Tree vigour, cropping, and phenology of sweet cherries in two systems of tree training on dwarf rootstocks

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Abstract

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Five cultivars and four rootstocks (Gisela 5, P-HL-A, P-HL-B, and Tabel Edabriz) were evaluated on trees in fruiting stage trained like spindle and on trellis. Tree vigour was significantly related to cultivar, rootstock and to tree training. Spindles were generally more vigorous than trees on trellis with exception of cv. Kordia. In several cases special combinations of cultivar, rootstock, and method of tree training differed significantly from mean effects of the three factors. Time of flowering was significantly dependent on the cultivar and varied annually within 15 days. Time of fruit harvest was also influenced by the rootstock and in two cases mutually contradictory to the tree training method. Yields per tree were generally dependent on the cultivar. With Burlat and cv. Kordia rootstock and tree training were also important. Higher specific yields were recorded on trellis-trained trees. Remarkable in this respect were Vanda and trees of Summit on P-HL-B and Starking Hardy Giant on Tabel Edabriz. Higher specific yields on spindle had Kordia on P-HL-A and Tabel Edabriz and Burlat on P-HL-A. Mean values of annual yields per hectare in spindle ranged between 10.0 to 17.5 t whereas in trellis between 6.7 to 12.3 t. The absolute highest annual yield (35.7 t) was recorded on spindle trees of Kordia on P-HL-A. In trellis the highest yield of 27.1 t had Kordia on Gisela 5. The advantage of spindle over trellis was greater in Burlat and Kordia but much lower in cv. Vanda. Fruit size mainly depended on the year. Only two rootstocks influenced fruit size differently in some years. Training system had no effect on fruit size.

Keywords: sweet cherry; rootstocks; cultivars; tree training; tree vigour; yields; yield efficiency; time of flowering; time of ripening; fruit size; relationships

Recent development in growing system with sweet cherry worldwide is focused on high density orchards of slowly growing trees on dwarf rootstocks trained in limited space using low canopies (Usenik et al. 2006; Webster 1996; Green 2005; Lang 2005; Lauri, Claverie 2005; Robinson 2005; Godini et al. 2008; Grzyb et al. 2008; Salvador De et al. 2008; Stehr 2008). In the Czech Republic, in Holovousy research in this area was in the first stage concerned with selection of proper rootstocks for this new growing system (Blažková 2001; Blažková, Hlušičková 2003, 2004, 2007). In continuity with this research, this paper aims to evaluate differences among training systems of trees using different cultivars and rootstocks.

MATERIAL AND METHODS

This study was done during 2005–2009 in Holovousy. Climate conditions of the location are characterised by the average annual temperature of 8.1°C and the average annual rainfall of 650 mm. The soil was medium loamy sand with a rather deep

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cultivated layer on gravel substrate. The orchard is located at the altitude of 280 m a.s.l. and it is situated on a very gentle slope facing north.

The experimental orchard was established in the spring of 1998 and it was completed in 1999. Trees in the older part were planted in a 5 × 1.5 m spacing and were trained like spindles, whereas the younger part was planted just aside with a 5 × 2 m spacing and trained to a trellis. In both parts the same experimental variants were used as follows. Cultivars: Burlat, Kordia, Starking Hardy Giant, Summit, and Vanda. Rootstocks: Gisela 5, P-HL-A, P-HL-B, and Tabel Edabriz. In the case of spindle training, every combination from these cultivars and rootstocks was planted in three randomly replicated blocks using four trees per combination. In the trellised trees only two replicated blocks were planted using three trees per combination. Vanda and Kordia cultivars on the rootstock P-HL-B rootstock were planted only in spindle-trained part of the orchard.

Experimental trees were cut back just after planting to induce side branching at the height of 0.7 m above ground level. Then, in the case of trees trained as spindles (supported individually by strong wooden stakes), shoot bindings and leggings were applied during growing season to achieve more horizontal positions of the side branches. Trees trained like trellis were treated similarly at the beginning but since the third year after planting two side axes growing bilaterally in the direction of the tree row were promoted and shoots growing in the direction of the working alleys between tree rows were restricted by cutting. In the following years the next levels of the side axes were established about 0.5 to 0.7 m over previous ones. This part of the orchard was equipped by supporting a construction consisting of three wires arranged in rows at a mutual span of 0.6 m to each other to make tree shaping easier.

In the following years the next storeys within canopies of the trees were gradually established using the same procedure. Proper density within tree canopies was permanently kept by removing excessive shoots and branches.

No irrigation was applied in the orchard. Clean strips were kept under trees by contact herbicides whereas frequently cut sod was kept in alleys between tree rows. Fertilisers were applied according to soil analyses. Spraying treatments against pests and diseases were conducted according to the recommendations for commercial orchards but integrated pest management was applied.

The following characteristics were evaluated during every growing season for each tree: the initial dates of flowering and fruit ripening, flower and fruit sets using a 1–9 rating scale (1 = no set), and weights of harvested fruits. At the end of growing seasons size parameters of tree canopies and trunk cross-sectional areas (50 cm above the graft union) were measured. All gathered data were processed by ANOVA and regression analyses. Intervals of least significant difference were calculated to separate the rootstock means.

RESULTS

Tree vigour

Two parameters of this characteristic, namely canopy volume and trunk-cross section area (TCA) that were measured at the end of the growing season 2009, are given in Table 1. There is no simple agreement between the measured values, TCA was generally much greater in relation to canopy volume in trees on trellis than in spindles and vice versa. Regarding cultivars the most vigorous was Summit followed by Burlat whereas trees of Vanda were relatively the smallest. Exceptional in this was, however, the TCA of Vanda in spindles which was similar to Summit.

Regarding rootstocks, trees on P-HL-B were mainly the most vigorous with the exception of TCA in trellis which, surprisingly, had the smallest parameter, whereas P-HL-A had the highest value. On the contrary the least vigorous were trees of Gisela 5 but again with exception of TCA on trellis. The mean values of trees in the both training systems were not significantly different but the differences were opposite on spindles and trellis.

Aside from general effects of evaluated factors described above, a significant influence of specific joint combinations was also found in several cases. It was for example the case of Kordia on Tabel Edabriz, where trees grew very vigorously. Similarly this was the case in the combination of Starking Hardy Giant on P-HL-B. The opposite extreme could be Vanda on P-HL-A which grew extremely weak. Trees of Starking Hardy Giant on Gisela 5 had medium size trained like spindles but grew very weakly on trellis.

Flower set and time of flowering

Except cv. Kordia all trees developed high flower set throughout the whole period of this evaluation.

Table 1. Tree size expressed as canopy volume and trunk-cross-section area in 2009 according to cutivars, rootstocks, and training used

Cultivar	Rootstock	Canopy volume (m^3)				Trunk-cross section (cm^2)			
		spindle		trellis		spindle		trellis	
		ø	SD*	ø	SD	ø	SD	ø	SD
Burlat	Gisela 5	11.0	0.7	8.0	0.6	115.2	3.1	134.2	2.6
	P-HL-A	10.7	0.9	10.1	1.1	112.5	3.2	156.3	3.7
	P-HL-B	10.5	1.0	7.4	1.0	107.9	2.9	121.0	3.1
	Tabel Edabriz	8.7	1.0	8.2	0.5	116.9	3.3	111.1	1.9
	Σ	10.2	0.9	8.5	0.9	113.1	3.1	132.0	3.2
Kordia	Gisela 5	8.0	0.9	9.7	1.0	97.8	3.1	123.7	3.9
	P-HL-A	10.5	1.0	8.6	0.9	117.1	3.6	121.7	3.7
	P-HL-B			10.8	0.9			105.9	3.1
	Tabel Edabriz	11.8	0.9	13.0	0.7	104.7	2.9	153.3	3.3
	Σ	9.7	1.0	10.4	0.9	107.3	3.3	114.6	3.4
S.H.Giant	Gisela 5	9.6	1.1	6.0	0.9	97.9	3.2	105.6	3.3
	P-HL-A	7.3	0.8	10.1	0.6	94.6	3.0	139.5	2.2
	P-HL-B	11.9	1.0	10.9	1.2	127.1	3.5	144.3	3.1
	Tabel Edabriz	8.8	1.0	6.3	0.6	101.0	2.8	79.8	2.2
	Σ	9.5	1.0	8.1	1.0	105.8	3.2	114.1	3.3
Summit	Gisela 5	9.6	1.0	10.6	1.0	117.2	3.0	165.8	3.9
	P-HL-A	12.4	1.1	10.6	1.0	115.6	3.2	150.3	3.1
	P-HL-B	11.9	0.8	12.6	1.2	122.4	3.4	136.7	3.3
	Tabel Edabriz	11.4	1.0	7.7	0.9	142.5	3.2	129.5	3.6
	Σ	11.3	1.0	10.3	1.0	123.7	3.2	147.2	3.5
Vanda	Gisela 5	7.4	1.1	5.6	1.2	115.4	3.3	84.2	3.8
	P-HL-A	6.5	0.9	6.5	1.1	122.7	3.4	109.1	4.0
	P-HL-B			8.0	0.6			99.5	2.8
	Tabel Edabriz	10.5	1.2	8.2	0.7	127.1	3.4	136.1	3.4
	Σ	8.2	1.1	7.4	0.8	122.1	3.3	103.5	3.4
Total	Gisela 5	9.0	1.0	8.1	1.0	108.5	3.0	123.3	3.5
	P-HL-A	9.5	1.0	9.1	1.0	113.0	3.1	134.8	3.3
	P-HL-B	11.4	0.9	9.7	0.9	119.1	3.4	109.7	2.9
	Tabel Edabriz	10.0	1.0	8.2	0.8	118.9	3.2	117.6	3.1
	Mean	9.8	1.0	9.0	0.9	114.4	3.0	119.2	3.2

*Significant difference at the level $P \leq 0.05$

In the case of Kordia, trees that had high fruit set in the previous year sometimes developed low levels of flower set (corresponding to the point 2 or 3 from 1–9 rating scale). Neither rootstock nor the way of tree training, however, influenced this phenomenon.

Table 2. Starting dates of flowering according to cultivars, rootstocks, and training of trees used

Standpoint criterion	Variants	Date of flowering start					
		2005	2006	2007	2008	2009	Mean
Cultivar	Burlat	17/4	25/4	13/4	19/4	10/4	17/4
	Kordia	21/4	27/4	14/4	22/4	12/4	19/4
	S.H. Giant	18/4	26/4	13/4	18/4	10/4	18/4
	Summit	19/4	26/4	14/4	21/4	11/4	18/4
	Vanda	19/4	26/4	12/4	18/4	11/4	18/4
Rootstock	Gisela 5	19/4	26/4	12/4	20/4	11/4	18/4
	P-HL-A	19/4	25/4	13/4	19/4	11/4	17/4
	P-HL-B	18/4	25/4	13/4	19/4	11/4	17/4
	Tabel Edabriz	19/4	26/4	13/4	20/4	11/4	18/4
Tree training	spindle	19/4	26/4	13/4	19/4	11/4	18/4
	trellis	19/4	26/4	13/4	20/4	11/4	18/4
Total mean		19/4	26/4	13/4	20/4	11/4	18/4

Time of flowering that varied annually within 15 days was significantly dependent on cultivars and less dependent on rootstocks (Table 2). Time of flowering of particular cultivars varied in some extent during 2005–2009 but in the mean Burlat flowered the earliest whereas Kordia the latest.

Rootstocks influenced time of flowering much less. Trees on P-HL-A started to bloom one day earlier, whereas those on Tabel Edabriz were in this respect relatively the latest. Tree training had no influence on this characteristic at all.

Time of harvest ripening

Similar to the time of flowering, time of fruit ripening was mainly dependent on the year and on the cultivar. Regarding the beginning of fruit harvest

Table 3. Beginning date of fruit ripening according to cultivars, rootstocks, and training of trees used

Standpoint criterion	Variants	Date of fruit harvest ripening start					
		2005	2006	2007	2008	2009	Mean
Cultivar	Burlat	13/6	16/6	2/6	13/6	1/6	9/6
	Kordia	2/7	9/7	20/6	6/7	29/6	1/7
	S.H.Giant	26/6	8/7	21/6	2/7	23/6	28/6
	Summit	25/6	29/6	15/6	26/6	16/6	22/6
	Vanda	25/6	4/7	14/6	23/6	23/6	24/6
Rootstock	Gisela 5	24/6	2/7	15/6	27/6	19/6	23/6
	P-HL-A	24/6	1/7	14/6	25/6	18/6	23/6
	P-HL-B	22/6	29/6	14/6	25/6	14/6	21/6
	Tabel Edabriz	23/6	30/6	14/6	25/6	16/6	21/6
Tree training	spindle	24/6	30/6	14/6	25/6	18/6	22/6
	trellis	22/6	1/7	15/6	26/6	17/6	22/6
Total mean		23/6	30/6	14/6	25/6	17/6	22/6

and ripening, the largest span in the years under observation was recorded in cv. Vanda where in comparing its extreme years 2006 and 2007 it was equal to 20 days (Table 3). In the remaining cultivars the effect of year was a few days shorter.

Comparing the cultivars themselves according to mean values of the beginning of fruit harvest, the earliest was Burlat and the latest was Kordia. The mean span between them in this characteristic was equal to 22 days.

Much less but still significant was the effect of rootstock on time of fruit ripening also influenced by rootstocks. According to mean values, fruits from trees on P-HL-B and Tabel Edabriz ripened two days earlier than on the remaining two rootstocks. In some years the difference was much larger. It was particularly larger in 2009 when trees on P-HL-B started ripening five days earlier than trees on Gisela 5.

Similarly in the case of flowering time, the time of fruit ripening was not visibly influenced by the system of tree training. However this was not the case of two cultivars, namely Kordia and Vanda, which reacted to tree training differently even in this characteristic, however, mutually contradictorily (Table 4). Fruits of Kordia were ready for harvest on spindles in the mean two days earlier than on trellis. The maximum difference of the phenomenon was recorded on trees of the cultivar on Tabel Edabriz where it was greater than three days. In the case of Vanda fruits on spindle trees ripened regularly one day later than those in trellis.

Yield per tree

The overall survey of quantities of fruits (kg/tree) harvested during the whole period of this study according to cultivars, rootstocks and both ways of tree training is given in Fig. 1. At first sight it is obvious that all these three factors and mainly their specific combinations had significant influence on yields of trees.

Regarding cultivars the highest yields were recorded on Kordia, followed by Starking Hardy Giant and Vanda, whereas those of Burlat and Summit were the lowest. The greatest differences between rootstocks were recorded on Kordia and Burlat whiles those on Vanda and Starking Hardy Giant were rather negligible. Kordia had the highest yields on Gisela 5, somewhat smaller on P-HL-A but very low on Tabel Edabriz. Regarding Burlat the worst croppers were trees on P-HL-B. In the case of Summit lower yields were recorded on P-HL-A and Tabel Edabriz than those on Gisela 5 and P-HL-B.

The greatest response to tree training had Kordia and Burlat. From trees of the both cultivars much higher quantities of fruits were harvested from spindles than from trellis. These differences were largest on P-HL-B rootstock and in the case of Kordia also on Gisela 5. On the contrary, Summit on Tabel Edabriz and Starking Hardy Giant on P-HL-B had higher yields from trees on trellis.

Table 4. Influence of tree training systems on harvest time of 2 cultivars during 2005–2009

Cultivar	Rootstock	Way of training	Starting date of fruit harvest ripening		
			mean	the earliest	the latest
Kordia	Gisela 5	spindle	1/7	20/6	9/7
		trellis	3/7	22/6	11/7
	P-HL-A	spindle	1/7	20/6	9/7
		trellis	2/7	23/6	9/7
	Tabel Edabriz	spindle	29/6	19/6	7/7
		trellis	2/7	22/6	9/7
	Total		1/7	20/6	9/7
Vanda	Gisela 5	spindle	25/6	14/6	6/7
		trellis	24/6	15/6	5/7
	P-HL-A	spindle	24/6	14/6	5/7
		trellis	23/6	14/6	5/7
	Tabel Edabriz	spindle	24/6	15/6	3/7
		trellis	23/6	16/6	2/7
	Total		24/6	14/6	4/7

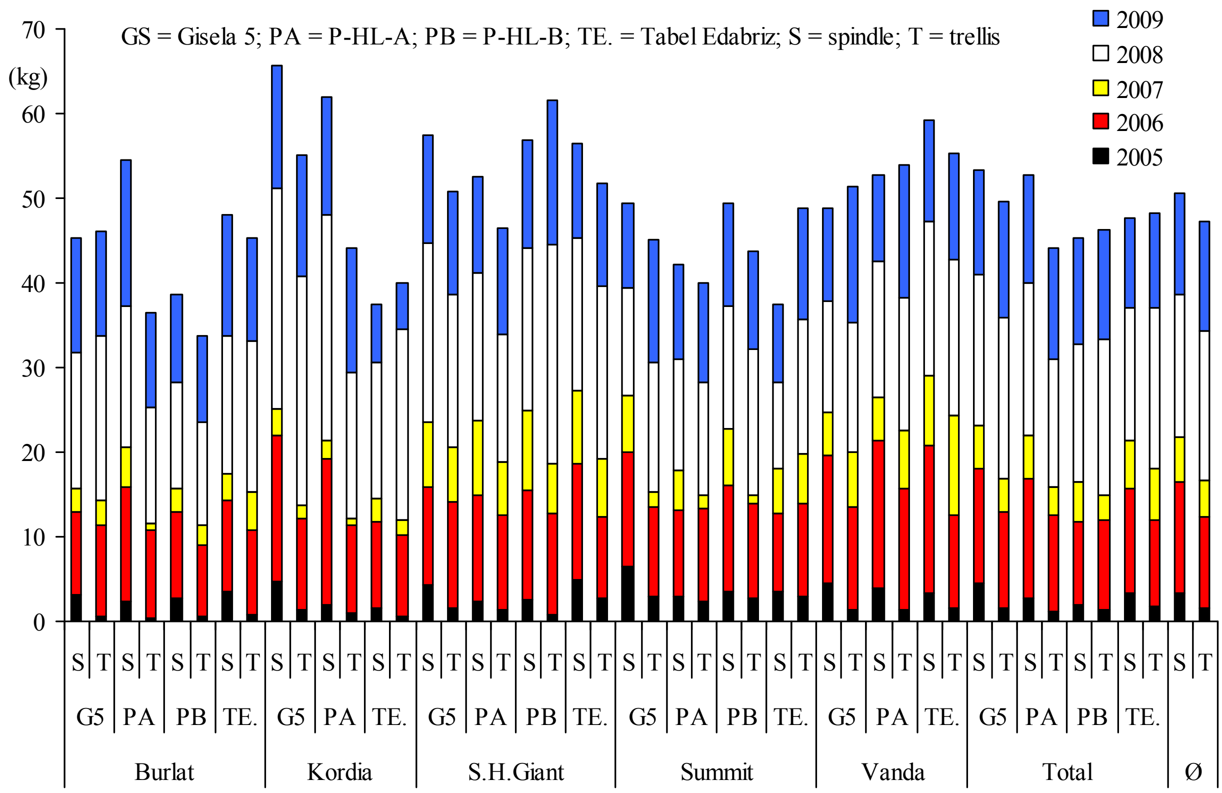

Fig. 1. Commulative yelds per tree (2005–2009) according to cultivars and rootstocks in two systems of tree training

Specific yields

Mean values of specific yields (kg/m^3 of canopy volume) that were obtained through dividing of annual tree harvests by its canopy volumes and their averaging are presented in Fig. 2. These values spanned from 1.08 to 2.66 kg. Generally higher specific yields were recorded on trellis. Remarkable in this respect was cv. Vanda and trees of Summit on P-HL-B and Starking Hardy Giant on Tabel

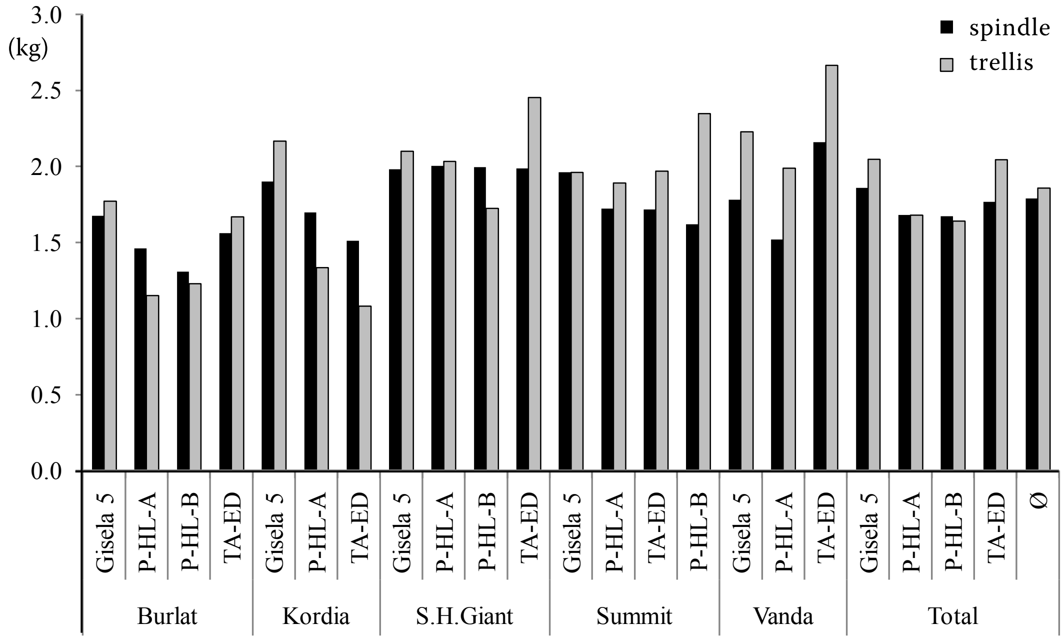

Fig. 2. Mean specific yields (kg/m^3) from 2005–2009 according to cultivars and rootstocks (TA-ED = Tabel Edabriz)

Edabriz. On the contrary higher specific yields on spindle were obtained with Kordia on P-HL-A and Tabel Edabriz as well as Burlat on P-HL-A.

The highest annual values of specific yields are presented in Fig. 3. The highest value (8.22 kg) was recorded on trees of Vanda on Tabel Edabriz on trellis. The lowest value of the parameter (2.59 kg) had Burlat on P-HL-B. Generally, trees of Vanda grown in trellis were outstanding in this characteristic and also some other cultivars grown on Gisela 5. With respect to spindle Starking Hardy Giant was also remarkable with exception of trees on Gisela 5.

Yields per acreage

Yields from the whole period of this study transferred to one hectare of the orchard area are presented in Table 5. Mean values of annual yields in spindle range between 10.0 to 17.5 t/ha whereas in trellis between 6.7 to 12.3 t/ha. The absolute highest annual yield (35.7 t) was recorded on spindle trees of Kordia on P-HL-A. In trellis, the highest yield of 27.1 kg was recorded in Kordia on Gisela 5. Yields from trellis were more than one third lower than those from spindles. This advantage of spindle over trellis was greater in Burlat and Kordia but much less in the case of cv. Vanda. With respect to rootstocks, trees on Tabel Edabriz in trellis had on average much better yields than those on the remaining rootstocks.

Considering yields per area, the following combinations of cultivars and rootstocks were relatively best and can be recommended for practical growing:

(a) in spindle: Burlat on P-HL-A, Kordia on Gisela 5 and P-HL-A, Starking Hardy Giant on all rootstocks, Summit on Gisela 5 and P-HL-B, and Vanda on all rootstocks.

(b) trellis: Burlat and Kordia on Gisela 5, Starking Hardy Giant on P-HL-B, Summit on Tabel Edabriz, and Vanda on Tabel Edabriz and P-HL-A.

Fruit size

Fruit size expressed in this study by fruit weight mainly depended on the cultivar (Table 6). From all the years the significantly largest fruits were obtained from Summit whereas the rest of cultivars did not differ much in this characteristic in the mean of one another. Weight of fruits was generally mainly dependent on the year. Its influence was partly connected with the level of fruit set but particular climatic conditions of each years seem to be more important in this respect.

Regarding rootstocks, their significant specific effect on fruit size was recorded in some years on some rootstocks only. For example in the case of cv. Burlat smaller fruits were harvested from trees on Gisela 5 in 2006 and on Tabel Edabriz in 2008.

Training system had no influence on fruit size in this study. Trees of any cultivar or its rootstock

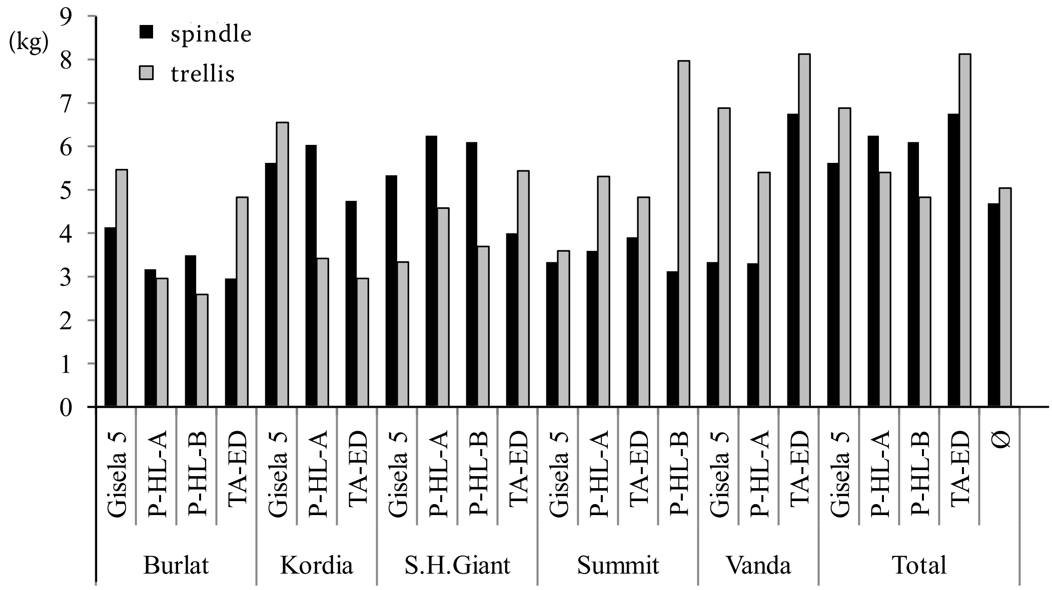

Fig. 3. Maximun specific yields (kg/m^3 of canopy volume) from 2005–2009 according to cultivars and rootstocks (TA-ED = Tabel Edabriz)

Table 5. Comparison of yields (t/ha) from 2005–2009 between spindle and trellis according to cutivars and rootstocks used

Cultivar	Rootstock	Spindle				Trellis			
		ø	IS*	Max	Min	ø	IS	Max	Min
Burlat	Gisela 5	12.1	0.9	21.5	3.7	9.2	0.7	19.4	0.6
	P-HL-A	14.6	0.9	23.2	3.1	7.3	0.7	13.7	0.4
	P-HL-B	10.3	1.0	16.8	3.6	6.7	0.9	12.2	0.6
	Tabel Edabriz	12.8	0.7	21.7	4.0	9.1	0.6	17.8	0.8
Kordia	Gisela 5	17.5	1.1	34.8	4.3	11.0	0.7	27.1	1.3
	P-HL-A	16.5	0.8	35.7	2.7	8.8	0.9	17.3	0.9
	Tabel Edabriz	10.0	1.2	21.5	2.1	8.0	1.2	22.7	0.5
S.H. Giant	Gisela 5	15.3	0.8	28.1	5.9	10.1	0.5	18.1	1.5
	P-HL-A	14.0	1.0	23.3	3.2	9.3	0.8	15.1	1.3
	P-HL-B	15.2	0.6	25.6	3.5	12.3	0.8	25.8	0.8
	Tabel Edabriz	15.0	0.7	24.0	6.7	10.4	0.6	20.3	2.7
Summit	Gisela 5	13.2	0.8	18.1	8.5	9.0	0.6	15.2	1.8
	P-HL-A	11.2	0.9	17.5	3.9	8.0	0.6	13.3	1.6
	P-HL-B	13.2	0.7	19.2	4.8	8.7	0.6	17.1	1.0
	Tabel Edabriz	10.0	0.8	13.5	4.8	9.8	0.6	15.8	2.9
Vanda	Gisela 5	13.0	0.9	20.3	6.0	10.3	0.7	16.2	1.3
	P-HL-A	14.1	1.2	23.2	5.3	10.8	0.7	15.8	1.3
	Tabel Edabriz	15.8	0.8	24.1	4.4	11.1	0.8	18.4	1.6
ø		13.5	0.9	22.9	4.5	9.4	0.7	17.9	1.3

*Interval of significant

Fig. 4. Flowering spindle trees of Vanda cv. on Gisela 5 in 2006

Fig. 5. Spindle trees of Vanda cv. on P-HL-A in 2007 before harvest

Table 6. Mean fruit weights according to cultivars and rootstocks

Cultivar	Rootstck	Mean fruit weight (g)*					
		2005	2006	2007	2008	2009	ø
Burlat	Gisela 5	7.8	4.6	10.1	7.2	6.4	7.2
	P-HL-A	7.5	5.6	10.3	7.5	6.5	7.5
	P-HL-B	7.7	5.3	10.0	7.2	6.5	7.3
	Tabel Edabriz	7.6	5.5	9.8	6.3	6.4	7.1
Kordia	Gisela 5	7.5	8.2	10.6	8.9	9.0	8.8
	P-HL-A	7.3	8.9	10.5	9.5	9.7	9.2
	Tabel Edabriz	7.4	7.3	10.2	8.5	9.8	8.6
S.H. Giant	Gisela 5	7.6	7.7	9.2	6.4	7.0	7.6
	P-HL-A	7.6	7.9	8.8	7.3	6.4	7.6
	P-HL-B	7.5	7.8	10.0	7.6	6.8	7.9
	Tabel Edabriz	7.7	7.8	9.0	6.5	7.0	7.6
Summit	Gisela 5	9.4	8.7	11.5	9.6	7.0	9.2
	P-HL-A	9.6	8.9	10.9	10.0	8.3	9.5
	P-HL-B	9.2	8.5	11.1	10.0	7.9	9.4
	Tabel Edabriz	9.6	9.4	10.8	9.1	7.9	9.4
Vanda	Gisela 5	7.4	7.1	9.1	7.7	7.4	7.7
	P-HL-A	6.9	8.0	10.5	8.2	7.4	8.2
	Tabel Edabriz	7.6	6.9	8.9	7.6	7.4	7.7

*Interval of significant for $P \geq 0.05$ is equal to 0.427

combination trained like spindle did not differ significantly in this characteristic from trees in trellis.

Interesting relationships

Within the present study, generally no influence of flower set was observed by fruit set in the previous year. The only significant exception in the matter was Kordia trained in spindle (Fig. 6). In this combination, trees with the highest fruit set (rated by points 8 or 9 within 1–9 rating scale) had lower flower set in the following year. This phenomenon did not occur on trees of this cultivar trained in trellis. Besides, a similar negative but very weak ($R^2 = 0.29$) relationship was found on trees of Summit trained in spindle.

Very interesting relationships were found between the level of fruit set and the time of ripening,

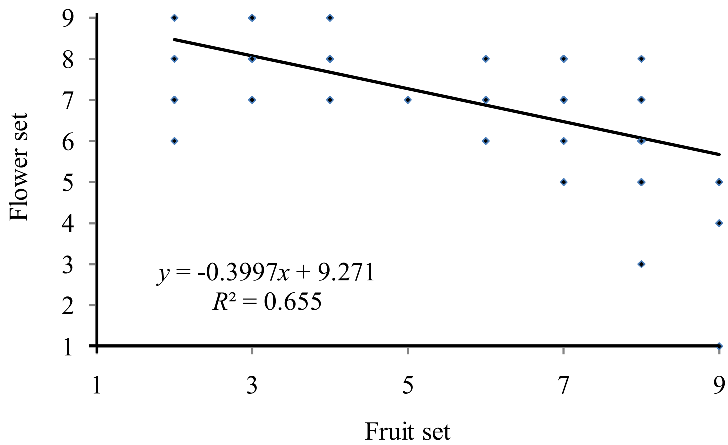

Fig. 6. Regression of flower set on fruit set in previous year for spindle trees of cv. Kordia

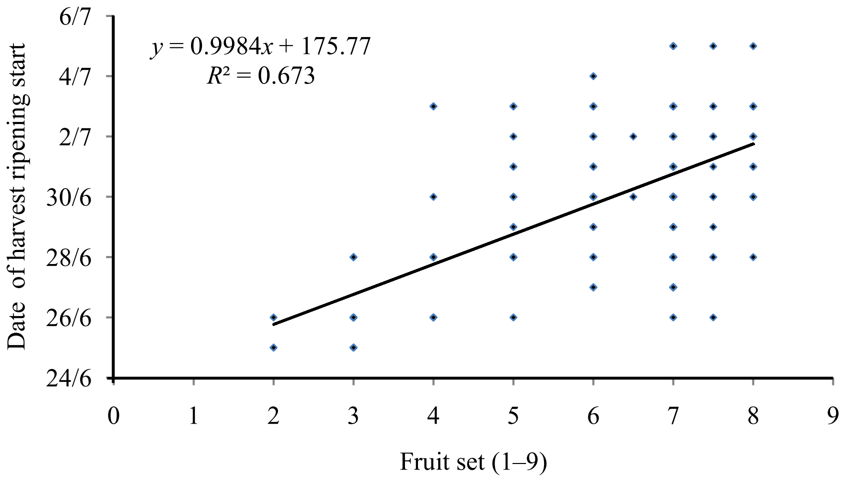

Fig. 7. Dependence of mean date of harvest ripening start on tree fruit set for cv. Sharking Hardy Giant

which was mainly dependent on the cultivar. The most significant positive relationship in this respect was observed on Starking Hardy Giant (Fig. 7). According to this relationship trees with the highest fruit set reached in the mean their proper harvest maturity about 4 days later than trees with very low fruit set. Similar relationships were also observed on Kordia (except for trees on Tabel Edabriz) and Vanda but highly significant were only those on trellis. No relationship between both characteristics existed in cv. Summit. A completely opposite negative relationship was recorded in cv. Burlat in both systems of tree training. Trees with higher fruit set started harvest maturity earlier than trees with low fruit set. Trees on P-HL-A rootstock were the most distinct by the highest level of the negative relationship.

DISCUSSION

Tree vigour

Concerning influence of rootstocks Tabel Edabriz and Gisela 5, our results are generally in agreement with conclusions of comparable trials from abroad (Hilsendegen 2005; Kappel et al. 2005; Usenik et al. 2006; Stehr 2005, 2008). Also growth parameters of P-HL-A correspond to findings from previous testing in Poland (Rozpara et al. 2004). Absolute values of canopy volume and trunk cross section area are difficult to compare as they are largely connected to soil quality, tree spacing and tree training systems used in the orchard (Green 2005; Lang 2005).

Growth parameters of older trees planted in dense spacing could also be restricted by their mutual competition. As soon as the tested trees fill up the allotted space in the planting their subsequent growth has to be regulated by restricted pruning. Therefore, measuring the canopy volume with advanced tree age becomes less accurate as indices of natural tree vigour. Similarly, the development of trunk-cross-section area can be negatively influenced by the increasing competition of adjacent trees. For these reasons, the nature of tree vigour should preferably be evaluated in plantings with sufficiently free spacing (Blažková, Hlušičková 2007).

Our present findings on influence of tree vigour by different tree training are in agreement with previous information published on the subject. Extent of tree pruning used in the first years after planting is probably the most important (Lang 2005; Robinson 2005).

Time of flowering

Differences in the start of flowering caused by rootstocks in this study were much less than those from our previous trials or found already in Germany (Blažková, Hlušičková 2007). This is evidently connected to the limited number of rootstocks and to the selection used in this study.

Time of ripening

Impact of some rootstocks on earlier start of fruit ripening observed in this study was already recorded in our previous observations (Blažková, Hlušičková 2007). There the span of the mean time of fruit ripening of Lapins cultivar on tested rootstocks was equal to 2.3 days. The earliest ripening was recorded on the rootstock Tabel Edabriz and the latest ripening on the rootstock G 154/7.

In Hungary, the cv. Germersdorfi 3 on Gisela 5 ripened 1 or 2 days earlier than on other rootstocks (Bujdosó, Hrotkó 2005). Even greater differences in time of ripening between rootstocks were observed in Poland (Rozpara et al. 2004).

Yields per tree

Quantities of fruits harvested from trees in this study were mainly dependent on the cultivar and its canopy volume. In some cases, however, also rootstock and tree training had a significant influence on this characteristic. Real incidence of these influences ensues from some assessments done in USA as well (Lang 2005).

Yield efficiency

Values of the characteristic in the study depended on tree training and on the special combination of cultivar and rootstock. Several among these most promising combinations could be supported by a range of previous findings from other countries. In a rootstock trial in Slovenia, Tabel Edabriz was evaluated as the rootstock with the highest yield efficiency (Usenik et al. 2006). In Germany, the highest productivity was achieved with Tabel Edabriz and Gisela 5 (Hilsendegen 2005). In Poland some cultivars had remarkable yield efficiency on P-HL-A (Grzyb et al. 2005).

Yields per acreage

In this characteristic, which is the most important for practical growers, the greatest difference was between both training systems of trees. In the mean, the advantage of spindles over trellis in this respect was very considerable. Despite it, even for growing on trellis it is possible to select some suitable cultivar-rootstock combinations that should be fully satisfactory for practical use. The other possibility for improvement of acreage yields consists in changing tree spacing according to tree vigour. The rationality of the conclusions is supported also from a range of current papers (Green 2005; Kappel et al. 2005; Lang 2005; Robinson 2005; Salvador et al. 2008; Stehr 2008).

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