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Growth Rate of Apple Fruits as a Method of Predicting Their Abscission

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Abstract: A study on the fruit growth rate of apple cultivars Golden Delicious and Granny Smith as observed from day 5 to day 25 after petal fall revealed that a decrease in growth rate and fruit growth break can be used as a relatively reliable method for the early evaluation of natural fruit drop.

Fruit growth to a diameter of about 5 mm was slow (about 1 mm/day), and subsequently, from a diameter of 5 to 15 mm, the growth was more rapid and almost linear (mean value being 5.5 mm/day).

The fruits experiencing growth break during the first shed period reached a size of 4.5-5.5 mm, and those whose growth broke during the second shed period (June drop) were 8-12 mm in size. At least 4 days elapsed between the moment of growth break and fruit dropping.

A decrease in fruit growth rate can serve as a fairly reliable indicator of approaching fruit drop at a stage when the fruits have reached a size of 5 mm. In fruits that are about to drop, the growth break occurs 2-4 days after the growth rate decrease down to 50% of the growth rate of surviving fruits.

Key words: apple, fruits, growth, abscission.

Introduction

Apple flower and fruit shed results from activation of the cells of the abscission layer, located between the fruit peduncle and bearing branch base

(Jackson 2003). The prevailing opinion today is that flowers and young fruit have a natural shedding tendency and that their survival on the fruit is a result of a specific hormonal stimulus originating most probably from young seeds (Luckwill 1953, Denis 1967, Abbot 1984).

Natural thinning of apple flowers and young fruits occurs during the first 4-6 weeks after full bloom (Ferree and Warrington 2003). According to Murneek (1954), it consists of four waves. The first wave includes shedding of the flowers where fertilization did not take place. In the second wave, usually overlapping with the first one, young fruits at the 2-4 endosperm nuclei stage are shed, and in the third one, the fruits having endosperm and 16-cell embryos are shed. The fourth wave includes shedding of the fruits with completely developed endosperm and embryo at different stages of development. The third and the fourth waves of natural fruit abscission generally overlap and occur towards the end of May and at the beginning of June, being manifested as a June drop. Following the June drop, the fruits become considerably more resistant to the effect of unfavourable factors and drop very little up to the time of fruit maturity (Jackson 2003).

Timely and adequate evaluation of the fruit set or of the degree of natural fruit abscission can serve as an essential precondition for an efficient use of chemical thinning. An early estimation of the degree of natural fruit abscission can serve as a more favourable starting point for defining an adequate model and rate of thinning (Green 2002). Green and Krupa (1999) suggested that "it is difficult to determine initial set until well after petal fall". A number of authors have examined the possibilities of establishing an optimal method of estimating the fruit abscission rate (Byers *et al*. 1991, Marini 1998, Green and Krupa 1999, Ward and Marini 1999, Kulina *et al*. 2009).

Very few detailed examinations have been made on the physiology of fertilization and abscission of fruits. The objective of this paper is to show the growth rate of young apple fruits at the stages when their natural abscission takes place. The paper is also aimed at an early estimation of the fruit growth break on the basis of diameter change and it can serve as a starting point for defining an efficient crop control model in apple.

Material and Methods

The investigations were conducted in 2005 and 2006, at Zubin Potok (Kosovo and Metohia), on Gold Delicious and Granny Smith cultivars, both on M9 rootstock. Each cultivar was represented by three trees, aged 11 years. The trees were trained to SolAxe.

Ten normally developed inflorescences collected from different canopy parts were, having been randomly chosen, marked on each selected tree, at the petal fall stage. A single central and a single lateral flower were left in each inflorescence, and the rest of the flowers were removed. The labelled infruitescences of the fruitlets were marked by oil colour for fruit diameter measurements to be made. This was a necessary step in eliminating measurement deviations due to the fruit asymmetry. The measurements were made from day 5 to day 25 after full bloom, at a 2-day interval, during morning hours. Measurements of the tree fruit diameter were made using a vernier caliper with

the least count and precision of 0.1 mm. In 2005 the first measurings in Granny Smith were made on 4 May and in Golden Delicious on 6 May, and in 2006 on 2 May and 5 May, respectively.

The obtained data were subjected to the "StatistiXL 1.8" statistical analysis programme.

Results and Discussion

The period during which the fruit growth rate was observed can be divided into two stages. At the first stage with the fruit size of 5 mm, fruit growth between two consecutive measurements ranged from 0.1 to 0.5 mm (an average of 0.1 mm per day). At the second stage with the fruit size above 5 mm, the fruit growth over the two-day period was more intensive, varying from 0.5 to 1.7 mm (an average of 0.55 mm per day). The studies by Denne (1960, 1963) on Cox's Orange Pippin cultivar showed a typical single–sigmoid growth curve, which could be divided into three phases: a slow increase in weight for the first 6–12 days after pollination, a phase of a rapid exponential increase lasting for 3–4 weeks, and a phase of progressive slowing of the rate of increase leading up to harvest. However, Schechter *et al*. (1993a, 1993b) defined the pattern of fruit growth of 4 apple cultivars (McIntosh, Delicious, Empire and Idared) as consisting of two linear phases. The first of these is very low growth, lasting about 40 days, and the second of steady linear growth at a rate of 0.21–0.28 g dry weight per day up to harvest.

Notwithstanding the fact that the effect of temperature on the fruit growth rate was not investigated in greater detail, fruit growth was observed to be more intensive during warmer than during colder days. This observation is in accordance with a controlled environment study by Warringron *et al*. (1999) which has shown that warm temperatures early in the season stimulate fruit growth. The effect of cultivar on the fruit growth rate was exerted, but it was low, and hence, negligible in terms of the aim of the examinations. The differences in fruit growth rates over the research years can also be neglected.

Our investigations suggested that a decrease in the fruit growth rate can serve as a reliable indicator of their approaching dropping, particularly at the later stage of development, when diameter changes are greater. Each fruit with an equal diameter in three consecutive measurements (a 4-day period) broke. If an equal diameter was determined in two consecutive measurements, this would clearly indicate a fruit growth break in fruits larger than 5 mm, whereas an error occurred in the fruits lower than 5 mm in 4.6% of cases. Green and Krupa (1999) reported that observation of the apple fruit growth rate can serve as an important indicator of their further behaviour. Also, Marini (1998) alleged that growth cessation is used by commercial apple growers to assess potential fruit drop before and after thinner applications.

In all cases at least 4 days elapsed between the moment of growth break and fruit dropping, while it took even more than 10 days after the growth break for certain fruits to drop. According to Byers *et al*. (1991), young apple fruits stop growing several days before abscission.

Without taking into consideration the non-fertilized flowers, the growth break of the fruits dropping at the first shed period occurred when the fruit size

reached about 4.5-5.5 mm. In fruits which dropped during the June drop, the growth break occurred when the fruits had reached the 8-12 mm diameter. Generally, the fruit growth rate in the first ten days after petal fall decreased, and afterwards, increased and became almost linear, if no excessive temperature variations took place. The most intensive growth, particularly in the second part of the research period, was recorded with the non-dropping fruits or the fruits which were likely to have set (Figure 1), with the fruits that dropped during the June drop, whereas diameter growth in the fruits that started to drop early did not exceed 0.3 mm in any one case during the two consecutive measurements.

Up to the fruit size of 5-6 mm, the growth rate of fruits that were about to drop in the 3rd and 4th drop waves (June drop) was most similar to the growth rate of the fruits persisting up to the period of harvest. It was only after the fruits had reached the size of more than 5-6 mm that the growth of fruits that were about to drop started to decrease, compared to the growth of persisting fruits.

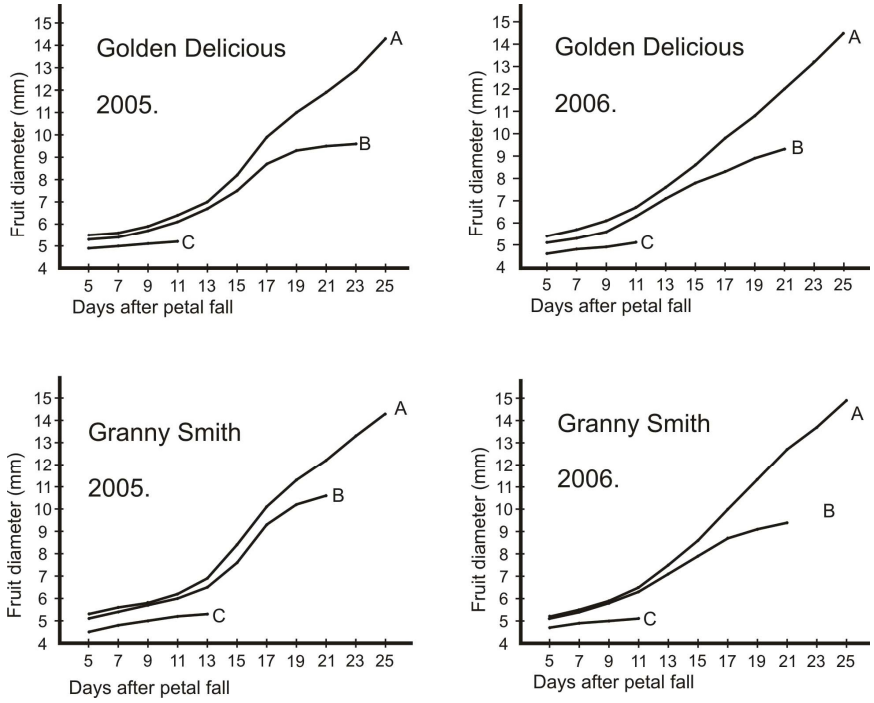

Fig. 1. Growth rate of different categories of apple fruits as observed from day 5 to day 25 after petal fall. A) Fruit that will persist to harvest; B) Fruit dropped in the second (June shed) period; C) Fruit dropped in the first shed period (during two weeks after petal fall).

Tab. 1. Growth rate of different categories of apple fruits as observed from day 5 to day 25 after petal fall. Data were analyzed by a repeated measures analysis of variance and all changes in fruit diameter between measurement dates were significantly different ($P<0.05$).

Cv.	Categories of fruits	Year	Days after petal fall										
			5	7	9	11	13	15	17	19	21	23	25
Golden delicious	Fruit dropped in the first shed period	2005	4.9	5.0	5.1	5.2	Growth is stopped						
		2006	4.6	4.8	4.9	5.1	Growth is stopped						
	Fruit dropped in the second shed period	2005	5.3	5.4	5.7	6.1	6.7	7.5	8.7	9.3	9.5	Growth is stopped	
		2006	5.1	5.3	5.6	6.3	7.1	7.8	8.3	8.9	9.3	Growth is stopped	
	Fruit that will persist to harvest	2005	5.5	5.6	5.9	6.4	7.0	8.2	9.9	11.0	11.9	12.9	14.3
		2006	5.4	5.7	6.1	6.7	7.6	8.6	9.8	10.8	12.0	13.2	14.5
Granny Smth	Fruit dropped in the first shed period	2005	4.5	4.8	5.0	5.2	Growth is stopped						
		2006	4.7	4.9	5.0	5.1	Growth is stopped						
	Fruit dropped in the second shed period	2005	5.1	5.4	5.7	6.0	6.5	7.6	9.6	10.2	10.6	Growth is stopped	
		2006	5.3	5.4	5.7	6.3	7.1	7.9	8.7	9.1	9.4	Growth is stopped	
	Fruit that will persist to harvest	2005	5.2	5.5	5.8	6.2	6.9	8.4	10.1	11.3	12.2	13.3	14.7
		2006	5.2	5.5	5.9	6.5	7.5	8.6	10.0	11.3	12.7	13.7	14.9

According to Green *et al*. (2005), the first measurable response signalling that a fruit will abscise is a reduction in growth rate, and the fruit growth rate decrease to less than 50%, when compared to the category of fruits with the highest growth rate, can serve as a reliable indicator for early estimation of their approaching dropping.

In this way, the estimation of the fruit setting degree can be made several days earlier than when using the fruit growth break criterion. As the fruit diameter growth in the first ten days after petal fall is low (averaging 0.1 mm per day), a growth rate decrease in the shed period is not a reliable indicator of their dropping. At the higher fruit growth rate (of about 0.5 mm per day), a decreasing fruit growth rate may serve as a successful method for their further estimations. Our investigations showed that the growth rate decrease in the fruits about to drop to 50% of the growth rate of the fruits to survive occurred 2-4 days before their complete growth break. It can be assumed that if only central fruits in infruitescences were used in fruit growth comparisons, an even earlier and more reliable fruit set indicator would be obtained.

Conclusion

The two-year study on the apple fruit growth rate as observed from day 5 to day 25 after petal fall suggests the following:

- fruit growth starting from diameter of about 5 mm is almost linear and sufficiently rapid to serve as a reliable indicator of the approaching fruit dropping;
- four days at least will elapse between the moment of growth break and fruit dropping;
- the fruit growth break in the first and second shed periods generally takes place when the fruits reach the size of about 4.5-5.5 mm, and 8-12 mm, respectively;
- the fruit growth rate decrease down to 50% of the growth rate of fruits to survive occurs 2-4 days prior to growth break of fruits that are about to drop.

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DINAMIKA RASTA PLODOVA JABUKE KAO METOD PROGNOZE NJIHOVOG OTPADANJA

- originalni naučni rad -

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Rezime

Ispitivanje dinamike rasta plodova sorti jabuke zlatni delišes i greni smit u periodu od 5 – 25 dana posle otpadanja čašičnih listića pokazalo je da smanjenje i prestanak rasta plodova može da se koristi kao relativno pouzdan metod za ranu procenu njihovog prirodnog otpadanja. Rast plodova do prečnika 5 mm spor je (oko 1 mm dnevno), a kasnije, od 5 – 15 mm, rast je brži i skoro linearan (srednja vrednost iznosi 5,5 mm/dan). Plodovi koji su prestali da rastu u prvom periodu otpadanja dostigli su veličinu od 4,5 do 5,5 mm, a oni koji su prestali da rastu u drugom periodu otpadanja (junsko otpadanje) 8—12 mm. Od momenta prestanka rasta do otpadanja plodova prođe najmanje 4 dana. Smanjenje tempa rasta plodova može da posluži kao prilično pouzdan indikator njihovog skorog otpadanja u fazi kada plodovi dostignu veličinu od 5 mm. Kod plodova koji će da otpadnu, prestanak rasta nastaje 2 – 4 dana posle smanjenja tempa njihovog rasta na 50% tempa rasta plodova koji će da se održe.