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Growth and productivity of plum cultivars on various rootstocks in intensive orchard

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Summary: Trees of three plum cultivars (Stanley, Čačanska Lepotica and Althann's Gage) were planted at Szigetcsép experimental station in Spring 1994 and trained to slender spindle with the aim to test their growth, effect of productivity under not irrigated conditions and to evaluate the adaptability of rootstock/scion combinations to intensive orchards. As control, trees on Myrobalan C 162/A (*P. cerasifera*) seedling are planted. In the trial two rootstocks are from Slovakia: Myrobalan MY-KL-A (red leaf) and Myrobalan MY-BO-1, vegetatively propageted. Further on two French rootstocks, the Marianna GF 8-1: Marianna plum (*P. cerasifera x P. munsoniana*) and the Sainte Julien GF 655/2 (*P. insititia*) were involved. The Hungarian bred plum Fehér besztercei (*P. domestica*), which is recommended as apricot rootstock is also tested. Rootstocks MY-BO-1 and Fehér besztercei were planted with cultivar Stanley only. Trees were planted to a spacing of 5×3 m trained to slender spindle with 3–4 permanent basal branches. After yield start (1997) trees have been pruned only in summer, after harvest. In the alleyway the natural plant vegetation is mown, the orchard is not irrigated.

Based on tree size, vigorous rootstocks are Marianna GF 8–1 and Myrobalan C 162/A seedling, medium vigorous are MY-BO-1 and MY-KL-A; vegetative propageted myrobalan plums from Slovakia, while St. Julien GF 655/2 and Fehér Besztercei proved to be growth reducing rootstocks. No significant difference between the rootstocks was found in turning to bearing. Under non-irrigated condition at Szigetcsép, cultivar Stanley produced the highest yield per area unit on vigorous rootstock (GF 8–1). The cultivar Althann's Gage produced the highest yield efficiency on Marianna GF 8–1 and they were healthy in the last 10 years. The symptoms of Althann's Gage trees on MY-KL-A rootstock indicate a possible incompatibility. The average fruit weight was significantly influenced by crop load on cultivar Čačanska lepotica, while no statistically proved differences were found on Stanley and Althann's Gage. The Čačanska lepotica trees produced significantly lower yield and larger fruit weight on St. Julien GF 655/2 rootstock. Adaptability to spindle training system depends on vigour of scion/rootstock combination: low or medium vigour cultivars (C. lepotica, Stanley) are good choice for spindle training systems even on vigorous rootstock; while the St. Julien GF 655/2 can be recommended only for vigorous Althann's Gage under our soil and climate conditions.

Key words: Fehér besztercei, fruit weight, graft compatibility, growth vigour, MY-BO 1, MY-KL-A, Myrobalan seedling, Marianna GF 8-1, productivity, Saint Julien GF 655/2, spindle tree training, turning to bearing, varieties

Introduction

Plum growers in Hungary today are more interested in mechanical harvesting which needs large plant distances and vigorous rootstocks. That is why nurseries in Hungary bud plum trees almost all on myrobalan *(Prunus cerasifera)* seedlings of selected seed trees (*Hrotkó* et al. 2002). However, the future market development may be directed more to fresh market quality, there is no, or very little information on the behaviour of plum tree on growth reducing rootstocks under our dry, non-irrigated environmental conditions, which is typical to our plum growing areas.

In the last fifteen years, large number of new rootstocks have been examined providing considerable tree size reduction (*Hrotkó* et al 2002, *Sitarek* et al. 2002, *Achim* et al. 2004, *Balkhoven-Baart & Maas* 2004, *Botu* et al. 2002, 2004, *Grzyb* 2004, *Lepsis* et al. 2004). Further rootstocks were selected tolerant or resistant to iron-induced chlorosis in dry calcareous soils, nematodes (*Moreno* 2004), and some with cold tolerance and winter hardiness (*Lepsis* et al. 2004). Some of them are nowadays widespread used in the European plum growing. These new rootstocks combined with the training system could serve as an appropriate basis for high density orchards (*Mika* et al. 1998, *Čmelik* et al. 2002, *Grzyb* et al. 2002, *Balkhoven-Baart & Maas* 2004, *Botu* et al. 2004, *Sitarek* et al. 2004). Rootstocks used in different sites must be adapted to local environmental conditions, which is an important factor in efficient production (*Hrotkó* et al 2002). Thus rootstock testing plays an important role in plum research.

The main goal of our trial, started in 1994, was to test some vegetative propagated rootstocks considering their growth, yield efficiency and compatibility in our soil and climate conditions. On the other hand, this trial allows us to evaluate the adaptability of rootstock-scion combination to spindle training system, which was new to Hungarian conditions (*Hrotkó* et al 2002).

Materials and methods

Tested rootstocks

Myrobalan C 162/A (*Prunus cerasifera*) seedling (Hungarian Myrobalan selection) as control

Myrobalan MY-KL-A: vegetative propagated, red-leaf myrobalan, selected in Slovakia Myrobalan MY-BO-1: vegetative propagated, selected in Slovakia also.

Marianna GF 8-1 (*P. cerasifera x P. munsoniana*): vegetative propagated Marianna plum selected in France.

'Sainte Julien' GF 655/2 (*P. insititia*): vegetative propagated St. Julien plum, selected in France also.

'Fehér besztercei' (*P. domestica*): vegetative propagated Hungarian selection, used as apricot rootstock, as plum rootstock not tested yet.

Tested cultivars: 'Stanley', medium vigorous, 'Čačanska lepotica', low vigor and 'Althann's Gage', extremely vigorous, served as indicator of graft incompatibility.

The soil was sandy loam layered on alluvial ground, with high pH (7.8) and Ca content (18%), land low organic matter content (1.2%). The climate characteristics: yearly average temperature was 10.8 °C, 1998 sunshine hours total in a year, yearly precipitation 520 mm in average of the past 50 years.

Orchard conditions: Planting in 1994 spring to a plant distance: 5×3 m. The tree architecture was spindle with permanent basal branches, fruiting branches were formed on central leader and on basal branches. Pruning was done once a year, in summer, after harvest. In the alleyway mown natural vegetation grew from the third year. The orchard was non-irrigated.

Trial design: 3 trees/plot, repeated four times in randomized blocks. Measured data were trunk circumference, canopy size/tree, crop weight/tree, 50 fruits' weight/tree. Calculated data were trunk cross sectional area (TCSA) in cm^2, projected canopy area (CA) in m^2, canopy volume (CV) in m^3. Further calculated data on yield efficiency: cumulative yield (CY) 1997–2003 kg/tree, cumulative yield efficiency (CYE) 1997–2003 (kg/TCSA cm^2, kg/CA m^2 and kg/CV m^2), mean fruit weight (MFW) of 50 fruit/tree in g/fruit and calculated yield (t/ha). Data were tabulated and statistically analysed, means were separated by Duncans' Multiple Range Test.

Results

Trees planted in 1994 grew well, tree losses were not significant (*Table 1*). Tree size measured in 2003 showed significant differences in trunk cross sectional area on various rootstocks (*Tables 2, 5* and *8*). Largest TCSA and canopy area of Stanley trees was produced on those budded on C 162/A seedlings, while smallest produced on the Fehér besztercei understock. The canopy volume did not show significant differences (*Table 2*).

The cumulative yield efficiency calculated from data of seven years (1997–2003) shows significant differences among

Table 1. Tree number and survival

Rootstock	Stanley			Čačanska lepotica			Althann's Gage		
	1994	2003	%	1994	2003	%	1994	2003	%
Myr. C 162/A	15	14	*93*	13	13	*100*	13	12	*93*
MY-KL-A	14	12	*86*	14	14	*100*	12	9	*75*
MY-BO-1	15	14	*93*	–	–	–	–	–	–
GF 8–1	16	15	*94*	17	17	*100*	12	12	*100*
GF 655/2	15	14	*93*	7	5	*71*	10	10	*100*
F. Besztercei	10	9	*90*	–	–	–	–	–	–

Table 2. Tree size of 'Stanley' (Szigetcsép, 2003)

Rootstock	Trunk cross sectional		Canopy area area		Canopy volume	
	cm^2	%	m^2	%	m^2	%
F. Beszt.	62.56 a	*59*	4.41 a	*70*	6.61 a	*63*
GF 655/2	66.33 ab	*62*	5.12 ab	*82*	7.10 a	*68*
MY-BO-1	87.26 bc	*82*	5.67 ab	*90*	10.31 a	*98*
MY-KL-A	88.62 c	*83*	5.04 ab	*80*	7.90 a	*75*
C 162/A	106.23 c	*100*	6.28 b	*100*	10.49 a	*100*
GF 8–1	100.09 c	*94*	5.84 b	*93*	10.55 a	*101*
SZD5%	22.07		1.26		4.05	

Table 3. Cumulative yield and cumulative yield efficiency of 'Stanley'

Rootstock	Cumulative yield		Cumulative yield efficiency					
	kg/tree	%	kg/cm^2	%	kg/m^2	%	kg/m^3	%
F. Beszt.	54.07 a	*59*	1.01 a	*103*	15.69 a	*81*	11.18 a	*89*
GF 655/2	68.57 ab	*75*	1.21 a	*123*	16.93 ab	*87*	12.07 a	*96*
MY-BO-1	94.92 bc	*103*	1.31 a	*134*	21.77 bc	*112*	13.32 a	*106*
MY-KL-A	77.93 ab	*85*	1.01 a	*103*	19.25 abc	*99*	13.23 a	*105*
C 162/A	91.88 bc	*100*	0.98 a	*100*	19.41 abc	*100*	12.59 a	*100*
GF 8–1	119.80 c	*130*	1.34 a	*137*	23.64 c	*122*	14.36 a	*114*
SZD5%	29.66		0.37		5.19		3.77	

Table 4. Recommended plant distance and calculated yield (t/ha) for 'Stanley'

Rootstock	Canopy diameter, cm**	Yield, kg/tree*	Plant distance, m	Trees/ha	Yield, t/ha	
					1	2
F. Besztercei	184 a	10.4 a	3.5 × 1.6	1786	18.6	17.7
GF 655/2	210 ab	12.7 ab	4 × 1.8	1388	17.7	16.4
MY-KL-A	210 ab	17.5 bc	4 × 1.8	1388	22.6	20.0
MY-BO-1	213 ab	14.4 ab	4 × 1.8	1388	24.3	17.2
Myr. C 162/A	230 b	16.3 b	4 × 2	1250	20.3	18.9
GF 8–1	244 b	21.8 c	4 × 2	1250	27.2	25.6
SZD5%	35.7	5.4				

*average of last five years, **average of last three years, 1 – no tree loss, 2 – considering the survival rate

the trees budded on different rootstocks and the cultivars also performed differently in this consideration (*Tables 3 and 4*).

Largest cumulative yield was produced on Stanley trees budded on GF 8–1, followed by MY-BO-1 and C 162/A, while smallest on Fehér besztercei. Results on MY-KL-A, and GF 655/2 did not differ from Fehér besztercei. Yield efficiency calculated on canopy volume basis showed significant differences, largest on GF 8–1, followed by MY-BO, smallest on Fehér besztercei (*Table 3*). The cultivar Čačanska lepotica performed differently, the cumulative yield was significantly smaller only on St. Julien GF 655/2 rootstock. The largest yield efficiency on TCSA basis was found on Marianna GF 8–1, while significantly lower efficiency was found on Myrobalan C 162/A and St- Julien GF 655/2. On canopy area and volume basis there was no significant difference, but the highest efficiency showed the GF 8–1 rootstock (*Table 6*). Althann's Gage produced largest cumulative yield on Marianna GF 8–1 rootstock, significantly smaller on MY-KL-A. (*Table 7*) The largest yield efficiency on TCSA basis was found on St. Julien GF 655/2, while on MY-KL-A the cumulative yield efficiency was significantly the smallest (*Table 9*).

The trunk cross sectional area of Čačanska lepotica was largest on Marianna GF 8-1, followed by Myrobalan seedling and MY-KL-A, significantly smaller TCSA was produced on St. Julien GF 655/2. Considering the canopy (CA and CV) smallest size showed GF 655/2 (*Table 5*). The TCSA of Althanns Gage was largest on Marianna GF 8-1, followed by Myrobalan C 162/A seedling, while significantly smaller size was produced on MY-KL-A and St. Julien GF 655/2 rootstocks. In the canopy size (CA and CV) only the GF 655/2 showed consequently smaller size in comparison to GF 8–1 (*Table 8*).

The mean fruit weight performed typical to cultivars, largest fruits produced Althanns Gage, a little smaller fruits on cultivars Čačanska lepotica and Stanley. Considering the mean fruit weight in average of five full crop years no significant differences were found among the fruit samples collected from Stanley trees on various rootstocks, while the mean fruit weight differs significantly on Althann's Gage and Čačanska lepotica trees budded on various rootstocks. For Čačanska lepotica the trees

Table 5. Tree size of 'Čačanska Lepotica' (Szigetcsép, 2003)

Rootstock	Trunk cross sectional		Canopy area area		Canopy volume	
	cm^2	%	m^2	%	m^2	%
GF 655/2	63.65 a	*74*	3.41 a	*75*	4.74 a	*71*
MY-KL-A	86.23 b	*101*	4.24 a	*93*	6.27 a	*94*
C 162/A	85.83 b	*100*	4.56 a	*100*	6.64 a	*100*
GF 8–1	89.25 b	*104*	4.41 a	*97*	5.90 a	*89*
SZD5%	12.31		1.50		2.80	

Table 6. Cumulative yield and cumulative yield efficiency of 'Čačanska Lepotica'

Rootstock	Cumulative yield		Cumulative yield efficiency					
	kg/tree	%	kg/cm^2	%	kg/m^2	%	kg/m^3	%
GF 655/2	40.26 a	*74*	0.79 a	*85*	18.37 a	*92*	13.63 a	*101*
MY-KL-A	71.35 b	*101*	0.98 ab	*105*	22.81 a	*115*	15.44 a	*115*
C 162/A	69.65 b	*100*	0.93 a	*100*	19.86 a	*100*	13.47 a	*100*
GF 8–1	86.40 b	*104*	1.13 b	*122*	26.02 a	*131*	18.93 a	*141*
SZD5%	19.48		0.20		9.86		8.04	

Table 7. Recommended plant distance and calculated yield (t/ha) for 'Čačanska Lepotica'

Rootstock	Canopy diameter, cm**	Yield, kg/tree*	Plant distance, m	Trees/ha	Yield, t/ha	
					1	2
F 655/2	139 a	7.7 a	3.5 × 1.2	2381	18.2	12.9
MY-KL-A	180 b	12.1 b	3.5 × 1.5	1905	23.1	23.1
Myr.C 162/A	198 b	11.8 b	4 × 1.7	1470	17.4	17.4
GF 8–1	202 b	14.3 b	4 × 1.7	1470	21.1	21.1
SZD5%	28.0	3.3				

*average of last five years, **average of last three years, 1 – no tree loss, 2 – considering the survival rate

Table 8. Tree size of 'Althann's Gage' (Szigetcsép, 2003)

Rootstock	Trunk cross sectional		Canopy area area		Canopy volume	
	cm^2	%	m^2	%	m^2	%
MY-KL-A	114.22 a	*75*	4.45 a	*90*	6.47 a	*77*
GF 655/2	103.79 a	*68*	4.64 ab	*94*	7.13 ab	*85*
C 162/A	151.60 b	*100*	4.94 ab	*100*	8.39 ab	*100*
GF 8–1	159.84 b	*105*	5.37 b	*109*	9.17 b	*109*
SZD5%	27.69		0.77		2.20	

Table 9. Cumulative yield and Cumulative yield efficiency of 'Althann's Gage'

Rootstock	Cumulative yield		Cumulative yield efficiency					
	kg/tree	%	kg/cm^2	%	kg/m^2	%	kg/m^3	%
MY-KL-A	39.88 a	*76*	0.45 a	*107*	12.81 a	*91*	9.29 a	*106*
GF 655/2	53.59 ab	*102*	0.63 b	*150*	15.28 a	*108*	9.91 a	*113*
C 162/A	52.52 ab	*100*	0.42 a	*100*	14.13 a	*100*	8.74 a	*100*
GF 8–1	68.64 b	*131*	0.51 ab	*121*	16.08 a	*114*	9.94 a	*114*
SZD5%	20.69		0.16		5.12		3.59	

Table 10. Recommended plant distance and calculated yield (t/ha) for 'Althann's Gage'

Rootstock	Canopy diameter, cm**	Yield, kg/tree*	Plant distance, m	Trees/ha	Yield, t/ha	
					1	2
MY-KL-A	176 a	6.6 a	3.5 × 1.5	1905	12.6	9.4
GF 655/2	189 ab	8.8 ab	4 × 1.7	1470	13.0	13.0
Myr.C 162/A	193 ab	9.4 ab	4 × 1.7	1470	13.8	12.8
GF 8–1	214 b	10.6 b	4 × 1.8	1388	14.7	14.7
SZD5%	30.4	3.5				

*average of last five years, **average of last three years, 1 – no tree loss, 2 – considering the survival rate

Table 11. Mean fruit weight (MFW) of 50 fruit/tree (Szigetcsép, 1999–2003)

Rootstock	Mean fruit weight, g/fruit		
	Stanley	C. lepotica	Althann
F. Beszt.	32.1 a	–	–
GF 655/2	32.9 a	49.1 b	46.3 b
MY-BO-1	36.2 a	–	–
MY-KL-A	36.1 a	37.1 a	35.9 a
C 162/A	36.8 a	35.9 a	45.0 b
GF 8-1	36.7 a	36.5 a	44.8 b
SZD5%	6.0	10.1	7.3

budded on St. Julien GF 655/2 rootstock produced significantly largest, while for Althann's Gage on MY-KL-A rootstock was the smallest the fruit weight (*Table 5*).

Discussion

Our data collected over ten years in the orchard, in comparison to literature allows to evaluate the tested rootstocks and cultivars in spindle training system and dry conditions.

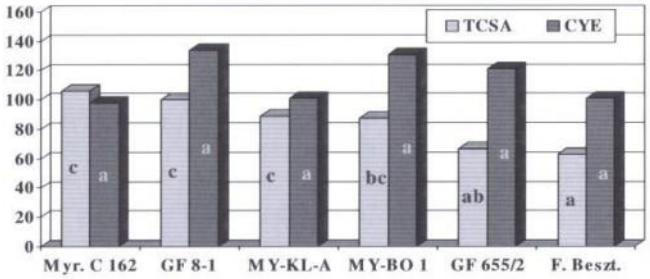

Figure 1 Growth (TCSA, cm^2) and cumulative yield efficiency (CYE, dkg/cm^2) of 'Stanley'

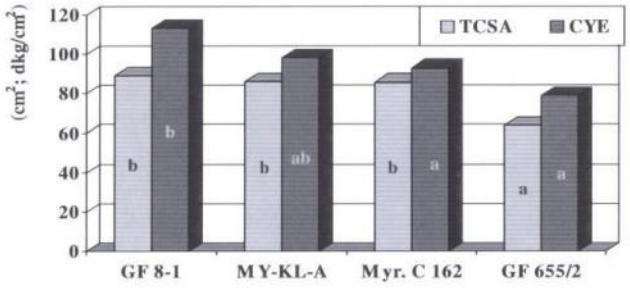

Figure 2 Growth (TCSA, cm^2) and cumulative yield efficiency (CYE, dkg/cm^2) of ' Čačanska lepotica'

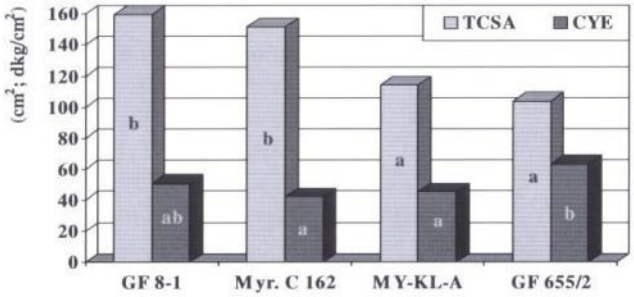

Figure 3 Growth (TCSA, cm^2) and cumulative yield efficiency (CYE, dkg/cm^2) of 'Althann's Gage'

Considering the growth vigour of rootstocks our results confirm the literature data and our statements in preliminary paper. Based upon the tree size the tested rootstocks could be assigned into three groups. Vigorous are the Marianna plum GF 8-1 and Myrobalan seedling C 162/A, medium vigorous are rootstocks MY-BO-1 and MY-KL-A, while considerable size reduction was showed by Saint Julien GF 655/2 and Fehér besztercei. The canopy size is not always proportional to the trunk cross sectional area, which is partly caused by the pruning, partly by the rootstock effect on the various spreading of the canopy. Cultivar Althanns Gage performed differently on MY-KL-A root, namely the trees seemed definitely dwarfed in the first four years, later on caught up with St. Julien GF 655/2. However, there is no considerable tree loss or breakage in the grafting unit of this combination, the leaf symptoms and the low efficiency, smaller fruit size indicate some graft incompatibility.

Trees in the fourth leaf turned to bearing. After analysing the yield efficiency of the first crops the vigorous rootstocks seemed to be more precocious, which can be explained by the non-irrigated conditions.

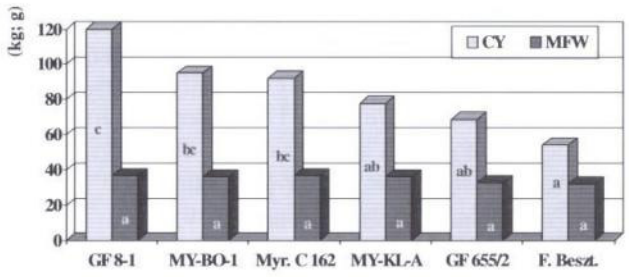

Figure 4 Mean fruit weight (MFW, g) and cumulative yield (CY, kg) of 'Stanley'

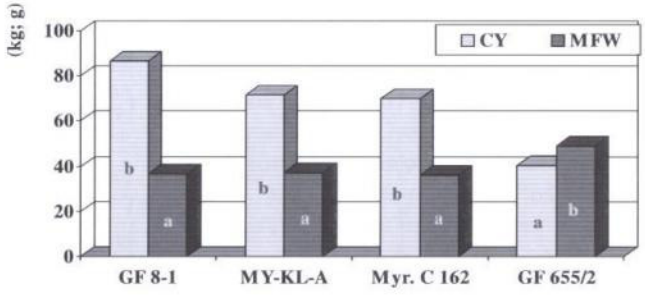

Figure 5 Mean fruit weight (MFW, g) and cumulative yield (CY, kg) of 'Cacanska Lepotica'

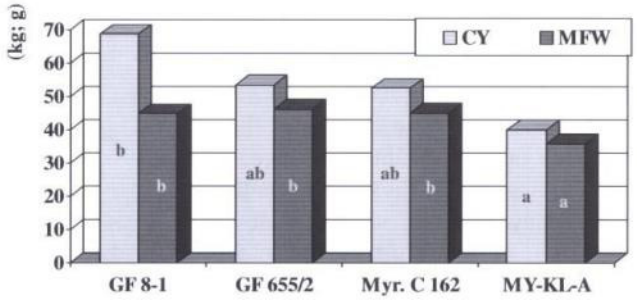

Figure 6 Mean fruit weight (MFW, g) and cumulative yield (CY, kg) of 'Althann's Gage'

Because of the different growth performance in TCSA and canopy size in the ranking of rootstock productivity there are some differences in the calculations on different basis. In the full crop years the productivity of Stanley and Čačanska lepotica trees also on vigorous rootstocks was higher, best results have been achieved on Marianna GF 8-1 on TCSA basis. Similarly good is the productivity of these cultivars on Myrobalan C 162/A and MY-BO, while and for Čačanska lepotica on MY-KL-A. In contrary to the literature data the low vigor rootstocks were not efficient, which may be caused by the non-irrigated conditions. The yield efficiency of the vigorous Althann's Gage was best on the semi dwarfing St. Julien GF 655/2 calculated on both basis, which agrees with literature data, but similarly good productivity was shown by the vigorous Marianna GF 8–1. The low productivity of tree on MY-KL-A might be caused by the suspected graft incompatibility mentioned before. We concluded that for low or medium vigour cultivars in non-irrigated conditions in Hungary first of all the vigorous Marianna GF 8-1, the Myrobalan seedling C 162/A, for Čačanska lepotica the MY-KL-A and for Stanley the MY-BO-1 can be recommended. The low vigour rootstocks should be tested in irrigated conditions, but for vigorous cultivars, like Althann's Gage, St. Julien GF 655/2 seems to be promising even in non-irrigated conditions.

The effect of rootstocks on mean fruit weight seems to be clear on tree Čačanska lepotica, although the comparison with the yield efficiency indicates some influence of fruit load on trees budded on St. Julien GF 655/2. Another tendency is on Stanley and Althanns Gage, the larger yield efficiency results in smaller fruit weight, but for cultivar Stanley there is no significant difference between rootstocks.

Well branched one-year-old nursery trees on medium vigorous and vigorous rootstocks provide proper plant material for further training to spindle trees while trees on dwarfing rootstocks are difficult to form in the first years because of the poor growth. Unpruned feathered trees turn to bearing earlier but the pruning of wide angled basal feathers helps to get well branched permanent basal limbs in the basis of the canopy. Leaving the central leader unpruned from the second year the terminal growth can be reduced in the third and fourth years and the tree turns to bearing. In the bearing years the spindle trees on vigorous rootstocks needed more summer pruning than those on medium vigourous or semi dwarf rootstocks.

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