crop production. A better understanding of how soil water deficit affects plant growth is fundamental for development techniques to minimize the negative effects of water deficit. For cultivated plants, final fruit size is main component of quality and yield, and the studies of tomato fruit growth attracted a lot of attention of researchers. It is well known, for horticultural crops, that increasing water availability in soil increases the final fruit size with greater impact on cell expansion rather than cell division. The aim of this study was analyzing response of tomato pericarp anatomy to different soil water content. Cell size is a structural component of fleshy fruit such as tomato berry, contributing to important trait such as fruit size. We specifically addressed how cell size and setup of pericarp cell layers respond to irrigation treatments during fruit development. Only a few studies have addressed the impact of environment, genotype or environment by genotype interactions on tomato fruit growth and pericarp structure (Bertin, 2005, Cheniclet et al., 2005, Fanwoua et al., 2012). However none of these studies analyzed the pericarp histology by combining quantitative (digestion of the tissue with cell wall degrading enzymes) and qualitative (tissue sectioning) methods. These methods provide data such as cell size, which makes the greatest contribution to the final fruit size.

Materials and Methods

Tomato plant, cv. Ailsa Craig was grown from seed in a growth chamber under full irrigation (FI), partial root zone drying (PRD), 70% of water supply than in FI and defficit irrigation (DI), 60% of water supply than in FI and deficit irrigation. For histological analyses, fruits were harvested at 10 time interval during development, from 3 to 55 daa (days after antesis). Tomato pericarp mean cell area was measured using the method of cell separation by pectinase solution (Bertin et al. 2002) and histological analysis. Slides for light microscopy were made according to standard paraffin procedure (Ruzin, 1999). Pericarp sections were observed with a Leica DMLS stereomicroscope and images were acquired with a Leica DC300 digital camera. For mean cell size measurements we used the public domain Image J software (Rasband, 1997-2009), using the “analyze particles” tool, after manually adjusting the segmentation threshold.

Results and Discussion

Number of cell layers increased rapidly from 3 to 12 daa and remained stable until ripe stage in FI. According to cross section analysis at 12 daa in wild type, fewer cell layers

were generated in PRD conditions (19) compared to FI (23) and even fewer in DI conditions (15), and these differences were maintained, to a lesser extent, until the ripe stage. Reduction in cell layer number noted during cell division has resulted in thinner pericarp, probably as consequence of cell size and number reduction under PRD and DI as noted by pericarp cell digestion method. To determine which of the pericarp layers were the most affected by the deficit irrigation treatments, we compared for each of the cell layers generated before 5 daa, kinetics of its cell growth in PRD and DI comparing with full irrigation. Whatever the irrigation treatment, the largest contribution to whole pericarp size was provided by layers E3, E4 and I3, followed by the first generated layers E2a, E2b, I2a and I2b. The negative effects of reduced irrigation (PRD or DI) on cell size appeared late in the course of development and reached maximum at the ripe stage for most outer cell layers (e.g. E3, E2a, E2b, E2c).

Conclusion

Detailed anatomical analysis of tomato pericarp under deficit irrigation treatments (PRD and DI) indicates negative fruit response comparing to FI. Comparing with pericap cell digestion method, tissue sectioning analysis gave detailed view of deficit irrigation impact on whole pericarp development, its cell layers and cell size. According to tissue sectioning analysis pericarp thickness reduction was observed in cell size reduction in outer pericarp and cell layer number in inner pericarp under PRD and in the most pericarp cell layers under DI treatment but without differences in cell layer number. Results indicate that the type of anatomical analysis could provide more reliable answers on the problems related to reactions of cell division and expansion processes, which enable adequate fruit development and yield under water deficit.

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