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THE EFFECT OF CULTIVAR ON THE GROWTH AND RELATIONS BETWEEN GROWTH CHARACTERS IN "KNIP-BOOM" APPLE TREES

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Abstract. The measurements have been performed in the nursery in the years 2007–2013 to study differences in size and correlations between selected growth factors in "knip-boom" trees of 6 apple cultivars on M.9 rootstock. The trees of 'Jonagold Decosta' ('Red Jonaprince' in 2013) and 'Fuji Beni Shogun' showed the strongest growth, 'Šampion' and 'Camspur' the weakest one, whereas 'Gala Must' and 'Golden Delicious Reinders' were characterized by moderate vigor. Mean length of one feather increased from the tree top towards its base, but did not depend significantly on the number of laterals per tree. Correlations between growth factors were similar to those found in maiden apple trees and the closest ones were between total length of lateral shoots and their number on the tree. A trunk diameter had stronger correlations with other growth parameters than tree height.

Key words: nursery of apple trees, cultivars, size, growth correlations

INTRODUCTION

The behavior of two-year-old trees with one-year-old crown ("knip-boom") in the first years of yielding in orchards including differences between cultivars, rootstocks and methods of propagation of apple trees, has been widely studied. Many authors showed advantages resulting from "knip-boom" trees planting: van Oosten [1978], van der Berg [2003], Bielicki et al. [2003], Świerczyński and Stachowiak [2003], Sadowski et al. [2006, 2007], Gudarowska and Szewczuk [2006], Pietranek and Jadczuk [2006] in apples; Jacyna [2004], Milosević and Milosević [2010] in pears; Jacyna and Lipa [2008] in sweet cherries. Consequently, growing interest of growers to plant such trees in orchards has been recently observed. The influence of cultivar on the growth and quality of "knip-boom" trees seems to be not sufficiently recognized, whereas such an effect in the case of maiden trees is well known [Ostrowska and Chełpiński 1997, Lipecki and Janisz 1999, 2004; Kopytowski et al. 2006, Jacyna 2007, Lewko et al. 2007, Milosević

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and Milosević 2010, Stachowiak and Świerczyński 2011]. It is interesting to find out whether there are similarities in growth tendencies between one-year-old and "knip-boom" trees. If so, it might be necessary to use different methods to stimulate feathers formation in "knip-boom" trees of some cultivars, including growth regulators, as it is practiced in production with of maidens cultivars having poor ability to feathering. According to: Kapłan and Baryła [2006], Kopytowski et al. [2006], Sadowski et al. [2006], Sazo and Robinson [2011] this practice is advised or already applied in a case of "knip-boom" trees.

The relationships between growth characters in one-year-old fruit trees were studied by numerous authors [Ostrowska and Chełpiński 1997, Lipecki and Janisz 1999, Jacyna 2007] and several regularities have been reported. For example, Lipecki and Janisz [1999] found highly significant correlation between the trunk diameter and total length of laterals; it was much higher than between the stem diameter and tree height. Thus, the authors concluded that stem diameter is more adequate than height in evaluating the quality of a tree, since the ability to early yielding is closely related to the number and size of feathers [Poniedziałek et al. 1996]. Similar data concerning "knip-boom" type trees are limited. A knowledge on this subject is essential for better understanding their biology and – consequently – for reasonable management of trees. Relations between growth and bearing of the trees in the orchard are well recognized [Lauri et al. 2006, Tworkoski and Miller 2007].

The purpose of the investigations reported here was to establish the effect of cultivar on size of "knip-boom" type of apple trees and to check whether correlations between several growth indices in this type of trees are similar to those observed in maidens and whether they are changing in the years.

MATERIAL AND METHODS

Experiments were performed in a commercial nursery located in Lublin area (22°34'E, 51°14'N) in the years 2007–2013 on the soils never used before for nursery or fruit production, with medium content of mineral elements, without irrigation. For example, the soil in the experimental field in the year 2007 contained 4.5 mg·100 g^{-1} of P, 12.4 of K and 7.4 of Mg, with pH in the superficial layer of 4.92.

The lowest rainfalls occurred in 2012 (372.4 mm in vegetation period), the highest in 2010 (610.8 mm); means for other experimental years was 436.2 mm (tab. 1). The mean air temperatures in vegetation period were similar: from 14.2 to 14.6°C and exceeded the long-term average by about 1.3°C. Generally, soil and weather conditions were proper for nursery production. The following apple cultivars were compared: 'Gala Must', 'Fuji Beni Shogun', 'Golden Delicious Reinders' and 'Jonagold Decosta in 2007 and 'Gala Must', 'Fuji Beni Shogun', 'Jonagold Decosta 2008; 'Jonagold Decosta' and 'Šampion' in 2009, 'Šampion' and 'Camspur' (spur-type cultivar) in 2012 and 'Golden Delicious Reinders' and 'Red Jonaprince' in 2013. Cultivars were chosen according to recent recommendations for fruit growers. Every 10–15 tree in randomly selected rows in nursery was measured and total number of trees in autumn was 776 ('Fuji Beni Shogun' – 60, 'Gala Must' – 60, 'Golden Delicious Reinders' – 339, 'Jona-

Table 1. Mean monthly air temperatures and precipitation in the years 2007–2013 against the multi-year mean values (1951–2012) in AES Felin near Lublin

	Month	2007	2008	2009	2010	2011	2012	2013	Multi year mean
Temperature (°C)	April	8.7	9.4	11.4	9.4	10.0	9.2	8.1	7.4
	May	15.0	13.5	13.6	14.5	13.6	14.6	15.3	13.0
	June	18.1	18.2	16.4	18.0	18.0	16.8	18.5	16.3
	July	19.2	18.8	19.9	21.6	17.9	20.7	19.2	18.0
	August	18.4	18.9	19.0	20.2	18.2	18.5	19.2	17.2
	September	13.0	12.7	15.3	12.5	14.6	14.4	11.8	12.6
	October	7.1	9.8	6.9	5.6	7.5	7.7	10.0	7.6
Precipitation (mm)	April	17.4	59.0	2.9	24.5	34.0	39.1	51.1	39.0
	May	81.5	74.3	71.1	156.7	54.1	33.8	101.6	60.7
	June	87.5	29.4	125.5	65.6	79.7	67.6	105.9	65.9
	July	87.0	99.4	57.1	101.0	166.6	61.2	126.1	82.0
	August	37.6	31.0	54.7	132.8	32.0	44.7	17.8	70.7
	September	129.8	83.3	21.0	119.0	5.1	38.4	64.6	53.7
	October	17.7	36.8	103.6	11.2	26.7	87.6	5.4	40.1

gold Decosta' – 90, 'Red Jonaprince' – 79, 'Šampion' – 88, 'Camspur' – 60). Trees damaged or deformed were omitted. They were propagated by chip-budding in 2007 and by grafting in winter in the next years, on M.9 T337 rootstock. All trees were treated according to the methods commonly used in commercial nursery production; details are described by Lipecki et al. [2013]. In the years 2007–2009 stem diameters of trees were measured in spring at three points: below and above the place of budding/grafting and at the height of 60 cm, on which the trees were headed according to Czarnecki [1998] and Bielicki et al. [1998]. The measurements were performed again in autumn, including tree height, length of lateral shoots longer than 10 cm and stem diameters at two points, omitting the height 60 cm. Total and mean length of laterals and number of them per one tree were then calculated. To simplify the presentation of the results, the average data were calculated separately for cultivars and years, independently of production method. Statistical analysis were performed according to complete randomization design and means were compared with Duncan's multiple range test, separately for each year. Correlation coefficients between characters studied were counted with the use of Statistica software.

RESULTS AND DISCUSSION

An average number of feathers per one tree was 8.0; two trees (0.4%) had no lateral shoots, whereas the highest number of laterals per one tree was 17. Generally, the distribution of trees with different shoot number was normal, 61.8% of trees had 6–11

lateral shoots. Stem diameter of trees in spring one year after planting in nursery (before heading) varied depending on the year, but was not clearly related to the cultivar (tab. 2). There were no statistically proved differences in this character in 2007. In spring 2008 trees of 'Gala Must' had stems significantly thinner than other cultivars and in spring 2009 diameters of 'Šampion' stems were significantly bigger than those of 'Jonagold Decosta' except the diameter below the place of grafting.

Table 2. The effect of year and cultivar on the stem diameter of trees in spring

Year	Cultivar	Diameter 'below' (mm)	Diameter 'above' (mm)	Diameter (mm) at the height of 60 cm
2007	Gala Must	15.35 a	11.41 a	8.76 a
	Fuji Beni Shogun	15.03 a	11.02 a	8.02 a
	Golden D.R.	15.23 a	11.20 a	8.51 a
	J. Decosta	15.23 a	11.81 a	8.82 a
2008	Gala Must	12.24 a	10.24 a	7.07 a
	Fuji Beni Shogun	14.13 b	12.35 b	7.99 b
	J. Decosta	13.88 b	11,68 b	8.85 c
2009	J. Decosta	14,66 a	11.43 a	8.85 a
	Šampion	15.03 a	12.33 b	9.40 b

Explanations: diameters were measured approx. 5 cm 'below' and 'above' the place of budding/grafting; means followed by the same letters do not differ significantly at 5% of probability (between cultivars within years)

In autumn 2007, the trees of 'J. Decosta', 'Golden Delicious Reinders' and 'Fuji Beni Shogun' were in most cases bigger than 'Gala Must' ones.

'Fuji Beni Shogun' trees had significantly thicker stems than other cultivars in the autumn 2008, but the strongest growth of laterals was observed in a case of 'Jonagold Decosta', with 'Gala Must' again giving the smallest trees. In autumn 2009 'Jonagold Decosta' trees were again the biggest, having significantly more and longer feathers than the 'Šampion' (tab. 3). Also, in 2013, trees of ('Red Jonaprince' cv. were bigger than those of 'Golden Delicious Reinders'. The height of trees was uniform except of 'Šampion' and 'Camspur', which were lower than those of remaining cultivars, they also had lower sum of lateral shoots, their number and mean length. However, in 2009 Šampion trees had thicker stems than those of other cultivars, similarly as it was in spring. Generally, 'Camspur' formed smaller trees than the other cultivars, including 'Šampion'.

The cultivars studied could be grouped as follows: 'J. Decosta' ('Red Jonaprince') and 'Fuji Beni Shogun' demonstrated strong growth and easy formation of laterals, 'Golden Delicious Reinders' showed intermediate results, whereas 'Šampion', 'Gala Must' and especially 'Camspur' were characterized by weak growth and low ability to form feathers.

Table 3. The effect of cultivar on the trees size and feathering in autumn

Year	Cultivar	Diameter 'below' (mm)	Diameter 'above' (mm)	Height (cm)	Total length of shoots (cm)	Number of shoots	Mean shoot length (cm)
2007	Gala Must	22.17 a*B**	14.85 aA	172.6 aA	341.0 aB	8.33 aA	41.1 aB
	Fuji B. Shogun	22.55 aA	14.89 aA	172.8 aA	406.8 bB	10.27 bB	40.2 aA
	Golden D.R.	22.49 aB	15.07 aA	174.9 aA	454.9 bC	10.27 bC	44.6 bC
	J. Decosta	22.91 aB	16.03 bA	171.3 aA	430.7 bB	10.17 bA	42.2 abB
2008	Gala Must	18.26 aA	14.67 aA	171.6 aA	246.0 aA	7.27 aA	33.4 aA
	Fuji Beni Shogun	22.56 cA	19.12 cB	184.7 bB	320.5 aA	7.17 aA	44.7 bA
	J. Decosta	19.48 abA	16.39 bA	187.9 bB	486.6 bB	11.67 bA	41.4 bB
2009	J. Decosta	21,92 aB	16.79 aA	179.2 bAB	387.2 bA	9.88 bA	37.7 bAB
	Šampion	21.54 aA	17.10 aB	166.0 aB	171.1 aB	6.54 aA	24.3 aA
2012	Camspur	21.22 a	13.75 a	140.9 a	86.7 a	3.20 a	27.1 a
	Šampion	21.44 aA	14.99 bA	155.1 bA	144.5 bA	6.21 bA	23.2 aA
2013	Golden D.R.	21.42 aAB	15.32 aAB	180.8 aB	191.2 aA	6.72 aA	28.5 aA
	Red Jonaprince	21.04 aAB	15.63 aA	179.5 aAB	335.9 bA	10.40 bA	32.2aA

Explanations: means within column followed by the same letters do not differ significantly at 5% of probability; * – small letters point out differences between cvs. within the year, ** – capital letters – differences between years within cultivar

It seems that despite different environmental factors occurring in the years, biological predispositions of cultivars decide about the vigor and the mode of growth of trees propagated on the same rootstock [Świerczyński and Stachowiak 2003, Kopytowski et al. 2006].

The results described above agree with those obtained by Czarnecki [1998], Lipecki and Janisz [2004], Lewko et al. [2006, 2007], Sadowski et al. [2007], Milosević and Milosević [2010] and other authors, who showed differentiation in the size of trees in nursery depending on cultivar and/or rootstock. There was no clear relationship between the size of the trees in spring and in autumn; for example, 'Jonagold Decosta' trees were bigger than 'Gala Must' ones in autumn 2007, although trees of both cultivars had similar size in spring 2007. In the experiments performed in the same nursery, maidens of 'Jonagold Decosta' also showed stronger growth than those of 'Gala Must' cv. [Lipecki, unpublished data]. However, the trees of 'Šampion' had thick stems in spring and autumn of 2009, which means that also in a case of stem size the effect of cultivar is predominating. Differences between years in case of 'Golden Delicious Reinders' in this paper and in research Lipecki et al. 2013 are evident, with the year 2009 giving the weakest growth [Lipecki et al. 2013]. This seems to be related to the lowest rainfalls observed in 2009, especially in April, July and August. Similar reaction occurred in case of 'J. Decosta' trees, especially when number and length of laterals were taken into consideration.

Mean length of one lateral shoot increased gradually from the top towards low part of the "knip-boom" tree up to the fifth feather (tab. 4). There were small changes in the value of this parameter between the 5th and the 10th feather and again the tendency towards increase of length was observed – with some fluctuations – between the 12th and the 15th laterals; the last (17th) shoot was a single one. All cultivars studied showed the same or similar directions in the changes of lateral shoot length depending on its position on a stem. There were no significant differences in the mean length of one feather depending on the number of laterals per tree (data not shown in the paper).

Table 4. Mean length (cm) of one lateral shoot depending on the cultivar and position on a stem when measured from the tree top towards its lower parts

Shoot nos.	Gala Must	Fuji B. Shogun	Golden D.R.	J. Decosta + Red Jonaprince	Šampion	Camspur	Mean
17				20.0↓			20.0↓
16			31.0↓	26.1↓			28.5↓
15			51.0↑	47.3↑			49.1↑
14		50.0↓	41.0↓	38.3↓			43.1↑
13		54.0↑	44.8↑	39.4↓			46.1↑
12	38.0↓	42.2↓	42.9↓	48.5↑			42.9↑
11	44.7↑	47.0↑	45.6↑	39.6↓	19.5↓		39.3↑
10	40.4↑	36.6↓	40.6↑	46.6↑	21.5↓		37.1↕
9	39.0↓	42.9↑	38.6↑	43.7↑	23.4↓		37.5↕
8	45.9↑	37.9↓	38.2↓	42.3↓	24.6↓		37.8↓
7	38.6↕	42.5↕	39.7↑	45.0↕	31.2↑	36.0↑	38.8↑
6	38.5↕	42.2↕	38.3↕	45.8↑	26.1↕	29.0↓	36.6↕
5	36.6↓	42.0↕	38.5↑	41.2↓	26.1↓	37.3↑	36.9↑
4	37.2↑	43.0↕	36.9↑	42.9↑	26.8↑	27.5↕	35.7↑
3	36.4↑	41.7↕	35.5↑	38.1↑	24.7↑	27.6↑	34.0↑
2	34.1↑	42.5↕	34.9↑	32.9↓	21.7↑	26.7↑	32.3↑
1	33.4	37.8	30.4	34.3	18.0	21.0	29.1

Explanation: ↑ means increase; ↓ decrease and ↕ stabilization of the feather length

All correlation coefficients between characters of trees measured in the spring were highly significant and varied between 0.634 and 0.884 with 'Fuji Beni Shogun' showing the lowest and 'Gala Must' the highest values. 'Fuji Beni Shogun' trees confirmed this tendency in autumn (mean value of coefficient was 0.434, tab. 5), whereas the highest value of the correlation were noted in case of 'Jonagokd Decosta' (0.600). The closest and highly significant relationships were observed between the total length and number of feathers (0.860) and between stem diameters measured below and above the place of budding/grafting (0.741). Relationships between tree height and other characters (mean 0.373) were weaker in comparison to those in which stem diameters were engaged (di-

ameter ‘below’ 0.531, ‘above’ 0.512). Negative relationships were observed between number of laterals and their length (-0.195 in ‘Fuji B. Shogun’, -0.250 in ‘Camspur’). Generally, ‘Camspur’ trees showed the weakest relations between the measured parameters, especially when height of a tree was included in calculations, probably as an effect of spur type of growth (mean value of coefficient was 0.299).

Table 5. Mean values of correlation coefficients for cultivars in autumn

Parameters	Fuji B. Shogun	Gala Must	Camspur	Golden D.R.	Jonagold Decosta + Red Jonaprince	Šampion	Mean
1 × 2	0.635	0.825	0.770	0.765	0.757	0.693	0.741
1 × 3	0.260	0.450	0.130	0.475	0.475	0.647	0.406
1 × 4	0.620	0.620	0.670	0.685	0.707	0.470	0.629
1 × 5	0.425	0.550	0.610	0.565	0.610	0.337	0.516
1 × 6	0.340	0.430	0.030	0.425	0.565	0.413	0.367
2 × 3	0.415	0.450	0.180	0.540	0.447	0.573	0.434
2 × 4	0.700	0.715	0.630	0.725	0.690	0.547	0.668
2 × 5	0.545	0.645	0.590	0.575	0.640	0.493	0.581
2 × 6	0.345	0.425	0.000	0.535	0.517	0.370	0.365
3 × 4	0.525	0.560	-0.040	0.535	0.550	0.403	0.422
3 × 5	0.325	0.365	-0.140	0.490	0.372	0.300	0.285
3 × 6	0.355	0.480	0.300	0.375	0.622	0.340	0.412
4 × 5	0.825	0.865	0.900	0.855	0.870	0.847	0.860
4 × 6	0.385	0.555	0.110	0.450	0.770	0.693	0.494
5 × 6	-0.195	0.150	-0.250	0.140	0.407	0.263	0.086
Mean	0.434	0.539	0.299	0.542	0.600	0.493	

Explanations: 1 – stem diameter below the budding/grafting point, 2 – stem diameter above the budding/grafting point, 3 – tree height, 4 – total length of lateral shoots per tree, 5– number of feathers per tree, 6 – mean length of one shoot. All details concerning the results are available from the corresponding author

Trees of ‘Šampion’ also presented a different type of growth than the other cultivars. This was confirmed by the higher, in comparison to the other cultivars, values of correlation between stem diameters and tree height for ‘Šampion’ and the tendency to form thick stems and short feathers. Correlations found in “knip-boom” trees are very close to those stated in maidens of the same cultivar [Lipecki and Janisz 1999] and ‘Golden Delicious Reinders’ “knip-boom” trees in the years 2008–2010 [Lipecki et al. 2013]. For example, for ‘Golden Delicious Reinders’ trees the values of correlation coefficient between the diameter above the place of budding/grafting and the total length of shoots were 0.685 and 0.725 for maidens and “knip-boom” trees, between the diameter ‘above’ and height correlations had the values 0.482 and 0.540 and between diameter ‘above’ and the number of feathers 0.526 and 0.575, respectively. The highest variability in correlation coefficient values was observed between total length of laterals and the

mean length of one feather: 0.110 (‘Camspur’), 0.770 (‘Jonagold Decosta’ + ‘Red Jonaprince’) and between the diameter ‘below’ and the height: 0.130 (‘Camspur’), 0.647 (‘Šampion’). The authors did not find data concerning these relationships in the literature.

CONCLUSIONS

1. The size of “knip-boom” trees depended on the cultivar, with ‘Jonagold Decosta’ (‘Red Jonaprince’) and ‘Fuji Beni Shogun’ giving bigger trees than other cultivars. The trees of ‘Šampion’ formed smaller crowns than other cultivars, but they had thick stems and ‘Camspur’ formed the smallest trees.

2. The effect of cultivar on the size of “knip-boom” type apple trees was similar to that observed in maidens.

3. Variability of results obtained in the years was probably due to different environmental conditions in the period of time the experiments were conducted.

4. Mean length of one lateral increased from the tree top towards its low part, but did not depend significantly on the number of feathers per tree. There were some fluctuations between cultivars in this respect, but generally these tendencies were clear.

5. Correlations between growth indices found in “knip-boom” trees showed the same tendencies as those in maiden trees. There were, however, differences between cultivars, with ‘Jonagold Decosta’ (‘Red Jonaprince’) showing stronger correlation between characters studied than other cultivars, whereas in case of ‘Camspur’ they were the weakest.

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WPŁYW ODMIANY NA WZROST I ZALEŻNOŚCI MIĘDZY CECHAMI WZROSTU DRZEW JABŁONI TYPU „KNIP-BOOM"

Streszczenie. Pomiarów dokonano w szkółce w latach 2007–2013 w celu zbadania różnic we wzroście i określenia korelacji pomiędzy wybranymi cechami wzrostowymi drzewek

typu „knip boom" sześciu odmian jabłoni na podkładce M.9. Najsilniejszy wzrost wykazywały drzewka 'Jonagold Decosta' ('Red Jonaprince' w 2013) i 'Fuji Beni Shogun', natomiast najsłabszy 'Šampion' i 'Camspur', podczas gdy 'Gala Must' i 'Golden Delicious Reinders' charakteryzowały się średnią siłą wzrostu. Średnia długość pędu bocznego zwiększała się od szczytu drzewka do jego podstawy, lecz nie była istotnie zależna od liczby pędów bocznych. Korelacje pomiędzy cechami wzrostu były podobne do, tych jakie zaobserwowano w przypadku okulantów, przy czym najsilniejsza była zależność pomiędzy całkowitą długością pędów bocznych i ich liczbą na drzewie. Średnica pnia była silniej skorelowana z innymi cechami wzrostowymi, niż wysokość drzewek.

Słowa kluczowe: szkółka jabłoni, odmiany, drzewka "knip-boom", rozmiary, korelacje wzrostowe

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