International Journal of Horticultural Science 2006, 12 (2): 77–85
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

Alternate bearing of 'Golden Reinders' and 'Summered' apples

Racskó, J.[1], Nagy, J.[1], Szabó, Z.[1], Soltész, M.[2], Holb, I.J.[3] & Nyéki, J.[1]

[1]*University of Debrecen CAS, Institute for Extension and Development, H-4032 Debrecen, Böszörményi út 138. Hungary*
[2]*College of Kecskemét, College Faculty of Horticulture, Department of Fruit Production, H-6000 Kecskemét, Erdei Ferenc tér 1–3. Hungary*
[3]*University of Debrecen CAS, Department of Plant Protection, H-4032 Debrecen, Böszörményi út 138. Hungary*

Summary: The aim of the present study was to study the effect of biennial bearing (irregular yields) on the generative production of apple cultivars 'Golden Reinders' and 'Summerred' on M.9 rootstock. The observations were made at Nagykutas in West-Hungary for four years. The authors have studied the flowering time, flower density, fruit density, fruit drop, seed content, yielding and fruit quality in the on-year and off-year. Based on the results, it can be stated that the alternation does not cause a significant change in the flowering time of cvs. 'Golden Reinders' and 'Summerred': the difference between the flowering time of trees in the on-year and off-year period was 0-1 day. However, there were significant differences in the flower density. 'Golden Reinders' proved to have a weaker tendency to alternation similarly to the statements of the literature. Alternation (off-year) was observed only in three years from the studied four years. While in the case of 'Summerred', strong alternation was observed in all four years. In fruit density, there were differences among the cultivars and among the different cycles of biennial bearing. Fruit density (and its opposite, fruit drop) changed inconsistently in the period between flowering and harvest. In the case of 'Golden Reinders' and 'Summerred' 2 and 4 fruit drop periods were detected, respectively. In the off-year, the different periods were less distinct, in most cases they were overlapping each other. The dynamics of fruit frop was related to seed content per fruit. The lower the seed number was, the higher the degree of fruit drop was. In both the high- and off-year cycles, the number of seeds in fruits on the tree and on the ground increased with time. In the yield parameters (fruit number, fruit load, yield efficiency), the differences were greater among the yields of trees in the high- and off-year cycles for 'Summerred'. The fruit quality parameters were greatly influenced by the fruit load of the trees in the different alternation cycles. In general, it can be stated that fruit mass, diameter and height were lower on trees in the on-year. A similar trend could be observed in flesh firmness, cover colour and dry matter content, but the differences were smaller. 'Summerred' was more sensitive to the differences in fruit load.

Key words: apple, alternation, flowering time, flower density, fruit density, seed content, yield quantity, yield efficiency, fruit quality, fruit mass, flesh firmness, dry matter content

Introduction

The alternation of yield among the years (alternate bearing) has been a serious problem of apple production, especially in orchards with high yielding capacity (*Soltész*, 2002). The average annual yield of apple trees prone to alternation (average of off-year and on-year) is usually considerably lower than those with regular yielding (*Racskó*, 2006). The strong vegetative growth of trees in the off-year trees makes the tree more prone to irregular yielding. Moreover, the strong shoots developing on the peripherial and top parts of the tree shadow the lower fruit-bearing shoots, consequently, less and low quality fruits will develop (*Vigl*, 2005).

The proneness of the cultivars to irregular yielding is very different (*Tóth*, 2001). Biennial bearing is especially characteristic to 'Elstar', 'Summerred', 'Fuji', 'Boskoop', 'Berlplesch' and 'Delbarestivale'. *Crassweller* et al. (2005) classifies into this group also the 'Fortune', 'Golden Supreme', 'Pristine', 'Suncrisp' and 'Yataka' based on their high alternation index (0.6<). 'Jonagold', 'Cox's Orange Pippin', 'Braeburn' and 'Rubinette' have a medium proneness to biennial bearing. Alternate bearing is characteristic to the 'Gala' cultivars and 'Pinova', 'Golden Delicious', 'Arlet', 'Idared' and 'Topaz'.

The reason for alternation is the inhibiting effect of fruits on flower formation (*Handschack*, 2000; *Dolega & Link*, 2002). This effect is probably induced by the hormone production of the seeds developing in the fruits. However, we should suppose the presence of the fruit itself is also an influencing factor.

Dennis (1970) performed experiments with apple cultivars producing seedless fruits. The flowers of these, due to the special flower structure, are fertilized rarely, therefore, most of the fruits are parthenocarp. Hand pollination results in seed formation and a higher fruit density, as a result of this, the ratio of short flowering shoots is reduced in the next year. This effect could be attributed to gibberellic acid. However, even *Dennis* (1980 cit. *Bubán*, 2003) himself pointed out that it is impossible to determine whether flowering is dependent upon seed content or fruit density or both.

The seeds of fruits have a relatively high concentration of gibberellins (*Luckwill*, 1977), which are transported to the buds and there they inhibit flowering (*Luckwill*, 1970).

Gibberellins inhibit flower formation only if fruits are present on the tree (*Fulford*, 1973). When there are fruits next to buds on the tree, then GA_{4+7} treatments reduce the number of leafs in the developing buds and the flowering in next year, but the number of nodes on short shoots without fruits is not reduced even if a GA_{4+7} treatment is applied (*McLaughlin & Greene*, 1991).

According to *Chan & Cain* (1967), the inhibiting effect of fruits on flower formation is asserted very early, within three weeks after flowering. At that time, there is no or hardly detectable hormone production in the ovules. In the trees of alternate bearing cultivars the inhibition of flower formation was detected in the on-years only if the fruits were left on the trees for 6–8 weeks after flowering (*Luckwill*, 1970). In pear trees, the inhibiting effect of fruits on flower formations is significant 30–40 days after flowering (*Huet*, 1972 cit. *Bubán & Faust*, 1982).

Materials and methods

Experimental site and materials

The experiments were carried out at Nagykutas in West-Hungary for four years between 2002 and 2005. For the experiments, two apple cultivars with very different alternate bearing characteristics were selected in order to ensure the comparison of the generative production of a strongly and less strongly alternating cultivar. One of the cultivars was 'Golden Reinders', which is known to have less tendency to alternate bearing. The other selected cultivar was 'Summerred' of summer ripening, which is prone to irregular bearing. The trees were planted in the autumn of 1999 on M.9 rootstock. Distance between and within rows was 3.50 and 0.54 m, the alleys were covered by grass. Trees were pruned to a thin spindle shape and integrated pest management (IPM) was applied. The orchard was not irrigated.

For the assessments, 20 trees per cultivar were selected in the spring of 2002, out of which 10 and 10 trees were in their on- and off-year cycles, respectively. So the ratio of the trees was 50:50%. The selection was made based on flower production. Trees with flower production values ranging from 0.0 to 5.0 were classified as off-year trees, while trees with flower density values between 5.1–10.0 were considered on-year trees. However, the initial ratio has changed during the years (*Table 1*). In the case of 'Golden Reinders' we did not find trees in their off-year cycle in 2003.

Table 1 The ratio of trees in their on- and off-year cycles in the years of the experiment

Cultivar	2002	2003	2004	2005
Golden Reinders	50:50	100:0	95:5	40:60
Summerred	50:50	30:70	55:45	45:55

The yields on off-year trees (with irregular yields) were compared with the yields of trees with optimal crop load in each year. For this reason, a fruit thinning experiment was also set up for the period of 2002-2005. In the experiment, 20 tress were selected and thinned by hand after fruit density at the end of May, so that the fruit leaf ratio before the fruit drop in June was 1:10–15.

Assessment indices

Flowering time: The start of flowering was counted from the opening of the first flower. At the main flowering, more than 50% of all the flowers on tree were open. By the end of flowering all the flowers had dropped their petals. The flowering phenophases were indicated by the calendar days.

Flower density: Flower density was indicated on a 0-10 scale. 0 indicated a tree without flowers, while 10 stood for the maximum flower density. The values were determined for each tree, therefore, the differences in the stand in flower formation could be detected.

Fruit density: 300–600 flowers were selected on 10 shoots from parts representing the four cardinal points for each cultivar. The fruit density from free-pollination was assessed in each two weeks from pollination until harvest. The number of fruitlets on the tree was expressed as the % of the total number of flowers.

Fruit drop: It was calculated from the value of fruit density by deducting the percentage of fruit density from free-pollination from the total number of flowers which was considered to be 100%.

Seed content: It was assessed for each fruit separately both for the dropped fruits and fruits on the tree. Each sample contained 100 fruits. The measurement unit was: *n°/ha*.

Fruit number: Fruits were counted at the time of harvest both on the on- and off-year trees. Measurement unit: *n°/tree* and *n°/ha*.

Crop load: To calculate crop load we used the number of fruits per tree and the average fruit weight of that specific tree. These two values were multiplied by each other resulting in crop load, which was expressed as *kg/tree*. It was also calculated for unit area, for which the amount of fruits per tree and the number of trees per unit area (5291 trees/ha) were used. These two values were multiplied by each other and gave the crop load as *t/ha*.

Yield efficiency: This measure was calculated by dividing the crop load by the cross-section area of the trunk. Yield efficiency was given as $n°/cm^2$ and kg/cm^2.

Fruit quality: Fruit quality was described by fruit mass, diameter and height, flesh firmness, the ratio of skin colour and dry matter content. Each fruit quality assessment was performed at harvest on 100 fruits per combination. Fruit mass was determined with 0.1 g accuracy with a LPWN-150 digital scale. Fruit diameter was measured along the longest transversal diameter with a Mitutoyo IP66 (500-623) digital sliding caliper with 0.1 mm accuracy. Fruit height was measured with a similar method and equipment along the longest longitudinal diameter. Skin colour was assessed visually by indicating in percentage for each fruit, where 0% meant the fruits without a skin colour, while 100% indicated fruits with a total colour coverage. Flesh firmness was measured with an Effegi-type hand-held penetrometer. We measured it on the two opposite sides of the fruit along the longest transversal diameter. It was expressed as N/cm^2. Dry matter content was measured with an Atago PAL-1 digital hand rephractometer, expressed as 0.1 °Brix.

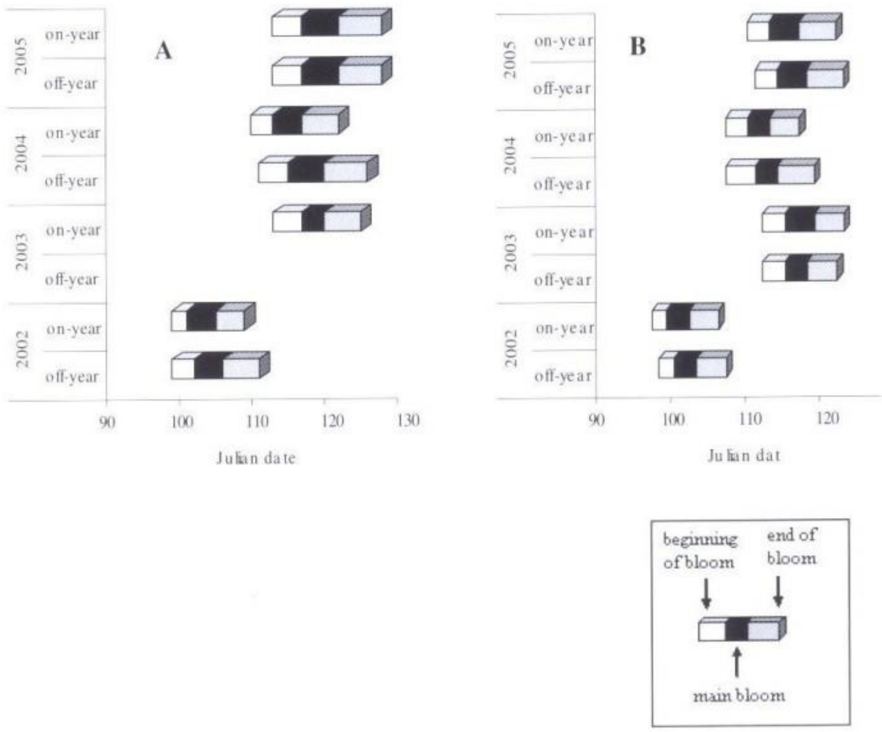

Figure 1 Flowering times of apple (A) 'Golden Reinders' and (B) 'Summerred' in the different cycles of biennial bearing

Results and discussion

Flowering time and flower density

The flowering times of 'Golden Reinders' and 'Summerred' were very close to each other during the four years of the experiment, usually the flowers of 'Summerred' opened 1–2 days earlier (*Figure 1*). In 2002, the 'Golden Reinders' trees in their on- and off-year cycle started to flower on 8 April, while for 'Summerred' these dates were 8 April and 7 April, respectively. On off-year trees of 'Golden Reinders' the flowering was longer, because the petals fell 3 days later than on the on-year trees. In 2003, flowering started on 23 April on the on-year trees of both cultivars. For 'Golden Reinders', we did not find trees in their off-year cyle in this year. In 2004, the on-year trees of 'Golden Reinders' started to bloom 1 day earlier (20 April) than the off-year trees (21 April). However, for cv. 'Summerred', we did not detect a difference between the trees in the two cycles of alternate bearing, flowering started uniformly on 18 April. In 2005, both the on- and off-year trees of 'Golden Reinders' started to bloom simultaneously (on 23 April), while for 'Summerred', there was a difference in the flowering time, on on-year trees flowering started 1 day earlier on 21 April as compared to off-year trees (22 April).

As opposed to flowering time, more significant differences were observed in flower density among the trees in the different cycles of alternate bearing. The differences between the two cultivars and the years are presented in *Table 2*. In the on-year trees of 'Golden Reinders', the lowest fruit density values were always much higher than the minimum value of 5.1. In two years, it even reached the maximum value of 10.0. In the off-year, the minimum values ranged between 1.2 (2002) and 2.1 (2005). The maximum flower density can be considered very high with 3.4–5.0. In 2003, we did not find trees in their off-year cycle. All observed trees had flower density values higher than 5.0, which is the boundary between the on- and off-year. This observation is also supported by the literature, which describes 'Golden Reinders' as a highly persistant cultivar less prone to biennial bearing (*Soltész & Szabó*, 1998).

In the case of 'Summerred' higher differences were observed in flower density among the on- and off-year (*Figure 2, Table 2*), than for 'Golden Reinders'. In on-year, the flower density of trees was very high, since the maximum values ranged between 9.2 and 10.0. The minimum values were between 6.1 and 7.2. In the off-year, minimum flower density ranged from 0.0 to 1.2. In this case, 0.0 showed that the cultivar had no flowers after on-year. The maximum flower density values were between 3.1 and 4.6. The average values indicated a high difference in the flower density between the on- and off-year, which is determined by the yield of the previous year. That is the higher the flower density and yield in a year under optimal conditions for fertilization, the lower the flower formation due to the inhibiting effect resulting in lower flower density and yield. This statement is especially valid for 'Summerred'.

On on-year apple trees the annual flower formation (that is the tendency to biennial bearing) is determined by the number of fruits developing at the same time (as hormone sources) (*Bubán*, 1997). The low flower bud formation on the

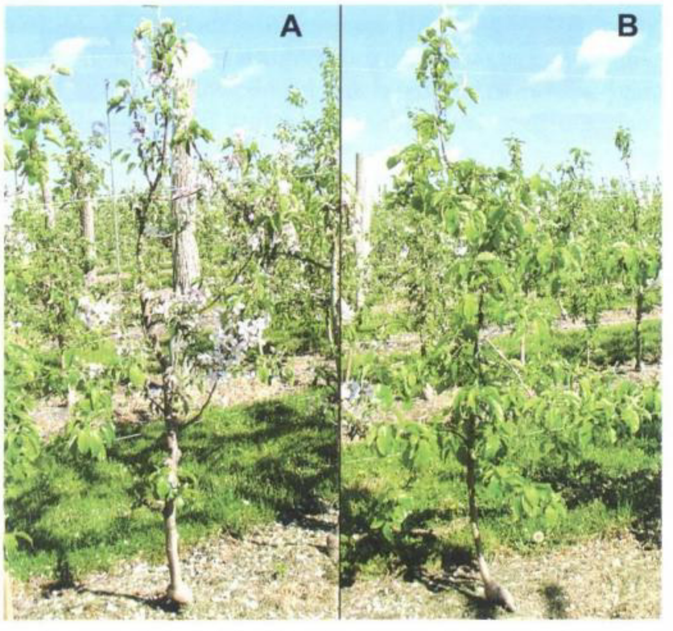

Figure 2 Flowering of trees of the apple cv. 'Summerred' (A) in on-year and (B) off-year cycles

on-year trees was attributed earlier to the depletion of the tree's carbohydrate and nitrogen stocks. According to our present knowledge, the reasons of low flower formation are rather hormonal than nutritional (*Luckwill*, 1974). The inhibiting effect of the ovules of young fruits on flower bud formation was first observed by *Tumanov & Gareev* (1951, cit. *Luckwill*, 1977), but it became widely known based on the publication of *Chan & Chain* (1967) .

Fruit density and fruit drop

The dynamics of fruit density and fruit drop in 'Golden Reinders' are presented in *Figure 3*. The change in fruit density shows a hyperbolic curve both for the on-year and off-year trees. The difference can be observed in the slope of the curve, since the fruit density decreases more steeply, especially in first two months after flowering (*Figure 3/A*) . Accordingly, the degree of fruit drop is higher for the on-year trees and the amount and time of fruit drop is more heterogeneous. In both alternation cycles, two periods of fruit drop were observed. In the on-year trees, two distinct fruit drop peaks can be observed, while for the off-year trees there is a significant overlapping between the phases. The first drop period of on-year trees is at the beginning of May, while the second occurs at mid-June. The first drop period of trees in the off-year starts at the end of May (*Figure 3/B*). The second period coincides with that of the on-year trees. After the fruit drops, the average fruit set of on-year trees was 11.3% by harvest, while this value was almost double for the trees in off-year cycle: 22.4%.

The degree of fruit density and the changes in fruit drop for cv. 'Summerred' are presented in *Figure 4*. This cultivar has a shorter fruit development period, since ripening finishes by the end of August. In spite of this shorter period, more drop periods can be observed in the on-year and off-year trees as compared to 'Golden Reinders': 4 abscision periods were detected in total. The first significant abortion of fruits can be detected at the beginning of May for on-year trees (11.4%) (*Figure 4/A*). Following this, the second period starts at mid-June, when the highest fruit drop occurs. The significance of this period is well demonstrated by the observation that about 27% of all the fruitlets drop in the two-week period between 4 June and 18 June. Consequently, the steepness of the curve for fruit density is the highest in

Table 2 The changes in flower density of apple cultivars 'Golden Reinders' and 'Summerred' in the different cycles of biennial bearing

Cultivar	Year	Cycle of alternation	Flower density (1–10 scale)		
			Minimum	Maximum	Average
Golden Reinders	2002	on-year	6.4	10.0	7.5
		off-year	1.2	5.0	4.0
	2003	on-year	6.6	9.7	8.7
		off-year	–	–	–
	2004	on-year	6.2	10.0	8.5
		off-year	1.4	3.4	3.0
	2005	on-year	6.3	9.3	7.9
		off-year	2.1	4.9	4.1
	Average	on-year	6.4	9.8	8.2
		off-year	1.6	4.4	3.7
Summerred	2002	on-year	6.8	9.2	7.1
		off-year	0.0	4.3	2.4
	2003	on-year	6.1	10.0	7.0
		off-year	0.0	4.6	2.0
	2004	on-year	6.3	9.8	7.5
		off-year	0.9	4.4	3.6
	2005	on-year	7.2	9.4	7.1
		off-year	1.2	3.1	1.9
	Average	on-year	6.6	9.6	7.2
		off-year	0.5	4.1	2.5

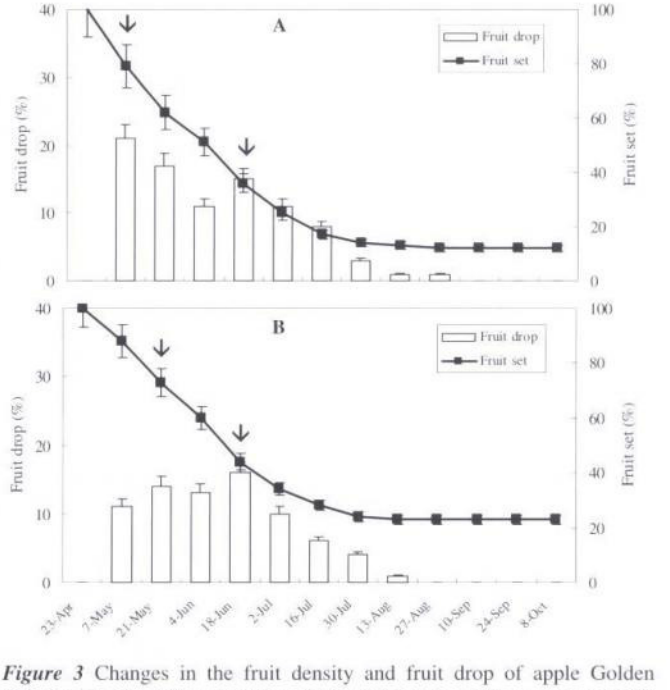

Figure 3 Changes in the fruit density and fruit drop of apple Golden Reinders' in the different cycles of biennial bearing: (A) on-year and (B) off-year years, from flowering until harvest (2005). The major periods of fruit drop are indicated by arrows (↓).

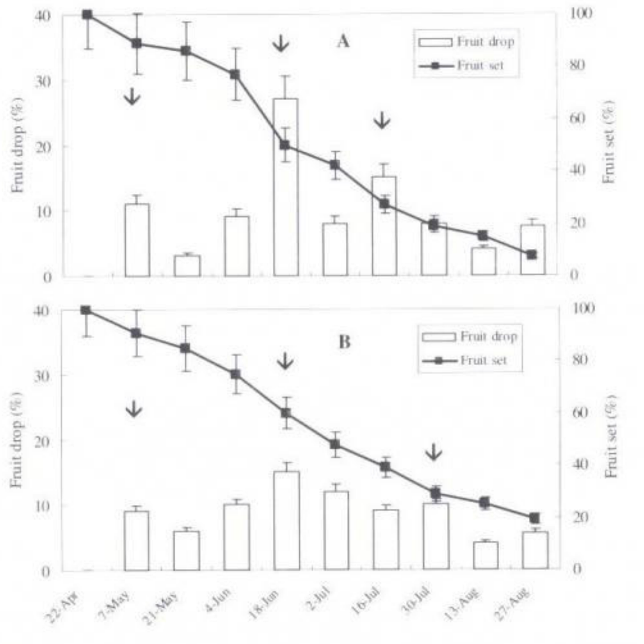

Figure 4 Changes in the fruit density and fruit drop of 'Summerred' in the different cycles of biennial bearing: (A) on-year and (B) off-year in the period between flowering and harvest (2005). The main periods of fruit drop are indicated by arrows (↓).

this period. The third drop periods occurs at the middle or end of June, the amount of which is not negligible either. Finally, the last, fourth period can be observed directly before harvest. The degree of fruit drop is the smallest in this period, but due to the high individual weight of the fruits, the yield loss is significant. In 2005, we calculated a fruit density of 7.4% after the four fruit drop periods.

For the 'Summered' trees in their off-year, the number of fruit drop periods were also four. However, the different periods could hardly be separated from each other, they are overlapping each other (*Figure 4/B*). The first and second abscission periods occur at around the same time as for the on-year trees. The third period starts at a later time, at the end of July. The fruit drop ratios in the different periods are similar to those of the on-year, but the values are much smaller and they are not clearly distinct. Consequently, the slope of the fruit density curves is almost the same from 21 May until 30 July. The fourth fruit drop peak occurs also directly before the harvest, but it is not so significant. Finally, the fruit density by the time of harvest is 19.3%, which thrice as high as that of the on-year trees. In spite of the fact that the leaf:fruit ratio is very high for the trees in the off-year, the fruit drop before harvest still occurs, the literature attributes this to the cultivar in the case of 'Summerred' and not to the high fruit load. According to Soltész (1997), the fruit drop before harvest might be increased by the early formation of the abscission zone between the stalk and the stalk base, the unfavoruable weather conditions (strong wind) and the short stalk in cultivars prone to fruit density in clusters as a result of which the fruits "push" each other from the branch.

Seed content

The degree of fruit drop is related to the number of fertilized stigmate per flower that is to the seed content of the future fruits (*Nyéki* et al., 1982; *Soltész*, 2003b). The auxin level of the ovules reaches the maximum 4–5 weeks after flowering, which is followed by a second peak after the 7th week probably originating from the embryo (*Westwood*, 2003). The amount of auxin transported through the stalk of the fruit is determined not only by the number of ovules. In addition to the fact that in the trees of regular cropping the average seed number is 5 and in the fruits of alternate bearing trees the number of seeds is 8, the auxin flow is 60% higher in the latter (*Bubán*, 1997). It has also been stated, that even if the fruits are seedless (in principle, not having an inhibiting effect on flower formation) fruits, the formation of flower buds is moderate or unsatisfactory if the short shoots have less than 6 leaves (lower than 70 cm^2 leaf area).

In *Figure 5*, the seed content of the fruits of 'Golden Reinders' on the ground and in the tree is presented in the different cycles of alternate bearing. *Figure 5/A.* demonstrates the seed content of fruits in on-year trees. There is a large difference between the fruits on the tree and on the ground in the seed content, which difference is reducing as harvest is nearing. After fruit density, the young fruits on the tree contain 3.9 seeds. However, the number of seeds in the dropped fruits was only 1.9. By the time of harvest, fruits on the tree had 5.6 seeds, while the number of

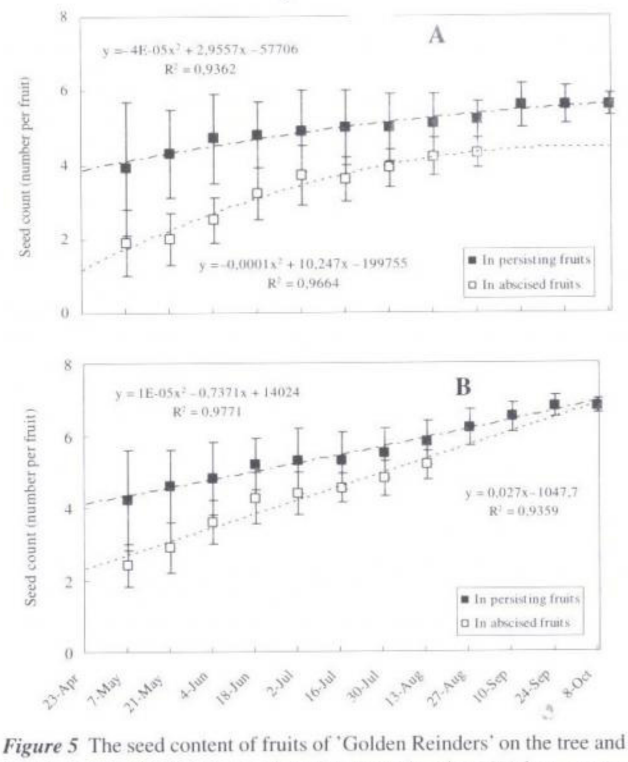

Figure 5 The seed content of fruits of 'Golden Reinders' on the tree and on the ground in the different cycles of alternate bearing: (A) in on-year and (B) off-year (2005). In the case of on-year trees we could not find dropped fruits at the assessment dates 10 September, 24 September and 8 October. For the off-year trees, the last dropped fruits were found on 13 August.

seeds in the sample of the last dropped fruits was 4.3. The Figure demonstrates that the standard deviation of the the seed content of both the dropped fruits and fruits on the tree is decreasing from fertilization until harvest. This indicates that those fruits fall which have the lowest seed content, therefore, the fruist staying on the tree have a higher seed content and a lower standard deviation. The changes in the seed content can be described most precisely by a quadratic polynomial function for both the high- and off-year trees.

The fruits from off-year usually have a higher seed content, then those from on-year (*Figure 5/B*). There was not such a high difference in the seed content between the fruits on the tree and on the ground as in the on-year and by the time of the harvest the values were almost the same. The seed content of fruits on the tee after fruit density was 4.2 seeds/fruit, while in the dropped fruits it was only 2.4. The number of seeds per fruit on the tree at harvest was 6.8. The last dropped fruits were collected on 13 August, and their average seed content was 5. The standard deviation of seed content was also decreasing in this case both for the fruits on the ground and on the tree. The change of this measure for fruits on the tree could be best described by a quadratic polynomial function, while for the dropped fruits the linear function proved to be the best.

The decreasing difference between the seed content of the fruits on the tree and on the ground as nearing to harvest indicates that the role of seed content in fruit drop decreases near ripening and the role of other factors (water and nutrient supply) increases (*Soltész*, 2003b).

The seasonal changes in the seed content of fruits of 'Summerred' are presented in *Figure 6*. In *Figure 6/A*, the seed contents of fruits of on-year trees are shown. There is a significant difference in the seed contents of fruits on the tree and on the ground during May (1.5 seeds/fruit), which decreases until fruit drop in June and then it starts to increase again. After fruit density, the persistent fruits contained an average of 3.1 seeds, while in the dropped fruits 1.6 seeds were counted. The difference between the seed content of fruits on the tree and on the ground was the smallest on 2 July (0.3/fruit). The reason for this is that the highest fruit drop was observed just before this date (between 18 June and 2 July), and the fruits with the smallest seed number fell at this time. By the time of harvest, the difference in seed content increased to 1.4 seeds/fruit, fruits on the tree contained 5.6 seeds, while fruit on the ground had only 4.2 seeds. An interesting observation was made that the distribution of seeds in the compartments of fruits was frequently irregular in the dropped fruits and the shape of the fruits was asymmetrical.

In the case of off-year trees, the differences between the seed contents of fruits on the tree and on the ground were higher than for the on-year trees (*Figure 6/B*). After fruit density, the number of seeds in fruits on the tree and on the ground was 4.3 and 2.4. respectively. The changes in the seed content were similar to those of on-year trees, that is the difference between the seed content of fruits on the tree and on the ground were high after fruit density and then

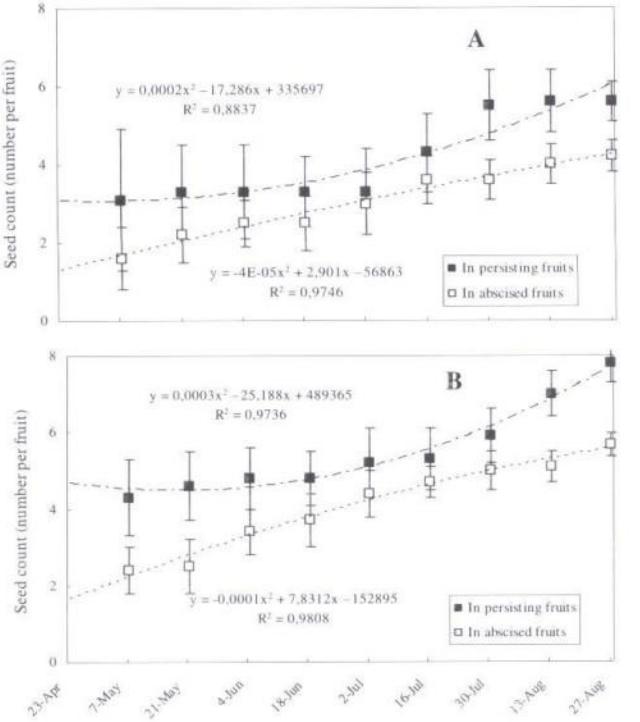

Figure 6 Seed content of fruits of Summerred' on the tree and on the ground in the different cycles of alternate bearing: (A) in on-year and (B) off-year (2005)

decreased by the beginning of July (0.9/fruit). Subsequently, the difference increases until harvest (2.1 seeds/fruit). At harvest time, fruits on the tree and on the ground contained 7.8 and 5.7 seeds, respectively.

Yield

Table 3 represents the yield characteristics of the two cultivars in the different years. In the case of cv. 'Golden Reinders' no extreme differences were found between the on- and off-year trees. During the four years, the lowest number of fruits was recorded in 2002 for the on-year trees (38.2 fruits/tree), while the highest number was observed in 2005 (44.7 fruits/tree). The smallest number of fruits per tree for the off-year trees was 14.8 (2002). In 2003, no off-year trees were found. The highest fruit number was detected in 2004 (18.1 fruits/tree). The number of fruits per tree calculated for a unit area (1 ha) showed the same trend due to the method of calculation. Crop load could also be described by a similar trend, however, it was slightly modified by the individual weight of fruits. The highest crop load on on-year trees was observed in 2005 (10.0 kg/tree), while the lowest one was measured in 2002 (8.3 kg/tree). The fruit load on off-year trees was 3.5 kg/tree and 4.5 kg/tree in 2002 and 2004, respectively. The crop load per unit area (1 ha) could be described by a similar pattern due to the method of calculation. The highest yield efficiency was recorded in on-year trees in 2003 (5.7 fruits/cm^2 and 1.1 kg/cm^2). The lowest values were observed in off-year trees in 2005 (1.1 fruits/cm^2 and 0.3 kg/cm^2)

Table 3 Changes in the yields of apple cultivars 'Golden Reinders' and 'Summerred' in the different cycles of alternate bearing. Significant differences are presented in columns 'y' and 'c', in which the different letters in column 'y' indicate significant differences in yields between the different years, while in column 'c' the signs * and ** indicate significant differences between the yield indices of the two alternation cycles within the same year.

Cultivar	Year	Alternation cycle of the tree	Number of fruits						Fruit load						Yield efficiency					
			Fruit/tree	y	c	Fruit/ha	y	c	kg/tree	y	c	t/ha	y	c	fruit/cm²	y	c	kg/cm²	y	c
Golden Reinders	2002	on-year	38.2	b	*	202116	b	*	8.3	b	*	44.1	b	*	6.4	a	*	1.4	a	*
		off-year	14.8	A	**	78307	A	**	3.5	B	**	18.5	B	**	2.4	A	**	0.6	A	**
	2003	on-year	44.7	ab		236508	ab		8.9	ab		47.2	ab		5.7	ab		1.1	ab	
		off-year	–			–				–			–			–			–	
	2004	on-year	40.0	b	*	211640	b	*	8.9	ab	*	46.9	ab	*	3.9	b	*	0.9	b	*
		off-year	18.1	A	**	95767	A	**	4.5	A	**	23.9	A	**	1.7	AB	**	0.4	AB	**
	2005	on-year	49.4	a	*	261375	a	*	10.0	a	*	53.1	a	*	3.5	b	*	0.7	b	*
		off-year	17.2	A	**	91005	A	**	4.4	A	**	23.4	A	**	1.1	B	**	0.3	B	**
	Average	on-year	43.1			227910			9.0			47.8			4.9			1.0		
		off-year	16.7			88360			4.1			21.9			1.7			0.4		
Sum-merred	2002	on-year	55.0	a	*	291005	a	*	9.2	a	*	48.9	a	*	8.7	a	*	1.5	a	*
		off-year	10.4	A	**	55026	A	**	1.9	A	**	9.9	A	**	1.6	A	**	0.3	A	**
	2003	on-year	35.2	c	*	186243	c	*	6.2	b	*	32.7	b	*	4.3	b	*	0.8	b	*
		off-year	2.5	C	**	13228	C	**	0.5	C	**	2.6	C	**	0.3	B	**	0.1	B	**
	2004	on-year	59.8	a	*	316402	a	*	10.1	a	*	53.3	a	*	4.7	b	*	0.8	b	*
		off-year	7.1	B	**	37566	B	**	1.3	B	**	7.1	B	**	0.5	B	**	0.1	B	**
	2005	on-year	40.3	b	*	213227	b	*	7.0	b	*	37.1	b	*	2.2	c	*	0.4	c	*
		off-year	1.5	C	**	7937	C	**	0.3	C	**	1.5	C	**	0.1	C	**	<0.1	C	**
	Average	on-year	47.6			251719			8.1			43.0			5.0			0.9		
		off-year	5.4			28439			1.0			5.3			0.6			0.1		

The differences in yield between the on-year and off-year trees of 'Summerred' were higher. The number of fruits on on-year trees was very high in 2004 (59.8 fruits/tree), and very low in 2003 (35.2 fruits/tree). In the case of the off-year trees the differences between the years were more: in 2004, the number of fruits was 10.4 per tree, while in 2005, it was only 1.5. This trend was also valid for the number of fruits per unit area (1 ha). Crop load on the yielding trees was the highest in 2004 (10.1 kg/tree), and the smallest in 2003 (6.2 kg/tree). The former and the latter values meant yields of 53.3 t/ha and 32.7 t/ha, respectively Crop load was significant for the off-year trees in 2002 (1.9 kg/tree and 9.9 t/ha). A very low crop load was observed in 2005: 3 kg/tree (1.5 t/ha). Yield efficiency was highest in 2004 on the on-year trees (4.7 fruits/cm^2), which meant 0.8 kg/cm^2. The same value was observed in 2003 on the on-year trees. The value of this figure was very low in 2005 for the off-year (1.1 db/cm^2).

The yield reduced in each off-year year as compared to the on-year ones (*Table 4*). The average reduction in the case of 'Golden Reinders' was 60.4% and 54.4%. For fruit number and fruit load, respectively In yield efficiency, average reductions of 62.5% (fruits/cm^2) and 56.7% (kg/cm^2) were detected. In the case of 'Summerred' more significant reductions were observed for the former indices. The number of fruits and fruit load decreased by 87.1% and 86.0% in the average of four years as compared to on-year cycles. For yield efficiency, the observed reductions were 89.9% (fruits/cm^2) and 93.9% (kg/cm^2).

Figure 7 demonstrates the average yields of the two cultivars between 2002 and 2[illegible] In the case of 'Golden Reinders' no significant differences were observed between the trees with regular yielding (8.2 kg/tree) and irregular yielding (7.5 kg/tree). However, in cv. 'Summerred' the yield per tree can be significantly increased if thinning is applied and as a consequence the trees have a regular yield. In this cultivar, the alternating trees had a yield of 4.3 kg per tree, while those with a regular yield (thinned) had 7.4 kg/tree.

Fruit quality

Biennial bearing had a significant effect on fruit quality parameters (*Table 5*). In the case of on-year trees, fruit

Table 4 Percentage reductions in the yield indices of 'Golden Reinders' and 'Summerred' in the off-year cycles as compared to the on-year cycles. Fruit parameters in the on-year cycle = 100%.

Cultivar	Year	Number of fruits		Crop load		Yield efficiency	
		n°/tree	n°/ha	kg/tree	t/ha	n°/cm²	kg/cm²
Golden Reinders	2002	–61.3	–61.3	–57.8	–57.8	–62.5	–57.1
	2003	–	–	–	–	–	–
	2004	–54.7	–54.7	–49.4	–49.4	–56.4	–55.6
	2005	–65.2	–65.2	–56.0	–56.0	–68.6	–57.3
	Average	–60.4	–60.4	–54.4	–54.4	–62.5	–56.7
Summerred	2002	–71.1	–71.1	–69.4	–69.4	–81.6	–80.0
	2003	–92.9	–92.9	–91.9	–91.9	–93.0	–98.7
	2004	–88.1	–88.1	–87.1	–87.1	–89.4	–98.7
	2005	–96.3	–96.3	–95.7	–95.7	–95.5	–98.0
	Average	–87.1	–87.1	–86.0	–86.0	–89.9	–93.9

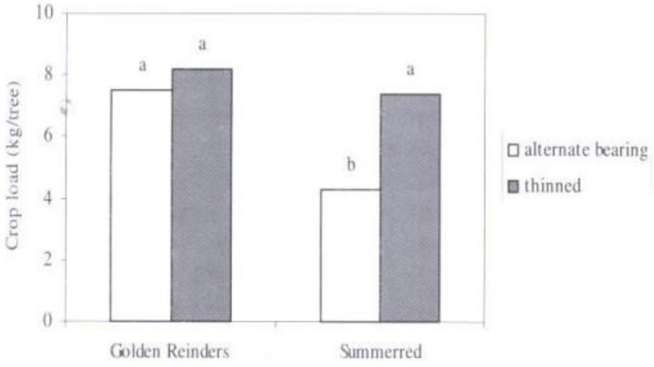

Figure 7 The average yield of trees of 'Golden Reinders' and 'Summerred' with irregular (alternating) and regular yields (thinned) between 2002 and 2005. Significant differences at P=5% are indicated by the different letter above the columns.

weight, diameter and height were significantly lower than for off-year trees. A similar but less significant trend was observed for flesh firmness, skin colour and dry matter content. The reason for the differences was probably the fruit load. 'Summerred' was more sensitive to differences in fruit load.

Fruit quality improved in almost all cases in the off-year as compared to the on-year ones (*Table 6*). The average value of increase for 'Golden Reinders' was 5.0%, 3.8% and 6.6% fruit mass, fruit diameter and fruit height, respectively. Flesh firmness was 3.9% higher on average in the off-year cycle than in the on-year one. Skin colour was thrice as high in the off-year cycle. In dry matter content, the increase was 3.8%.

In 'Summerred', the increase in the above parameters was higher. The indices of fruit size (fruit weight, diameter and height) in the average of your years were higher by

Table 5 Changes in the fruit quality parameters of 'Golden Reinders' and 'Summerred' in the different cycles of biennial bearing. Significant differences are presented in columns *'y'* and *'c'*, in which the different letters in column *'y'* indicate significant differences in fruit quality between the different years, while in column *'c'* the signs * and ** indicate significant differences between the fruit quality parameters of the two alternation cycles within the same

Cultivar	Year	Alternation cycle of the tree	Fruit weight			Fruit diameter			Fruit height			Flesh firmness			Skin colour			Dry matter content		
			(g)	*y*	*c*	(mm)	*y*	*c*	(mm)	*y*	*c*	(N/cm²)	*y*	*c*	(%)	*y*	*c*	(°Brix)	*y*	*c*
Golden Reinders	2002	on-year	218.3	b	*	81.5	a	*	75.9	a	*	65.2	a	*	1.2	a	*	13.2	ab	*
		off-year	236.1	B	**	82.8	A	*	79.4	A	*	66.7	A	*	5.7	A	**	14.2	A	**
	2003	on-year	199.5	c		79.2	a		75.4	a		67.5	a		0.8	a		12.9	b	
		off-year	–			–			–			–			–			–		
	2004	on-year	239.0	a	*	82.0	a	*	76.6	a	*	66.8	a	*	4.3	a	*	13.8	a	*
		off-year	249.8	A	**	84.8	A	*	81.7	A	**	69.2	A	*	8.4	A	*	13.8	A	*
	2005	on-year	241.3	a	*	79.9	a	*	75.1	a	*	64.2	a	*	2.0	a	*	13.5	a	*
		off-year	247.1	A	*	84.9	A	**	81.5	A	**	67.9	A	*	4.6	A	*	14.0	A	*
	Average	on-year	210.7			80.7			75.8			65.9			2.1			13.4		
		off-year	247.5			84.2			80.9			67.9			6.2			14.0		
Sum-merred	2002	on-year	168.0	a	*	72.9	b	*	69.7	a	*	61.2	a	*	67.3	a	*	10.5	a	*
		off-year	209.8	A	**	87.2	A	**	76.1	AB	**	66.8	A	**	78.4	A	**	11.6	AB	**
	2003	on-year	175.4	a	*	72.9	b	*	68.1	a	*	65.1	a	*	58.2	ab	*	10.2	ab	*
		off-year	199.0	A	**	88.6	A	**	81.4	A	**	65.2	A	*	65.9	B	*	12.1	A	**
	2004	on-year	168.6	a	*	77.1	a	*	70.5	a	*	59.3	a	*	66.8	a	*	9.8	b	*
		off-year	190.1	B	**	89.0	A	**	75.1	B	**	64.8	A	*	74.0	A	*	11.5	B	**
	2005	on-year	174.0	a	*	73.0	ab	*	69.7	a	*	62.4	a	*	56.3	b	*	10.7	a	*
		off-year	192.2	B	**	83.7	A	**	72.7	B	*	65.8	A	*	70.2	AB	**	12.5	A	**
	Average	on-year	171.5			74.0			70.0			62.0			62.2			10.3		
		off-year	190.25			76.1			73.65			65.7			288.5			47.7		

Table 6 Percentage increments of the fruit quality parameters of 'Golden Reinders' and 'Summerred' in the off-year cycle as compared to the on-year cycle. Fruit quality parameter in the on-year cycle = 100%.

Cultivar	Year	Fruit weight	Fruit diameter	Fruit height	Flesh firmness	Skin colour	Dry matter content
Golden Reinders	2002	+8.2	+1.6	+4.6	+2.3	+375.0	+7.6
	2003	-	-	-	-	-	-
	2004	+4.5	+3.4	+6.7	+3.6	+95.3	0.0
	2005	+2.4	+6.3	+8.5	+5.8	+130.0	+3.7
	Average	+5.0	+3.8	+6.6	+3.9	+200.1	+3.8
Summerred	2002	+24.9	+19.6	+9.2	+9.2	+16.5	+10.5
	2003	+13.5	+21.6	+19.5	+0.2	+13.2	+18.6
	2004	+12.8	+15.4	+6.5	+9.3	+10.8	+17.3
	2005	+10.5	+14.7	+4.3	+5.4	+24.7	+16.8
	Average	+15.4	+17.8	+9.9	+6.0	+16.3	+15.8

15.4%, 17.8% and 9.9%, respectively, as compared to the high yielding cycle. The increments were +6.0% for flesh firmness, +16.3% for skin colour in the off-year cycle. Dry matter content was 15.8% higher in the fruits of off-year trees.

Acknowledgements

The present study was supported by the project OMFB 00909/2005 of the National Research and Technology Office.

References

Bubán, T. (1997): Virágrügyképződés. In: Soltész, M. (ed.): Integrált gyümölcstermesztés. Mezőgazda Kiadó, Bp. pp. 332–352.

Bubán, T. (2003): Hormonal aspects of flower formation and fruit set. In: Kozma, P., Nyéki, J., Soltész, M. & Szabó, Z. (ed.) (2003): Floral biology, pollination and fertilisation in temperate zone fruit species and grape. Akadémiai Kiadó, Bp. pp. 3–24.

Bubán, T. & Faust, M. (1982): Flower bud induction in apple trees: Internal control and differentiation. Hort. Rev. 4:174–203.

Chan, B. & Cain, J. (1967): The effect of seed formation on subsequent flowering in apple. Proc. Amer. Soc. Hort. Sci. 91:63–68.

Crassweller, R., McNew, R., Azarenko, A., Barritt, B., Belding, R., Berkett, L., Brown, S., Clemens, J., Cline, J., Cowgill, W., Ferree, D., Garcia, E., Greene, D., Greene, G., Hampson, C., Merwin, I., Miller, D., Miller, S., Moran, R., Obermiller, J., Rosenberger, D., Rom, C., Roper, T., Schupp, J. & Stover, E. (2005): Performance of apple cultivars int he 1995 NE–183 Regional Project Planting: I. Growth and yield characteristics. J. Amer. Pom. Soc. 59(1):18–27.

Dennis, F.G. Jr. (1970): Effect of gibberellins and naphthaleneacetic acid on fruit development in seedless apple clones. J. Amer. Soc. Hort. Sci. 95:125–128.

Dolega, E. & Link, H. (2002): Blütenbildung In: Link, H. (2002): Lucas' Anleitung zum Obstbau. Eugen Ulmer GmbH & Co., Stuttgart (Hohenheim). pp. 23–29.

Fulford, R. (1973): Flower initiation – effect of gibberellin sprays. Rept. East Malling Res. Sta. 1972: 93.

Handschack, M. (2000): Komponenten der Ertragsbildung, Ertragsschwankungen und ihre Ursachen, Bekämpfung der Alternanz In: Friedrich, G. és Fischer, M. (szerk.) (2000): Physiologische Grundlagen des Obstbaues. Eugen Ulmer GmbH & Co., Stuttgart (Hohenheim). pp. 210–227.

Luckwill, L.C. (1970): Progress int he control of flowering and fruiting. Proc. 18^{th} Int. Hort. Congr. (Tel Aviv) 4:177–185.

Luckwill, L.C. (1974): A new look at the process of fruit bud formation in apple. Proc. 19th Int. Hort. Congr. (Warsawa) 3:237–245.

Luckwill, L.C. (1977): Growth regulators in flowering and fruit development. Pestic. Chem. 20th Century Symp. 1976. Amer. Chem. Soc. Symp. Ser. 37:293–304.

McLaughlin, J.M. & Greene, D.W. (1991): Fruit and hormones influence flowering of apple. II. Effects of hormones. J. Amer. Soc. Hort. Sci. 116(3):450–453.

Nyéki, J., Terpó, A., Tóth, M., Gyuró, F. & Soltész, M. (1982): Flowering biological and growth characteristics of *Malus* species and cultivars. Acta Botanica Academiae Scientiarum Hungaricae. 28(3–4):347–359.

Racskó, J. (2006): Cropload, fruit thinning and their effects on fruit quality of apple (*Malus domestica* Borkh.). J. Agric. Sci. (megjelenés alatt)

Soltész, M. (1997): Terméskötődés és -ritkítás In: Soltész, M. (ed.) (1997): Integrált gyümölcstermesztés. Mezőgazda Kiadó, Budapest. pp. 309–332.

Soltész, M. (2002): Alma In: Nyéki, J., Soltész, M. és Szabó, Z. (ed.) (2002): Fajtatársítás a gyümölcsültetvényekben. Mezőgazda Kiadó, Budapest. pp. 72–150.

Soltész, M. (2003a): A vegyszeres termésszabályozás In: Papp, J. (ed.) (2003): Gyümölcstermesztési alapismeretek. Mezőgazda Kiadó, Budapest. pp. 315–320.

Soltész, M. (2003b): Apple In: Kozma, P., Nyéki, J., Soltész, M. és Szabó, Z. (ed.) (2003): Floral biology, pollination and fertilisation in temperate zoe fruit species and grape. Akadémiai Kiadó, Budapest. pp. 237–316.

Soltész, M. & Szabó, T. (1998): Alma In: Soltész, M. (ed.) (1998): Gyümölcsfajta-ismeret és -használat. Mezőgazda Kiadó, Budapest. pp. 119–155.

Tóth, M. (ed.) 2001. Gyümölcsészet (második, átdolgozott és bővített kiadás). Primom Kiadó, Nyiregyháza. 489.

Vigl, J. (2005): Verhinderung von Alternanz bei der Sorte Fuji. Obst- und Weinbau. 2:48–50.

Westwood, M.N. (1993): Temperate zone pomology – Physiology and technology. Timber Press, Portland, Oregon.