Scientia Horticulturae 201 (2016) 362–369

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Sugar and phenolics level dependent on the position of apple fruitlet in the cluster

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ARTICLE INFO

Article history:
Received 16 November 2015
Received in revised form 28 January 2016
Accepted 2 February 2016
Available online 16 February 2016

Keywords:
Metabolites
'Golden Delicious'
UHPLC–MS
King flower
Lateral fruitlets
Natural thinning

ABSTRACT

The abscission process and the modifications in the levels of selected metabolites were monitored on 'Golden Delicious' apples in a two-year study. Individual sugars were analyzed using HPLC-RI and individual phenolics by UHPLC–PDA–MS. Fruitlets from lowest positions were most likely to shed. Moreover, fruits from the position nearest to the king fruitlet often dropped. The experiment initially focused on the comparison of sugar and phenolic contents among fruitlets within individual apple clusters. Central (king) fruitlets are bigger in comparison to lateral fruitlets and differ to a certain degree in the contents of metabolites. In general, the results indicate that phenolic contents are higher in fruitlets more susceptible to abscission but the level of sugars does not differ.

1. Introduction

In apple trees, intensive shedding of young fruits (fruitlets) appears in a process termed the 'June drop' even in the Southern hemisphere. This self-regulatory mechanism essentially singles out fruitlets which can potentially develop into fully mature fruit and sacrifices those which cannot be supported until harvest. The reason is well-defined but the mechanisms of abscission are not yet fully understood. There are two theories (Untiedt and Blanke, 2001) which explain apple fruitlet abscission. The first concept is based on insufficient supply of assimilates to selected fruitlets and the second on hormonal regulation of advanced shedding of young fruit, which are prone to diminished fruit growth in later developmental stages.

Although Bangerth (2000) reported a number of confirmations in favor of the hormonal theory, the assimilatory theory is at least partly responsible for fruit abscission. The glucose level in the pedicel of the developing fruit may be a factor in the control of the abscission process of young apple fruit (Beruter and Droz, 1991). Intense fruitlet shedding has also been linked to tree shading and poorer availability of assimilates. For example, Stopar et al. (2001) and Dash et al. (2012) reported that reduced canopy light interception during certain periods of fruitlet development (shortly after flowering) stimulates apple fruitlet abscission. Moreover, shading results in changes in the expression of carbohydrate metabolism-related genes (Dash et al., 2012).

Sugars not only fuel cellular carbon and energy metabolism but also play important roles as signalling molecules. In plants, different sugar signals are generated by photosynthesis and carbon metabolism in source and sink relationships to modulate growth, development, and stress responses (Rolland et al., 2006).

Phenolics can be synthesized as an answer to various types of stress (Slatnar et al., 2012; Treutter, 2001; Zupan et al., 2015). Induced synthesis of phenolics and increased activity of phenylalanine ammonia lyase (PAL), major enzyme in their biosynthetic pathway, is affected by stress situations in apples (Treutter, 2001) Abscission may be regulated by a highly programmed developmental process and additionally promoted by environmental stress (Taylor and Whitelaw, 2001).

During the process of abscission, all fruitlets are not equally prone to abscise. Central/king fruitlets habitually remain in the cluster while fruitlets from lateral positions drop (Bangerth, 2000; Jakopic et al., 2015). In the correlative dominance of organs, auxins (particularly IAA) are important components because dominant organs always export more IAA (Bangerth et al., 2000). Beside this, the natural dominance of central fruitlets over lateral ones is reflected in an increased supply of sugars to the latter (Celton et al., 2014). Several studies compared the abscission process among fruitlets within individual corymbs (inflorescences). In some studies, authors grouped lateral fruitlets to small, medium and big

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http://dx.doi.org/10.1016/j.scienta.2016.02.011
0304-4238/

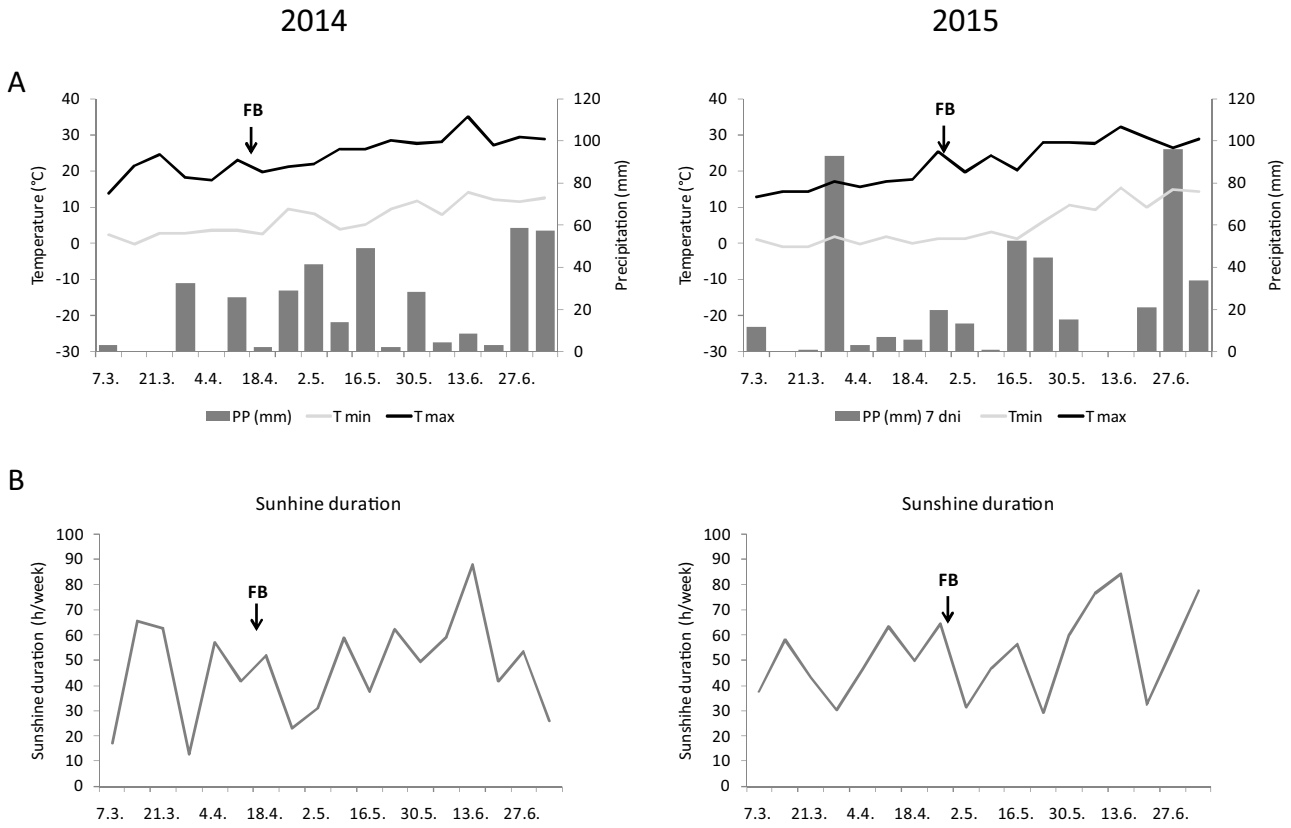

Fig. 1. Basic meteorological data from the beginning of March till the end of June in 2014 and 2015.
A—Minimal (grey line) and maximal (black line) daily temperature (°C) and precipitations (mm).
B—Sunshine duration (h/week).
Arrows indicate the time of full bloom (FB) in each year.

(Celton et al., 2014; Eccher et al., 2014), or only compared central fruitlet to lateral fruitlets, irrespective to their position in the cluster (Botton et al., 2011).

In an apple tree, spur leaves and a cluster of flowers develop from generative buds. Flowers, and later fruitlets, are arranged in the form of a corymb and a comparison among fruitlets from different positions along the peduncle seems reasonable.

The magnitude of fruitlet abscission depends on its position in the corymb (Bangerth, 2000), sink strength (Blanke, 2009) and environmental conditions (Untiedt and Blanke, 2001), particularly drought and shade (Greene, 2002) the latter either in form of clouds or artificial shading (Dash et al., 2012).

Therefore, the aim of this study was to compare the contents of selected metabolites in fruitlets from different positions in the cluster. Sugars were analyzed because of their reported influence on shedding. In addition to basic metabolic profile, phenolic compounds were also investigated. Their potential influence on the shedding process has been discussed as the content of specific compounds is known to increase as a result of many types of stress (Dixon and Paiva, 1995). To our best knowledge, abscission process has not been evaluated from this perspective (Bangerth, 2000; Greene, 2002; Untiedt and Blanke, 2001). Detailed knowledge on the mode of operation of the natural shedding process will help to improve the thinning practice in apple orchards.

2. Material and methods

2.1. Plant material

The study was carried out in growing seasons 2014 and 2015 at the experimental orchard of Biotechnical Faculty in Ljubljana (latitude 46.05 N, longitude 11.47 E, altitude 289 m). Rows are N-S oriented and the space between the rows is covered with grass. The orchard is not equipped with hail nets or an irrigation system. Key meteorological data are summarized in Fig. 1. Apple trees cv. 'Golden Delicious', grafted on M9 rootstock, planted in the year 2002 at a distance of 3.5×1.2 m and trained to a solaxe training system were selected for the experiment. The orchard is maintained according to the integrated production method.

2.2. Sampling

During the shedding process in the early stages of fruit development, twenty random clusters (each cluster represent a single replication) were harvested every week (from 27 days after full bloom (DAFB) till 62 DAFB) in 2014. In this experimental year, 248 flower clusters were analyzed. The positions of shedded as well as attached fruitlets were marked in each cluster, and the diameter of the fruitlets and their weigh were measured. Fruitlets were classified according to the positions from central (K1) to basal (L2–L6) fruitlets as shown in our previous paper (Jakopic et al., 2015). All fruitlets from harvested clusters were used for chemical analysis.

Clusters with 5 flowers were most frequent in 2014. Therefore, the analysis of the abscission process (the frequency of shedding at each individual position) only focused on 5-flowered apple clusters in 2015. Forty random branches, which averagely developed five 5-flowered clusters, were labeled and the abscission process was monitored in all clusters (the number of shedded fruitlets as well as their positions) every two weeks. At the same sampling dates twenty random 5-flowered clusters were harvested for laboratory analysis: fruitlet weight, diameter and the content of individual