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PREDICTION OF THE HARVESTING TIME FOR FOUR APPLE CULTIVARS ON THE BASIS OF BEGINNING OF FLOWERING AND ATTAINING OF T-STAGE OF FRUITLETS AND DEPENDENCE OF DIAMETER OF FRUITLETS AT T-STAGE AND FRUITS AT RIPENING STAGE

Research note

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ABSTRACT

The growth of fruits was evaluated during three growing seasons on four apple cultivars 'Angold', 'Jonagold', 'Rubinola' and 'Topaz'. The follow-up period was defined by the start of flowering, the date of attaining of T-stage by fruitlets and the start of optimal harvest ripening, which for each cultivar was determined on the basis of starch index, flesh firmness and soluble solids. The close relationships were detected between time of attaining the T-stage and term of harvest maturity for three of four studied cultivars.

Key words: fruit growth, T-stage of fruitlets development, time of ripening

INTRODUCTION

Optimum harvest term is fundamentally a prerequisite to maximize economic returns from the production of all fruit crops. A correct set of optimal harvest time is especially important for late-ripening apple cultivars, as the fruits from these cultivars are primarily used for long-term storage. If the harvest is too early, the economic losses are significant because fruit weights are needlessly smaller. The fruits harvested too early have inferior consumption quality, have less attractive coloration and their taste is worse on the basis of lower content of sugars and other nutritious solids. These fruits are more susceptible to bruising, their skin fades too early and they suffer for skin blight, which more often occurs during their storage. On the other hand, if the harvest is too late, growers are frequently afflicted by high economic losses due to fruit fall, fruits are more often devalued by physiological disorders and have a shorter shelf life (Braun et al. 1995; Ingle et al. 2000; Juan el al. 1999; Eccher Zerbini et al. 2003). Determination of the correct harvest window plays a key role in optimizing the relationship between the total yield of apples and their appropriate storage conditions during the post-harvest period (Rutkowski et al. 2008; Vielma et al. 2008).

The start time of fruit harvest maturity is a primary characteristic of each cultivar and is closely connected with climatic conditions of the location. It fluctuates yearly depending on weather conditions and is influenced by the rootstock used, soil conditions and soil treatment. Beside these, several other factors may be involved such as fruit-set level, tree healthiness, tree canopy management, irrigation applied, etc. For a determination of optimum harvest maturity in late-ripening apple cultivars, one must evaluate the state of starch break up (amyloid test), flesh firmness typical for the given cultivar and content of refractometric dry matter (Lafer 1998; Lötze & Bergh 2004; Alegre et al. 2006).

For growers, besides the determination of the optimal harvest time, the long-term prediction of the entry into this stage is also important. For the

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prediction of harvest maturity onset, most often utilized is the knowledge of number of days from full flowerage (DAFB) into harvest time, which is typical for every cultivar and growing region or, length of time from development of T-stage on young fruitlets to the start of their harvest maturity. In the T-stage the fruit bottom part and stalk are in the position forming a shape similar to letter T (Blanpied & Silsby 1992; Jager 1995).

For a determination of optimum apple harvest date, measurements of firmness, soluble solid concentration and starch degradation index (the Streif index) were recommended (Streif 1996; DeLong et al. 1999). The Streif index and certain changes of bio speckle activity seems to be the most useful for the best indicators or assessment of harvest windows in apples (Skic et al. 2016). Non-destructive techniques based on visible near-infrared hyperspectral imaging for measuring of soluble solid content and firmness in apples was recently developed in China, which might be also utilized for discerning optimal start of harvest (Zhou 2014). Also harvest quantity is important because it has close connection with harvest organization and planning of crop distribution. The most utilized is here the size of fruitlets in the phase of 50 days after full bloom (Costa et al. 2004; Corelli Grappadelli 2003).

The aim of this paper was to define an adequate method for prediction of term of harvest for four apple cultivars based on typical fruit developmental stages and a correlation between diameter of fruitlets at T-stage and fruits at harvest ripening.

Our research took place during the period 2013–2015, and in the study four cultivars were used, which were grown in an experimental orchard established in 1999, located at an altitude of 290 m above mean sea level. Trees on M 9 rootstock were planted in spacing 4 × 1 m and trained in slender spindle form supported by bamboo poles 2.4 m long kept in a vertical position by means of wires. The climatic conditions of the place are characterized by a mean annual temperature of 8.1 °C and rainfall around 650 mm. The soil conditions were brown earth, sandy clayish, medium deep on clayey subsoil. The standard agronomical practices were applied using mulched grass between tree rows and herbicidal strips under trees.

The study included four cultivars: ‘Angold’, for which the harvest time is just before ‘Golden Delicious’ and fruits are storable till April; ‘Jonagold’, for which the harvest time is very similar to ‘Golden Delicious’; ‘Rubinola’, which ripens 10 days before ‘Golden Delicious’ and ‘Topaz’, for which fruits mature about 1 week after ‘Golden Delicious’.

Annually, for the evaluation of each cultivar, 8–10 trees were chosen for their sufficient flower set. On these trees, onset dates of phenological stages were recorded starting from the date of the beginning of flowering and then the timing when fruitlets attained their T-stage. In this phase, twice 40 fruitlets (top and side ones in the inflorescence) were marked and their diameters were thereafter measured using a digital slide gauge. These measurements were repeated approximately in month intervals.

The start of fruit picking maturity was monitored using a starch test, followed by measurements of flesh firmness and refractive index of dry matter. The start of this stage for each cultivar was defined by our previous evaluation of these parameters with the maximum fruit storage life. The hand penetrometer (Mock-up FT 327, producer R. Byrce, Alfosine, Italy) was used for measuring flesh firmness (in $kg \cdot cm^{-2}$). The digital refractometer HI 96801 (HANNA Instruments, USA) was used to record the refractive index of dry matter content given in % of Brix. At the time of harvest maturity, 10 fruits of each cultivar were always evaluated. For the evaluation of starch content, a 1–9 rating scale was used where a value of 1 corresponded to its maximum and 9 the minimum. The optimum dates of harvest maturity start times were determined by extrapolation of measured values according to common recommendations. Analysis of variance and Fisher-protected LSD test at $p = 0.05$ were used for statistical description of the results. The standard regression analyses were applied among selected characteristics.

The season of flowering was the earliest in 2014 and the latest in 2015 (Table 1). Time to reach stage T was not correlated with flowering. The attaining of T-stage had different pattern that beginning of flowering. The fruitlets did not develop earliest in 2013.

Table 1. The main stages of fruit development of four cultivars

Cultivar	Year	No. of days From Jan. 1st to flowering beginning	From Jan. 1st to T-stage of fruitlets	From Jan. 1st to harvest ripening	From flowering beginning to harvest ripening	From T-stage of fruitlets to harvest ripening
‘Angold’	2013	114	154	273	159	119
	1014	110	164	281	171	117
	2015	116	169	287	171	118
mean		113	162	280	167±6.9 SD	118±1.0 SD
‘Jonagold’	2013	112	149	266	154	117
	2014	110	166	277	162	111
	2015	115	157	275	160	118
mean		112	157	273	159±4.2 SD	115±3.8 SD
‘Rubinola’	2013	112	148	259	147	111
	2014	108	163	265	157	102
	2015	115	155	269	154	114
mean		112	155	264	153±5.1 SD	109±6.2 SD
‘Topaz’	2013	114	148	272	158	124
	2014	110	160	277	167	117
	2015	119	164	283	164	119
mean		114	157	277	163±4.6 SD	120±3.6 SD

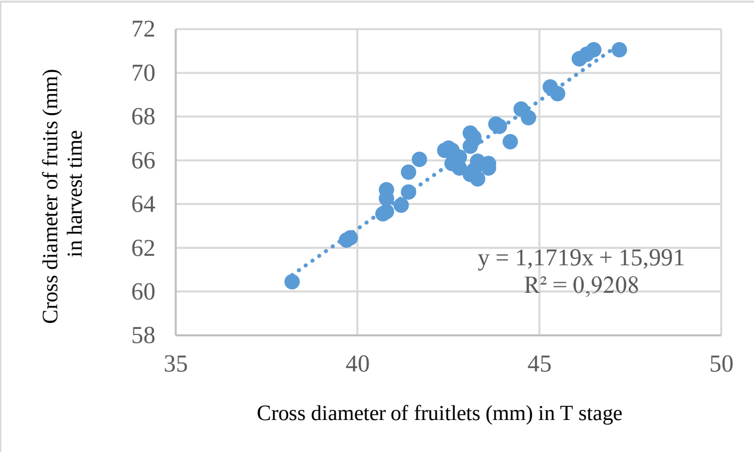

Fig. 1. Relationship between fruitlet size in T–stage and fruit diameter at harvest time in ‘Angold’ evaluated 2013

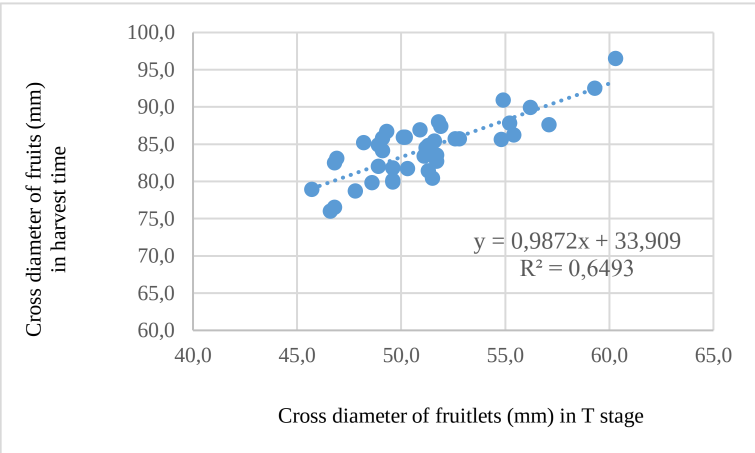

Fig. 2. Relationship between fruitlet size in T–stage and fruit diameter at harvest time in ‘Topaz’ evaluated 2015

The sequence of terms of start of fruit harvest maturity changed similarly as T-stage but differently from the beginning of flowering. The ripening was earliest in 2013 and in 'Rubinola'. Standard deviation values from means for three years were lower for number of days from attaining T-stage and harvest ripening for three cultivars. Only SD of 'Rubinola' was lower for number of days from beginning of flowering to harvest ripening. Therefore, the level of the prediction on the base of the T-stage seems to be more reliable than on the basis of flowering.

The relationship between the diameters of fruitlets in the T-stage and fruits attained at harvest maturity ranged in tightness of relation among that calculated for 'Angold' in 2013 (Fig. 1) and at the opposite extreme for 'Topaz' in 2015 (Fig. 2).
Ours results indicate that the number of days counted since start of flowering stage is less precise for setting of optimal start of harvest time of given cultivar possibly due to more weather deviations in the early spring at flowering than in the late spring at T-stage. More precise for prediction of the harvest term offers term of onset of fruitlets T-stage at least for the cultivars 'Angold', 'Jonagold' and 'Topaz'. Also, close relationships between diameters of fruitlets in the T-stage and size of fruits attained at harvest maturity led to advice to use the onset of T-stage for prediction of the harvest time and yield.

Fig. 3. Apple fruitlets at T-stage

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