International Journal of Horticultural Science 2006, 12 (2): 69–75
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Rootstock effects on fruit drop and quality of 'Arlet' apples

Racskó, J.[1], Nagy, J.[1], Nyéki, J.[1], Szabó, Z.[1], Budai, L.[1], Zaheri, S.[1] & Soltész, M.[2]

[1]*University of Debrecen, Institute for Extension and Development, H-4032 Debrecen, Böszörményi st. 138. Hungary, E-mail: racsko@agr.unideb.hu*
[2]*College of Kecskemét, Faculty of Horticulture, Fruitgrowing Department, H-6000 Kecskemét, Erdei Ferenc tér 4–6. Hungary*

Summary: The aim of this study is to investigate the effect of different growth inducing rootstocks on fruit drop of apple. This research was conducted for 3 years at Nagykutas, Western Hungary on apple cv. 'Arlet'. For the experiments, 3 different growth inducing rootstocks were choosen: M.9 (weak), MM.106 (moderate) and crabapple seedling (strong). There were 3 fruit shedding periods on the trees grafted M.9 and MM.106 rootstocks, but in the case of crabapple seedling, only 2 were found. The measure of fruit drop was closely related to seed count of fruits; seed number was the lowest, fruit drop was the highest. The lowest seed number was counted in fruits from trees on crabapple sedling. Seasonal changes of leaf:fruit ratio mainly depended on shoot growth and fruit drop. The rise of the curve of leaf:fruit ratio was very important during the first phase of fruit development, in especially at the end of June and in the beginning of July. The cause of this is that first and second periods of fruit drop appeared during this term. The rise of the curve was important in the beginning of June and the end of July on crabapple seedling. Decreasing tendency of quality parameters was found of fruits from trees on M.9, MM.106 and seedling rootstocks, except flesh firmness which was the highest in fruits from trees on crabapple seedling.

Key words: apple, fruit set, fruit drop, seed number, leaf:fruit ratio, fruit quality, skin color, flesh firmness, soluble solids content

Introduction

It is commonly known, that not all fruits set during the blooming period will attain full maturity because of being abscised prematurely. Fruit drop is essentially the expression of a kind of autoregulation mechanism in plants, which restores the physiological balance of the tree (*Szalay*, 2003).

The literature dealing with fruit drop mentioned 2-4 dropping periods but three of them are generally recognised as important (*Dorsey*, 1919; *Bradbury*, 1929; *Harrold*, 1935; *Luckwill*, 1953; *Kester & Griggs*, 1959). Some of the authors (*Dorsey*, 1919; *Bradbury*, 1929; *Bowman*, 1941; *Gardner* et al., 1952; *Kobel*, 1954) split the first shedding into two parts, therefore established four instead of three waves. The number of waves and their dynamics also depend on the extent of fruit set. A high rate of fruit set results in more waves of fruit shed. The first, purifying shed is sometimes hardly distinguished from the second one called June drop. Natural fruit drop and auxin-production are functionally related (*Luckwill*, 1953). Depending on the variety, June drop may prevail against the preceding purifying shed (*Blasse*, 1974). The latter case is expected in varieties, which develop the persistent separation tissue, slowly (*Soltész*, 1982). In those varieties, oversetting may be imminent and the use of chemical thinning, higher doses could be used safely (*Soltész*, 1997).

The most critical period of fruit drop is the first, the purifying shed. Its extent depends on variety, season and growing site. The higher the initial fruit set the less exact estimates are possible for predicting the yield (*Roemer*, 1969). After petal fall, temperatures of the 5–7 weeks' interval are crucial for fruit set. Within that period, first the cool spells, later the supraoptimal heat may cause severe drop (*Lu & Roberts*, 1952; *Grauslund & Hansen*, 1975).

The purifying shed depends, mainly, on the extent of fertilisation, on the number of flowers fertilised, whereas the June drop is related rather to the bearing capacity of the tree. After the first (purifying) shed, the effect of temperature gradually dwindles and nutritional factors show up increasingly (*Neumann*, 1953; *Teaotia & Luckwill*, 1956; *Wright*, 1956), or water requirements (*Stenz*, 1962; *Schwope*, 1963) become more decisive.

Interrelations of shoot growth and fruit (set) development are continuously changing aspects over the vegetation period. The weak onslught of leaf development during the blooming period diminishes chances of fruit set (*Soltész*, 1982). After petal fall, during 5–7 weeks, vigorous shoot growth (triggered e.g. by high temperatures) stimulates fruit drop. Later, however, weak growth may fail to provide adequate leaf surface, so a major June drop is elicited by the insufficient leaf:fruit ratio (*Quinlan & Preston*, 1971). In varieties known for their low fertility, a super-vigorous shoot growth may cause fruit drop even at modulate fruit load. Fruit drop may be subject to local effects of shoot growth initiated in the proximity, i.e. neighbouring branches (*Feucht*, 1980). The spur mutants of the scarcely setting 'Red Delicious' is markedly less inclined to drop fruit before harvest (*Gautier*, 1974).

Fruit drop waves of diverse background make estimation difficult with respect to the extent of the natural preharvest fruit drop as a varietal character and what the real differences between varieties are (*Roemer*, 1969; *Way*, 1973; *Gautier*, 1974). Studies have dealt with the innate susceptibility to preharvest fruit shed of different variety groups, as 'Red Rome' (*Faedi & Rosati*, 1973), 'Jonathan' (*Faedi & Rosati*, 1974), 'Stayman' (*Faedi & Rosati*, 1975), 'Golden Delicious' (*Rosati* et al., 1975), 'Red Delicious'. Other varieties are mentioned as subject to preharvest fruit drop:

- 'Close', 'Jerseymac', 'McIntosh', 'Quinte', 'James Grieve', 'Cox's Orange Pippin' (*Faedi & Rosati*, 1974),
- 'Alkmene', 'Chieftain', 'Staymared', 'Melba' (*Soltész*, 1982),
- 'Karmijn de Sonnaville' (*Engel*, 1982 cit. *Soltész*, 2002),
- 'Malling Suntan' (*Silbereisen*, 1983).

Way (1973) stated that major preharvest fruit drop is proper for summer-ripe apple varieties ('Summerred', 'Vista Bella'). *Lalatta* et al. (1978) claimed that altitude (above sea level) diminishes the incidence of fruit drop. *Greene* et al. (1986) proved the beneficial effect of the nocturnal red light treatment in diminishing fruit drop. Varieties adapted mainly to cool climate are prone to preharvest fruit drop as a consequence of high temperatures of the crucial period (*Soltész*, 1982).

Material and method

Experimental site and plant material

This study was conducted for 3 years (2002–2005) at Nagykutas, Western Hungary on apple cv. 'Arlet'. The orchard was planted in 1999 with the tree spacing of 3.50 × 0.54 m. Trees were grafted on different growth inducing rootstocks: M.9 (weak), MM.106 (moderate) and crabapple seedling (with strong vegetative vigour). Guard trees were placed at the end of each row. Site and soil preparation, fertilization and pest control were according to local recommendations and need. All trees were supported. Tree training was done according to commercial practices, with the general goal of a spindle-shaped canopy. Grass alleyways were used in the rows. Irrigation and fruit thinning were not used. Assessments were made on 20 trees per each rootstock-scion ('Arlet') combination. Means of these data are included in the tables and on the figures. Assessed trees were selected randomly at the beginning of the experiment in four blocks per combinations with five trees in each block.

Measured and calculated parameters

Fruit drop: In 2005, to collect and count the abscised fruits, a net was placed under each tree and the number of abscised fruits was recorded from 24th April through harvest (24th September) in every two weeks. The ratio of dropped fruits was expressed as a percentage of the total number of flowers.

Seed number: In 2005, seeds of persisting and abscised fruits were counted in every two weeks beginning at 24th April through harvest (24th September). Each sample consisted of 100 fruits.

Fruit number: In 2005, fruit number per tree was counted every two weeks beginning at one week after full bloom through harvest by five trees.

Leaf number: In 2005, leaf number per tree was counted every two weeks beginning at one week after full bloom through harvest by five trees.

Fruit quality parameters: In 2003, 2004 and 2005 fruit quality parameters were characterised with fruit weight (WT), fruit diameter (DI), fruit height (HT), flesh firmness, skin colour (SC) and soluble solids concentration (SSC). All quality measurements were done at harvest on 100 fruits per combination. WT was measured using LPWN-150 (Poland) digital analitical scale with 0.1 g accuracy. Fruit weight means the fresh mass of the washed fruit without peduncle. DI was measured by Mitutoyo IP66 (500–623) digital calliper (Japan) with 0.1 mm accuracy by taking the mean of the largest and smallest diameter of the fruit. HT was measured with the same calliper and a similar method along the greatest longitudinal circumference of the fruit. The ratio of red SC was estimated by visually and expressed as a percentage of the total fruit surface. 0% represents fruits without red overcolour and 100% means fruits with red colour on their total surface. FF was measured with the help of a hand-held Bishop fruit pressure tester (Italy) on the sunny and dark side of the fruit along the greatest cross-sectional diameter. It was expressed as a mean of the two values with 0.1 N/cm^2 accuracy. SSC was measured using a hand-held Atago PAL-1 digital refractometer (Japan) and expressed with 0.1 °Brix accuracy.

Results and discussion

Fruit set and drop

Seasonal changes of fruit set and drop of 'Arlet' apple can be seen on *Figure 1*. There are three abscission peaks on the trees grafted on M.9 rootstock (*Figure 1/A*). The first fruit abortion wave appears during May which is very important in amount; on 7th May 18.2% and 21st May 16.9% of fruits were dropped. Thereafter, the second dropping period was found during the end of June to the beginning of July which also resulted in a large amount of fruit abscission. On 18th June 14.1% and 2nd July 15.0% fruit drop was observed. As a result of these two abscission waves, the rise of the curve of fruit set was the highest in this period. The causes of fruit sed are the insufficient fruit set and low number of seeds. Any stress, water or nutritional defficiency, afflicts first those fruits, which contain less seed, so they are susceptible to be shed. The third shedding period appears in the middle of August (13[rd] August), and its measure (8.2%) does not also negligible. Fruit drop continues to the harvest but with less values. In 2005 after three dropping waves, 8.6% fruit set was calculated at harvest.

Figure 2 A fraction of seedless fruits of 'Arlet' apple often remains mummified in the inflorescence. These fruits are counted into dropped ones group.

Similar to M.9, on MM.106 rootstocks, there are three fruit shedding periods (*Figure 1/B*). The first one appears in the first part of May when unfertilised fruitlets are dropped. The following dropping period can be find during from the end of June to the beginning of July. Fruit set gradually diminishes in this term. Most fruit abscission occurs during these two waves. There is the third abscission peak in the middle and the end of August. In this time, large amount of dropping fruit is not characteristic. At last, directly before to the harvest, less abscising fruits are also observed. Measure and dynamic of fruit drop from the trees on MM.106 rootstock is very similar to M.9. Fruit set from open fertilisation is 11.8% at harvest. A special case of partehnocarpy is met when a fraction of seedless fruits does not grow normally, and does not shed, but rather remains mummified in the inflorescence (*Table 2*). This is found before in other varieties: for example 'Ingrid Marie', 'Elstar', 'Egri piros', 'Éva' and 'Jonager' (*Soltész*, 1997).

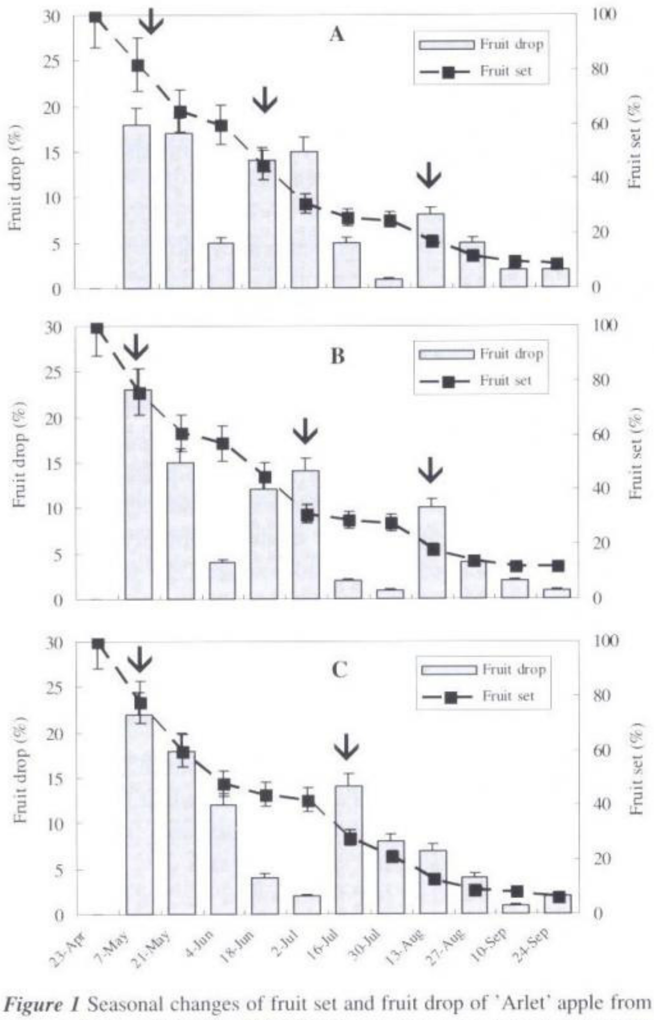

Figure 1 Seasonal changes of fruit set and fruit drop of 'Arlet' apple from trees grafted on M.9 (A), MM.106 (B) and crabapple seedling rootstocks (C). Arrows (↓) show the main dropping periods.

On crabapple seedling, as distinguished from the other two rootstocks, only two peaks of fruitset abscission were found. Believed third one is nott differ from the second, because they are overlapped with each other (*Figure 1/C*). First abortion peak of fruitlets occurs from the beginning to the middle of May which is similar to trees grafted on M.9 and MM.106 rootstocks. However, second shedding wave appeared about two weeks later (in the middle of May) than established by M.9 and MM.106. Ratios of dropped fruits from trees on crabapple seedling in each sample collecting time are a little bit higher than on the other two studied rootstocks. As a result of this difference, the curve of fruit set is characterised by a double hyperbolic function in which the first one is closely correlated with the first dropping period, and the second one with the second dropping period. The most important rise of the curve of fruit set is observed during the period from 23[rd] April to 21[st] May. Preharvest drop from trees on crabapple seedling is significantly higher (2.1%) than on M.9 and MM.106. Ratio of fruit set at harvest is 6.2% which is the half of the value of MM.106 and also lower than the ratio on M.9. At sum it up, the higher fruit set (or the lowest fruit drop) was observed on the trees grafted on MM.106 which is continued by M.9 and crabapple seedling rootstocks. These establishments are in tune with the experiences of *Nyéki* et al. (2004) and *Racskó* et al. (2004b).

Seed number

During the initial phase of fruit growth, the devêlopment of seeds is of special interest from the point of view of fruit drop (*Luckwill*, 1953, *Brittain*, 1933). On the contrary, *Abruzzese* et al. (1995) did not find significant difference between the seed content of fruits dropped and maintained on the tree.

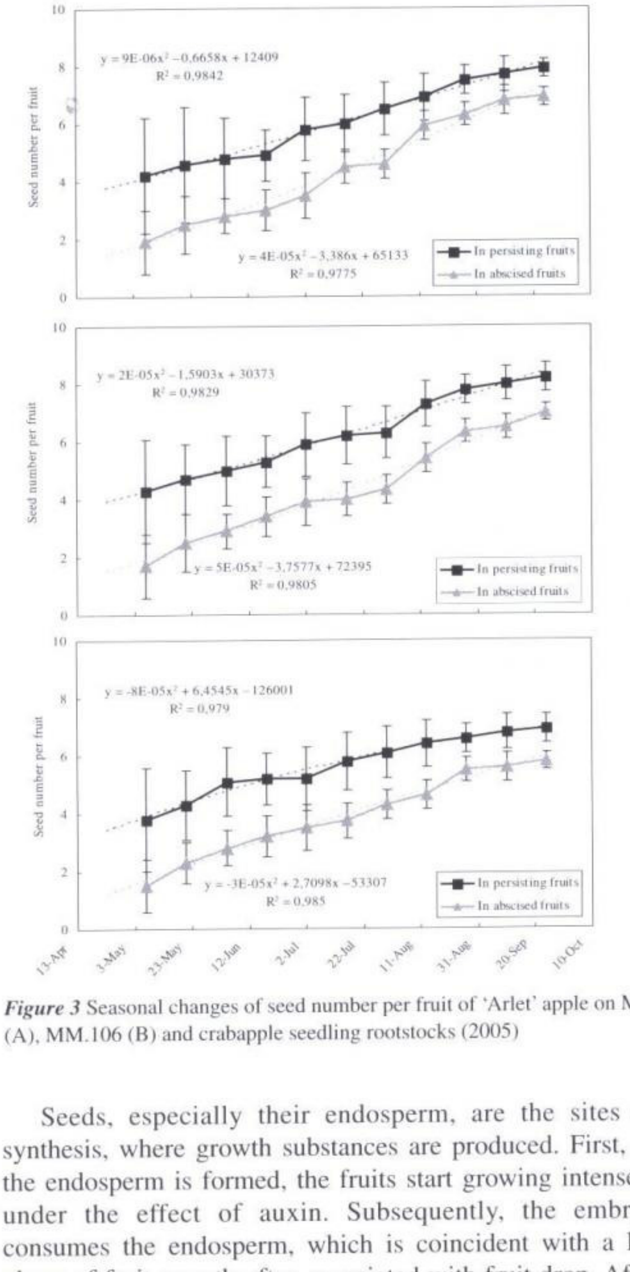

Figure 3 Seasonal changes of seed number per fruit of 'Arlet' apple on M.9 (A), MM.106 (B) and crabapple seedling rootstocks (2005)

Seeds, especially their endosperm, are the sites of synthesis, where growth substances are produced. First, as the endosperm is formed, the fruits start growing intensely under the effect of auxin. Subsequently, the embryo consumes the endosperm, which is coincident with a lag phase of fruit growth often associated with fruit drop. After the embryo have completed its growth, the formation of the secondary endosperm appears, which continues to produce auxin inhibiting abscission its turn.

Wareing & Phillips (1978) stated that auxin absorbs not only organic substances but influences also the distribution of cytokinins flowing to the fruit, which is an active sink of metabolites. The young organs compete successfully with the older parts of the tree, but the elimination of the seeds (by excising) changes drastically that relation (*Szalay*, 1994).

Figure 3 represents the seasonal changes of seed content of persisting and abscised fruits of 'Arlet' apples on each studied rootstock. Seed number of fruits from trees grafted on M.9 can be seen on *Figure 3/B*. There is a decided difference between persisiting and abscised fruits. This difference decreases coming closer to harvest. After fruit set, persisting fruits contain 4.2 number of seeds in average. In contrast, 1.9 number of seeds per abscised fruits were counted. At harvest, 7.9 number of seeds was characteristic for persisting fruits and only 6.9 for abscised ones. Seasonal changes of seed content of all two types of fruits can be estimated well with a polinomial curve of the second order.

Fruits from trees on MM.106 rootstock is generally characterised by a higher number of seeds than those ones on M.9 (*Figure 3/B*). Difference between seed number of persisting and abscised fruits is more important than by M.9. At harvest, seed count of studied two types of fruits reaches near the same number. After fruit set, for each persisting fruit is characterised by 4.3 number of seeds, but the abscised ones contains only 1.7. At harvest, 8.2 seeds per fruits were counted. Latest sample of abscised fruits was collected on 24^{th} September, in which dropped fruits contained 7.0 number of seeds in average. Seasonal changes of seed number in persisting and abscised fruits can also be estimated with a polinomial curve of the second order..

Changes in seed count of fruits from trees on crabapple seedling from fruit set through harvest can be seen on *Figure 3/C*. The most important difference between seed content of persisting and abscised fruits (2.3 number of seeds per fruit) was observed after fruit set, which regularly decreased to harvest. Persisting fruits contains 3.8 number of seeds in average after fruit set, but only 1.5 were counted in abscised ones. Difference between seed content of persisting and abscised fruits is inconsiderable, at the test time of 2^{nd} July (1.7 number of seeds) and 31^{st} August (1.1 number of seeds). The explanation of this phenomenon is that the highest amount of fruits was dropped in these periods and the fruitlets which contain less seed, they abscised in these periods. At harvest, difference in seed number between of persisting and abscised fruits is 1.1. Persisting fruits contain 6.9 number of seeds and abscised ones are characteristic with 5.8 at this time.

These results support the establishments in literature, that fruit species producing fruits containing more than one seed (apple, pear, quince or currants) drop preferably those fruits, which contain the less number of seeds. Therefore the varieties, which develop less seeds, genuinely, are more susceptible to environmental adversities, i.e. water stress, poor nutrition, etc. and are prone to drop fruits (*Stösser*, 2002). The most important precondition of the fruit to be maintained on the tree is its seed content. The critical number of seeds per fruit depends largely on the species or variety.

Teskey & Shoemaker (1972) claimed that in apple, fruits containing less than 3 seeds are shed first when fruit set was abundant. *Murneek* (1989) too estimated the fruit drop of pears containing less than 3 seeds per fruit.

Fruits derived from self-fertilisation are not competitive to cross-fertilised ones (*Teskey & Shoemaker*, 1972). Under tropical conditions, however, the shed of fruits containing less than 3 seeds is not expected because their competitors in monovarietal plantations are the seedless fruit occurring at rates of 14–18% (*Yuda*, 1981).

Leaf: fruit ratio

Figue 4 shows the seasonal changes of leaf:fruit ratio for 'Arlet' apple. Vegetative vigour of the studied differnt growth inducing rootstocks is dissimilar to each other. Leaf number per fruit is the lowest on trees on M.9 rootstock. The rise of its curve is important during the first period of fruitlet development, in especially at the end of June and in the beginning of July indicated that first and second wave of fruit drop was occurred in this period and strong shoot growth was also observed. Increasing leaf:fruit ratio after this period is a result of fruit drop exclusively. The rise of curve of MM.106 is very similar to of M.9 because of the similar tendency in fruit drop. Values are higher indicating increased vegetative vigour. The highest values of leaf:fruit ratio during test period are on trees grafted on crabapple seedling. The running of its curve is differ compared to trees on other rootstocks. The rise of the curve of crabapple seedling is important at two times: in the beginning of June and at the end of July. The highest amount of fruit drop was occurred at these times.

The number of fruits maintained on the tree depends on the sum of organic nutrients furnished by the leaves nearby, whereas the rest is doomed to be dropped (*Papp*, 2001). The photosynthetic apparatus of the tree is charged by both, the growing fruits as well as the growing shoots (*Szalay*, 2003). According to *Petrov* (1973), in peach, the fruit charge depends not so much from the volume of the fruits but rather from the number of fruits. The development of the endocarp of the stone is highly influenced by the competition of the vegetative organs of the tree (*Timon*, 1992). *Brunner* (1982), on the other hand, refers to the balance expressed by the ratio of leaves and fruits. At the time of the shed of petals, in apple 2–4 leaves are needed by one fruit set, around the June drop 10–15 leaves and at the end of fruit development 40 leaves provide the fruits. Relatively, higher leaf area is necessary for fruits set more than one per inflorescence and fruit drop did not occur (e.g. in 'Paulared', 'Summerred', 'Golden Delicious', 'Fuji', 'Fiesta') (*Soltész*, 1997).

The weak development of the leaf area around bloom (i.e. a low leaf/flower ratio) reduces the chances of fruit set and induces fruit drop. At 5–7 weeks after petals shed, the vigorous shoot growth (at warm weather) favours fruit drop. Later, on the other hand, slow growth of shoots may accentuate June drop by the insufficiency of leaf area. Apple varieties known to be weak in fruit set ('Cox's Orange Pippin', 'Starking' etc.) are afflicted by fruit drop caused by vigorous shoot growth even at a relatively low charge of fruits set. The inhibiting effect of the shoots is always influenced by their provision of nutrients on the tree or locally on the branch. Therefore, fruit drop may differ between trees of the same vigour of shoot growth (*Feucht*, 1980). Fruit drop may vary within the same tree according to the position of different branches (*Soltész*, 2002).

A clear correlation is evident in apple between the shoot growth and the tendency to fruit drop. Trees of strong shoot growth used to drop more fruit the weak growing trees, which may keep often supernumerary fruit primordia (mummies) on the fruiting structures. *Poma & Treccani* (1982) proved the role of vigorous (water-) shoots in fruit drop. Vigorous shoot growth is responsible also for fruit drop, in blueberry, significantly (*Eaton*, 1967). Fruit drop in pecan, shoot growth and fruit drop is also related with each other (*Isbell*, 1928; *Woodroof*, 1928).

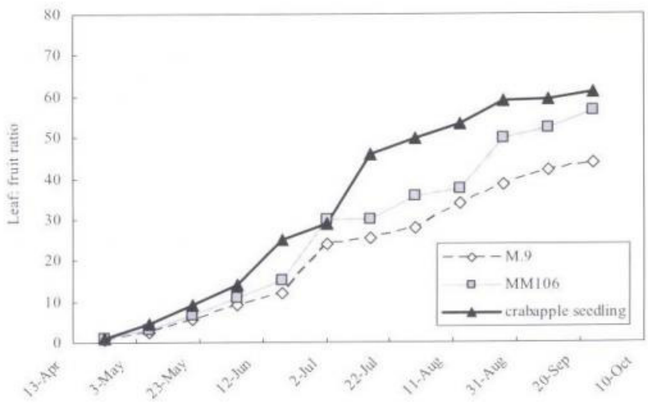

Figure 4 Seasonal changes of leaf:fruit ratio of 'Arlet' apple on M.9, MM.106 and crabapple seedling rootstocks (2005)

It is also an interesting observation that leaves may stimulate fruit abscission (*Dávid*, 1980). It is attributed to the translocation of ABA from the leaves to the fruits. *Goren & Goldschmidt* (1970) indicated that mature leaves of *Citrus* contain much ABA. The same was found in apple leaves by *Pieniazek & Rudnicki* (1967), in *Acer* (maple) and *Betula* (birch) by *Eagles & Wareing* (1964) and in *Coleus* by Chang (1971). Mature leaves are able to suppress the growth of apical buds even against the influence of GS_3 spray (*Cooper* et al., 1969). At the same time, young leaves may delay the abscission of ripe fruits, whereas mature leaves promote the abscission of fruits by stimulating the transport of ABA (*Dávid*, 1980).

Fruit quality

Fruit quality parameters of 'Arlet' apples in 2003, 2004 and 2005 from trees on M.9, MM.106 and crabapple seedling rootstocks can be seen in *Table 1*. Fruit quality parameters (fruit weight, fruit diameter, fruit height, skin colour and soluble solids content) are the highest on M.9, except flesh firmness which is the highest on crabapple seedling. Fruit weight was the highest on M.9 in 2005 (194.0 g), on MM.106 in 2004 (171.8 g) and on crabapple seedling in 2003 (164.3 g). Similar tendency was found by fruit diameter and height. Flesh firmness increases in order M.9<MM.106<crabapple seedling. The highest value of flesh firmness was measured in fruits from trees on crabapple seedling in 2003 (71.7 N/cm^2). In fruits from trees on MM.106 rootstock in 2004 and 2005, 67.8 N/cm^2 was measured, and on M.9 the highest value (66.2 N/cm^2) was observed in 2003. In these cases, that principle was predominated that the highest fruit size, the lowest flesh firmness (Racskó et al., 2005a, b). Skin colour

Table 1 Fruit quality parameters of 'Arlet' apples from trees on M.9, MM.106 and crabapple seedling rootstocks. Significant differences can be seen in coloumns 'r' and 'y', in which coloumn 'r' represents the significance level was examined between rootstocks within a year, and the different letters indicate significant difference at p=0.05. In coloumn 'y' the *, † and $ represents significant differences between years on the same rootstock at p=0.05

Year	Rootstock	WT			DI			HI			FF			SC			SSC		
		(g)	*r*	*y*	(mm)	*r*	*y*	(mm)	*r*	*y*	(N/cm²)	*r*	*y*	(%)	*r*	*y*	(°Brix)	*r*	*y*
2003	M.9	181.1	a	**	72.9	a	*	71.2	a	*	66.2	a	*	68.1	a	*	11.9	a	*
	MM.106	159.2	b	††	70.1	a	†	63.8	b	††	66.4	a	†	66.5	a	†	11.8	a	†
	seedling	164.3	b	$	71.8	a	$	65.6	b	$	71.7	a	$	51.4	b	$$	11.4	b	$
2004	M.9	190.8	a	*	75.0	a	*	72.8	a	*	61.0	b	*	65.3	a	**	11.3	b	**
	MM.106	171.8	bc	†	72.4	ab	†	68.8	ab	†	67.8	a	††	51.4	ab	††	11.2	b	††
	seedling	160.2	c	$	69.5	b	$	66.0	b	$	68.6	a	$	44.8	b	$$	10.6	c	$
2005	M.9	194.0	a	*	75.8	a	*	74.0	a	*	63.3	a	*	72.8	a	*	11.8	a	*
	MM.106	167.7	b	†	71.9	ab	†	67.3	ab	†	67.8	a	††	60.4	b	†	11.6	a	†
	seedling	139.3	c	$$	68.3	b	$	62.9	b	$$	69.0	a	$	61.2	b	$	11.5	ab	$
Average	M.9	188.6			74.6			72.7			63.5			68.7			11.7		
	MM.106	166.2			71.5			66.6			67.3			59.4			11.5		
	seedling	154.6			69.9			64.8			69.8			52.5			11.2		

was mostly influenced by vegetative vigour of rootstocks. The ratio of red surface colour was the highest on fruits from trees grafted on M.9 with the weakest vegetative vigour, and the lowest ratio was observed on fruit surface from tree on crabapple seedling. Differences between skin colour on weak and strong growth inducing rootstocks come from the different canopy microclimate of these stocks (*Lakatos* et al., 2005; *Racskó* et al., 2004a). The highest ratio of red colour (72.8%) was found on fruits from trees on M.9. Values on MM.106 and crabapple seedling were in order: 66.5% in 2003 and 61.2% in 2005. Generally, rootstock had little effect on soluble solids content. Significant differences between soluble solids content of fruits from trees on M.9 and MM.106 were not observed. Less values were measured by crabapple seedling. The highest value of soluble solids was measured on M.9 in 2003 (11.9 °Brix), on MM.106 in 2003 too (11.8 °Brix), and on crabapple seedling in 2005 (11.5 °Brix).

Trees on M.9 had generally fruits with slightly higher quality in all test years compared to trees on other rootstocks (*Table 2*). For fruits from trees grafted on MM.106 and crabapple seedling decraeses were observed in fruit weight (–13.5% and –22.9%), fruit diameter (–4.3% and –6.8%) and fruit height (–9.1% and 12.1%). However, on these rootstocks flesh firmness was increased. Flesh firmness of fruits from trees on MM.106 was 5.5% higher and on crabapple seedling 9.0% higher than those fruits from trees on M.9. The most important difference between rootstocks' effect were observed in skin colour. Average differences of this parameter from values of M.9 were measured –16.6% on MM.106 rootstock and –32.4% on crabapple seedling. The less effect of three rootstocks was found on soluble solids content. Trees on M.9 had fruits with higher content of soluble solids compared to trees on MM.106 (–1.1%) and crabapple seedling rootstocks (–4.5%).

Table 2 Changes in fruit quality parameters of 'Arlet' apples from trees on MM.1006 and crabapple seedling compare to trees grafted on M.9 rootstock. Fruit quality parameter measured on M.9 means 100%.

Year	Rootstock	WT	DI	HI	FF	SC	SSC
2003	MM.106	-13.8	-4.0	-11.6	+0.3	-2.4	-0.8
	seedling	-10.2	-1.5	-8.5	+7.7	-32.5	-4.4
2004	MM.106	-11.1	-3.6	-5.8	+10.0	-27.0	-0.9
	seedling	-19.1	-7.9	-10.3	+11.1	-45.8	-6.6
2005	MM.106	-15.7	-5.4	-10.0	+6.3	-20.5	-1.7
	seedling	-39.3	-11.0	-17.6	+8.3	-19.0	-2.6
Average	MM.106	-13.5	-4.3	-9.1	+5.5	-16.6	-1.1
	seedling	-22.9	-6.8	-12.1	+9.0	-32.4	-4.5

Acknowledgement

This research was supported by the grant OMFB 00909/2005. of the National Office for Research and Technology (NKTH).

References

Blasse, W. (1974): Sicherung der Besteubung in industriemsigen Obstanlagen. Gartenbau 21 (4): 113–115.

Bradbury, D. (1929): A comparative study of the developing and aborting fruits of *Prunus cerasus*. Amer. J. Bot. 16: 525–545.

Brittain, W.H. (1933): Apple pollination studies in the Annapolis Valley N.S. Canada, 1928–1932. Bull. Dep. Agric. Can. New Ser. No. 162.

Dorsey, M.J. (1919): The set of fruit in apple crosses. Proc. Amer. Soc. Hort. Sci. 18: 82–94.

Faedi, W. & Rosati, P. (1973): Indagini sul melo. 1. Rome Beauty, suoi mutanti e suoi incroci. Frutticoltura 35 (5): 25–34.

Faedi, W. & Rosati, P. (1974): Indagini sul melo. 2. Jonathan, suoi mutanti e suoi incroci. Frutticoltura 36 (10–11): 41–48.

Faedi, W. & Rosati, P. (1975): Indagini sul melo. 7. Stayman, suoi mutanti e suoi incroci. Frutticoltura 37 (5): 25–34.

Feucht, T. (1980): Wachstumsgesetze bei fruchtenden Apfelbäumen. Rheinische Monatsschrift. 4: 164–165.

Gardner, V.R., Bradford, F.C. & Hooker, H.D. Jr. (1952): The fundamentals of fruit production, New York.

Gautier, M. (1974): Les variétés de pommiers. L'Arboriculture fruitiére. 21(249): 21–27.

Gautier, M. (1983): La pollination des arbres fruitiers. L'Arboriculture fruitiére. 30 (349): 29–36.

Grauslund, J. & Hansen, P. (1975): Fruit trees and climate III. The effect of temperature on fruit set in apple trees. Tidsskrift for Planteavl. 79 (4): 481–488.

Greene, D.W., Craker, L.E., Brooks, C.K., Kadkade, P. & Bottecelli, C. (1986): Inhibition of fruit abscission in apple with night-break red light. HortScience. 21: 247–248.

Harrold, T.S. (1935): Comparative study of the developing and aborting fruits of *Prunus persica*. Bot. Gaz. 96 (3): 505–520.

Kester, D. & Griggs, W.H. (1959): Fruit setting in the almond: The effect of cross-pollinating various percentages of flowers and the pattern of flower and fruit drop. Proc. Amer. Soc. Hort. Sci. 74: 206–213 and 214–219.

Kobel, F. (1954): Lehrbuch des Obstbaus auf physiologischer Grundlage. Springer Verlag, Berlin.

Lakatos, L., Szabó, T., Racskó, J., Szabó, Z., Soltész, M. & Nyéki, J. (2005): Day and night temperature effects on fruit skin colour in an apple gene bank orchard. Agrártudományi Közlemények. 17: 45–53. (In Hungarian)

Lalatta, F., Marro, M. & Sansavini, S. (1978): La fertilà nel melo e nel pero. Relazione presentata al Seminario sulla „Fertilità delle piante da frutto". Progetto finalizzato C.N.R. „Biologia della riproduzione". Bologna, 15 dicembre 1978.

Lu, C.S. & Roberts, R.H. (1952): Effect of temperature upon the setting of Golden Delicious apples. Proc. Amer. Soc. Hort. Sci. 59:177–183.

Luckwill, L.C. (1953): Studies of fruit development in relation to plant hormones. I. Hormone production by the developing apple seed in relation to fruit drop. J. Hort. Sci. 28: 14–24.

Nyéki, J., Szabó, Z., Racskó, J., Soltész, M., Gonda, I. & Farkas, E. (2004): Effect of M9, MM106 and seedling rootstocks on flowering and productivity of 33 apple cultivars. 8th Intenational Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems. Hungary, Budapest. 13–18 June 2004. Abstracts, 101.

Racskó, J., Lakatos, L., Gonda, I., Nyéki, J., Szabó, Z., Glant, Z., Fári, M., Holb, I. & Soltész, M. (2004a): Effects of the differences of day and night temperature on different quality parameters of apple varieties. 2nd Central European Congress on Food. Hungary, Budapest. 24–26 April 2004. Abstracts, 272.

Racskó, J., Nyéki, J., Szabó, Z., Soltész, M. & Farkas, E. (2004b): Effect of rootstocks on blooming capacity and productivity of apple cultivars. J. Agric. Sci. 15: 14–20.

Racskó, J., Soltész, M., Budai, L., Szabó, Z., Farkas, E., Nagy, J. & Nyéki, J. (2005a): Rootstock effects on quality of apple (*Malus domestica* Borkh.). Agrártudományi Közlemények. 17: 39–43. (In Hungarian)

Racskó, J., Szabó, Z., Budai, L., Thurzó, S., Drén, G. & Nyéki, J. (2005b): The effect of rootstocks on fruit quality of apple. 11th Youth Scientific Conference. Hungary, Keszthely. 24 March 2005. CD. (In Hungarian)

Roemer, K. (1968–70): Bericht über die Beobachtungen des Blühverganges und des Ansatzes bei einigen Apfelsorten des niederelbischen Obstanbaugebietes in der Zeit von 1964 bis 1968. Mitteil. Obstver. Jork 23: 222–239, 25: 209–215, 242–249, 299–309, 354–361.

Rostai, P. & Faedi, W. (1975a): Indagini sul melo 9. Schede pomologische ed agronomiche di cloni spur di Red Delicious. Frutticoltura. 37 (9): 15–23.

Rosati, P. & Faedi, W. (1975b): Indagini sul melo 4. Un confronto fra Golden Delicious e Starkspur Golden Delicious, sue mutanza spur. Frutticoltura. 37 (10): 18–24.

Silbereisen, R. (1970): Selecting methods with fruiting apple-types. Station De Rech. Fruit, Angers, 79–97.

Soltész, M. (1982): Cultivar association in apple orchards. Ph.D. Thesis. MTA, Budapest. (In Hungarian)

Soltész, M. (1997): Fruit set and thinning (In Hungarian), In: Soltész, M. (ed.) (1997): Integrált gyümölcstermesztés. Mezőgazda Kiadó, Budapest. 309–331.

Soltész, M. (2002): Apple In: Kozma, P., Nyéki, J., Soltész, M. & Szabó, Z. (ed.) (2002): Floral biology, pollination and fertilisation in temperate zone fruit species and grape. Akadémiai Kiadó, Budapest.

Stösser, R. (2002): Von der Blüte zur Frucht In: Link, H. (ed.) (2002): Lucas' Anleitung zum Obstbau. Eugen Ulmer GmbH Co., Stuttgart. 29–37.

Szalay, L. (2003): Fruit development and ripening (In Hungarian) In: Papp, J. (ed.) (2003): Gyümölcstermesztési alapismeretek. Mezőgazda Kiadó, Budapest. pp. 203–209.

Teskey, B.J.E. & Shoemaker, J.S. (1972): Tree Fruit Production. The Avi Publishing Company, Westport, Connecticut.

Yuda, E. (1981): Tree fruit growing in Java. In: Ogo, T. (ed.): Ecological studies on the utilization of cultivated plants in rural communities of Southeast Asia and Oceania with special reference to fruit trees and production. Min. prog. rep., College of Agric., Okayama Un., 123–144.

Way, R.D. (1973): Summer and early fall apple varieties. Fruit Var. J. 27 (1): 6–9.