PROCEEDINGS OF THE LATVIAN ACADEMY OF SCIENCES. Section B, Vol. 71 (2017), No. 3 (708), pp. 137–143.
DOI: 10.1515/prolas-2017-0024

RESULTS OF A STUDY OF THE VEGETATIVE GROWTH, YIELD AND FRUIT QUALITY OF DIFFERENT GRAFTING COMBINATIONS OF THE APPLE CULTIVAR 'KRISTA'

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Communicated by Edīte Kaufmane

Long-term field trials with the apple cultivar 'Krista' on different vegetative rootstocks were held at the Polli Horticultural Research Centre (58°07`N, 25°32`E) in Southern Estonia in 2005–2015. Trees were grafted on 13 rootstocks: M26, M27, P59, E75, B9, B396, B491, MTT1, Supporter 1, Supporter 2, Supporter 3, Supporter 4, and MM106. The apple cultivar 'Krista' is well suited for growing in the climatic and soil conditions of Estonia. The cultivar performs best on vegetative rootstocks that are well-adapted to the Estonian climate: MM106, E75, B396, M26, M27, and P59. The rootstocks Supporter 1, Supporter 2, Supporter 3, and Supporter 4 did not turn out to be suited for growing in Estonia. The trees grafted on rootstocks MM106, E75, MTT1, and M26 grew taller, had a bigger crown spread and crown volume. In dense orchards with the planting scheme 4 × 1.5 m, trees with a smaller crown diameter may be grown on rootstocks MM27, P59, and Supporter 4. During the trial, the largest yields were harvested from trees grafted onto rootstocks MM106, MTT1, B396, M26, E75, and B9. Some rootstock combinations appeared to be positively related to average fruit weight in some years, but the same cannot be concluded for the whole duration of the trial.

Key words: *fruit weight, productivity, rootstock, vigour, winter hardiness.*

INTRODUCTION

Apples are the most important fruit culture in Estonia. The apple growing technology has changed considerably in the past 25 years. For example, vegetative rootstocks have replaced seedling rootstocks. The study and breeding of clonal rootstocks suited for Estonian climatic conditions started over 50 years ago (Veidenberg, 1985; Univer, 2000). According to Hrotko (2007), clonal rootstocks are being bred in 20 countries, and there are currently 240 commercially valuable clones, of which 46 are semi-dwarfing and 68 are dwarfing clonal rootstocks. So far, the most preferred rootstock in Europe is a dwarfing rootstock M9. This rootstock has not turned out to be winter-hardy in Estonia (Haak, 2003). New clonal rootstocks are being studied to ascertain their compatibility with different varieties and adaptability to different climatic and soil conditions (Bite *et al.*, 1999). Baltic joint studies of apple clonal rootstocks have given positive results (Haak, 2006; Univer, 2010; Kviklys *et al*., 2012; Kviklys *et al*., 2013; Univer *et al*., 2010). The results of comparative studies of different clonal rootstocks with older apple varieties have been summarised (Haak and Jalakas, 2001; Haak 2003; 2006). The current paper summarises the results of a study of a relatively new apple variety 'Krista': the effect of different rootstocks on the variety's tree size, yield and quality of fruit.

MATERIALS AND METHODS

The trials were conducted in Southern Estonia at the Polli Horticultural Research Centre (58°07`N, 25°32`E). Trees were grafted on 13 rootstocks: M.26, M.27, P59, E75, B9, B396, B491, MTT1, Supporter 1, Supporter 2, Supporter 3, Supporter 4, and MM106. Two-year-old trees were planted into an orchard with the scheme of 4 × 2 m (1250 trees/ha). Trees were planted in three plots with four replications (12 trees in total) per rootstock. The soil in the orchard was a sandy loam with mid-high content of nutrients. The comparison trial lasted 11 years (from 2005 to 2015).

The vegetative growth, the start of bearing yield, yield and fruit quality of the different grafting combinations of the apple cultivar 'Krista' were studied.

The trees included in the trial were measured for height, width of the crown, length of the leading shoot and trunk diameter at 20 cm from the grafting height. The crown volume was calculated according to the formula:
$TV= [(L+W: 4)^2 * \pi * H: 2]$ (Stehr, 2007).

Each year, the number of trees that perished in winter was recorded. In the young orchard, inflorescences and fruits were counted, and the mean fruit weight and yield per tree were determined. In the mature orchard, the mean fruit

weight was estimated based on the average of 50 fruits. Calculated total yield was found by multiplying the mean yield per tree by the number of surviving trees in both the young and the mature orchard.

The yearly average temperature was +6.7 °C, the minimum temperature was –35.3 °C in January 2010, –33.5 °C in February 2011, and –32.1 °C in February 2012. The precipitation was 600–700 mm.

RESULTS

The vegetative growth of a tree may be measured by tree height, diameter of the trunk, and length of the lead shoot. Young trees grew vigorously: the average length of the lead shoot was 36 cm. Growth slowed down as the orchard became older: the average length of the lead shoot was 22 cm. By the sixth year after planting into the orchard, the trees grafted on MM106, E75, M26, and B396 were taller and had a greater trunk diameter. The trees grafted on Supporter 3, Supporter 1, M27, Supporter 2, P59, and B491 were significantly smaller. Lead shoots were longer (over 40 cm) on the relatively vigorous MM106 as well as on less vigorous M27 and B491. By the 11th year in the orchard, the grafting combinations with MM106, E75, M26, MTT1, and B396 were relatively vigorous and the combinations with P59, Supporter 1, and B491 rather dwarfing. The effect of the rootstock on crown diameter was also noticeable. In the 11th year (2015), the diameter of the crown exceeded 2.5 m in the case of the combinations with MM106, E75, B396, and MTT1. The diameter was smaller in cases of the trees grafted on M27, P59, Supporter 4, Supporter 2, and Supporter 3.

Crown volume depends on the height of the tree and the diameter of the crown. The effect of rootstock was clearly evident in both crown diameter and crown volume. Crown volume was the greatest (10.2 m^3) for trees grown on the semi-vigorous rootstock MM106 (Table 1). The grafting combinations with semi-dwarfing rootstocks (E75, M.26, MTT1, and B396) had significantly smaller crowns (6.0–6.3 m^3). The crown volumes of trees grafted on dwarfing rootstocks were between 4.0 and 4.7 m^3. Trees grown on the rootstocks P59 and M.27 were especially dwarfing and had small crowns (1.9 m^3 and 2.6 m^3, respectively).

The young trees of the apple variety ‘Krista’ form a large number of inflorescences. Rudimentary inflorescences form in the terminal bud of the shoot as well as in the lateral buds of horizontally growing terminal buds. The first generative buds formed on the trees already in the nursery (in 2004), where the average inflorescence count per tree was 10.3. The trees were planted into the orchard in spring 2005. The count of open inflorescences in the first year showed that rootstocks had a statistically significant effect on the formation of generative buds (Table 2). The trees grafted on rootstocks MTT1, P59, E75, Supporter 3, and Supporter 4 formed many inflorescences (13–18 per tree). In the second year in the orchard the number of inflorescences per tree was more even (25–35 per tree), but fruit set was greater on trees grafted on MM106, M26, Supporter 1, and Supporter 4. Thus, fruit set and development of apples is dependent on the rootstock. During two years of the trial, fruit set varied between 3.1% and 20%. The mean fruit set was 13.1%. Trees grafted on rootstock E75 formed fewer fruit in the two years (the fruit set was 3.1% and 4.3%, respectively), although the inflorescence count was among the best (14 and 32 inflorescences per tree, respectively).

The mean yield was 1.4 kg per tree in the third, 2.1 kg in the fourth and 4.0 kg in the fifth year in the orchard. The effect of the grafting combination on the yield became apparent in the third year. The yield per tree was larger for trees on rootstocks MM106 (2.0 kg), M.26 and P59 (2.2 kg). In the

Table 1

THE VEGETATIVE GROWTH OF THE DIFFERENT GRAFTING COMBINATIONS WITH ‘KRISTA’ IN 2010 AND 2015

Rootstock	Tree height, dm		Length of lead shoot, cm		Trunk diameter, mm		Crown diameter, dm	Crown volum, m^3
	2010	2015	2010	2015	2010	2015	2015	2015
M.26	22.5 d	27 d	33 b	30 bc	43 bc	66 bc	24.7 cd	6.0 bc
M.27	16.3 b	21 b	47 d	17 a	28 a	48 a	19.2 a	2.6 a
P59	18.2 b	18 a	36 bc	15 a	37 ab	49 a	19.2 a	1.9 a
E75	25.2 de	30 e	45 cd	26 b	54 c	82 d	27.0 de	6.2 c
B9	19.2 bc	25 c	33 b	22 ab	37 ab	59 b	23.5 b	4.7 b
B396	22.8 d	27 d	39 cd	16 a	48 bc	68 c	25.5 cd	6.1 c
B491	18.3 b	23 b	47 d	18 a	32 ab	52 ab	23.7 b	4.1 b
MTT1	21.1 cd	27 d	35 b	20 a	42 bc	61 b	25.0 cd	6.3 c
Supporter1	14.5 a	23 b	27 a	22 ab	27 a	54 ab	24.0 bc	4.2 b
Supporter2	16.7 b	24 c	30 ab	25 b	26 a	51 ab	21.0 ab	4.0 ab
Supporter3	13.0 a	24 c	29 ab	26 b	25 a	53 ab	21.7 ab	4.1 b
Supporter4	20.1 c	26 cd	24 a	14 a	27 a	65 bc	19.7 a	4.0 ab
MM106	25.6 e	32 e	46 d	38 c	54 c	82 d	29.0 e	10.2 d

Note: Different letters indicate statistically significant differences in means (Duncan test).

Table 2

THE NUMBER OF INFLORESCENCES AND FRUIT FOR THE DIFFERENT GRAFTING COMBINATIONS OF THE APPLE VARIETY 'KRISTA'; FRUIT SET FOR YOUNG TREES AFTER PLANTING IN THE ORCHARD

Rootstock	Inflorescence count		Fruit count	Fruit set (%)	
	2005	2006	2006	2006	2007
M.26	4 a	35 b	19 c	10.8 b	13.5 b
M.27	8 ab	22 a	10 a	9.1 ab	12.9 b
P59	16 c	23 a	14 bc	12.2 b	11.5 b
E75	14 bc	32 b	5 a	3.1 a	4.3 a
B9	11 b	22 a	17 bc	15.4 bc	10.7 ab
B396	9 ab	28 ab	17 bc	12.1 b	17.3 bc
B491	8 ab	25 ab	17 bc	13.6 bc	20.0 c
MTT1	18 c	23 a	12 b	10.4 b	12.4 b
Supporter1	10 b	21 a	19 c	18.1 c	15.4 b
Supporter 2	2 a	23 a	6 a	5.2 a	20.0 c
Supporter 3	14 bc	24 a	17 bc	15.4 bc	24 c
Supporter 4	13 bc	27 ab	18 c	13.3 b	13.3 b
MM106	7 a	32 b	21 c	13.1 bc	13.5 b

Note: Different letters indicate statistically significant differences in means (Duncan test).

Table 3

THE YIELD PER TREE, TOTAL YIELD AND MEAN FRUIT WEIGHT OF THE APPLE VARIETY 'KRISTA' IN A YOUNG ORCHARD (2007–2009)

Rootstock	Yield per tree (kg)			Total yield (kg)	Average fruit weight (g)
	2007	2008	2009	2007–2009	2007–2009
M.26	2.2 b	2.0 a	5.6 c	9.8 b	128 ab
M.27	0.9 a	1.3 a	1.6 a	3.8 a	118 ab
P59	2.2 b	2.4 a	4.7 bc	9.3 b	121 ab
E75	0.9 a	1.9 a	3.2 ab	6.0 ab	132 ab
B9	1.0 a	2.0 a	5.2 bc	8.2 ab	134 ab
B396	1.6 a	2.5 a	5.7 c	9.8 b	140 b
B491	1.4 a	1.9 a	3.8 b	7.1 ab	122 ab
MTT1	1.5 a	1.2 a	5.4 bc	8.1 ab	132 ab
Supporter 1	1.3 a	4.3 b	1.2 a	6.8 ab	114 a
Supporter 2	1.2 a	2.2 a	2.4 ab	5.8 a	129 ab
Supporter 3	1.2 a	3.1 b	2.3 ab	6.6 ab	123 ab
Supporter 4	1.2 a	1.8 a	4.4 bc	7.4 ab	115 a
MM106	2.3 b	1.4 a	6.5 c	10.2 b	135 ab

Note: Different letters indicate statistically significant differences in means (Duncan test).

fourth year, the yield was greater for combinations on Supporter 1 (4.3 kg) and Supporter 3 (3.1 kg), and in the fifth year, on MM106 (6.5 kg), B396 (5.7 kg), and M.26 (5.6 kg). The total yield per tree for the three years varied between 5.8 and 10.2 kg in the young orchard. Based on the total yield in 2007–2009, the yield was higher for grafting combinations on MM106 (10.2 kg), M.26 and B396 (9.8 kg), and P59 (9.3 kg). The mean fruit weight was relatively similar for all combinations, varying between 114 and 140 g. The difference was statistically significant only in the extremes of the mean weight (Table 3).

The yield of trees varied annually, depending on tree age, vegetative growth, formation of generative parts and climatic conditions. Average yield was relatively high in 2012 (12.9 kg) and in 2014 (11.0 kg); medium in 2011 (7.0 kg), in 2013 (6.7 kg), and in 2015 (8.5 kg), and low in 2010 (3.7 kg). However, in 2010, the yield was still comparable to the other years when the average yields per tree are compared. Of all combinations, MM106 stood out for relatively high yield. The effect of the rootstock was clearly visible in years of generally high yield (2012 and 2014). The combinations with MM106, M.26, B396, MTT1, and B9 gave higher average yield.

In the mature orchard, the combination with MM106 gave the highest yield (119.3 kg as a total of six years). The yield was quite high in cases of the combinations with MTT1 (69.8 kg), B396 (65.1 kg), M.26 (60.1 kg), E75 (55.1 kg), and B9 (52.8 kg). The yield was smaller in cases of the combinations with Supporter 3 (22.2 kg), M.27 (23.3 kg), and Supporter 1 (27.8 kg) (Table 4).

The mean weight of fruit varied greatly, from 100 to 196 g, but was mostly between 121 and 141 g (Table 5). The variation was greater during years of small and medium yield. Although there were differences in some years, the effect of rootstock on the mean weight of fruit was not statistically significant as an average of 2010–2015.

The rootstocks included in the trial had different capacity for biological adaptation to the Estonian soil and climatic conditions. In the cases of Supporter 1, 2, and 3, over two-thirds of the trees planted in the orchard perished in the first three years. As the winters were quite cold, some trees perished on all of the rootstocks in the mature orchard. The trees grafted on rootstocks MM106, M26, E75, P59, B9, and B396 were relatively sturdy: only 1 or 2 trees perished for each combination. The trees grafted on MTT1 were somewhat less winter hardy (25% of the trees perished). On the other hand, 75 to 85% of trees grafted on Supporter 1, 2, 3, and 4 perished (Table 6).

The cumulative yield per hectare in the young orchard was greater (between 10.12 and 12.25 t/ha) for grafting combinations with B396, MM106, M.26, P59, and MTT1. In the 11-year-old orchard, the cumulative yield was the greatest for combinations with M26, B396, MTT1, E75, B9, and P59. The calculated yield per hectare in the second trial was smaller due to a greater number of trees that perished. Cropping efficiency per trunk cross sectional area was the greatest for grafting combinations P59, MTT1, and MM106 (2.45 to 2.67 kg/cm^2). Cropping efficiency was somewhat smaller for combinations with B491, B396, M.26, and Supporter 2. The combinations with rootstocks E75, Supporter 3, and Supporter 4 had low cropping efficiency. Cropping efficiency per crown volume was the greatest for the combination with P59 (13.39 kg/m^3) and relatively great for combinations with Supporter 4 and MM106. The other grafting

Table 4

THE YIELD OF THE APPLE VARIETY 'KRISTA' ON DIFFERENT ROOTSTOCKS IN THE MATURE ORCHARD

Rootstock	Mean yield per tree (kg)						Total yield (kg/tree)
	2010	2011	2012	2013	2014	2015	2010–2015
M.26	5.4 ab	11.1c	15.7 c	6.5 ab	11.1abc	10.3 abc	60.1 c
M.27	1.7 a	2.1 a	5.5 ab	4.0 a	4.5 a	5.5 a	23.3 a
P59	4.8 ab	4.8 a	11.4 bc	8.1 abc	7.5 ab	3.7 a	40.3 ab
E75	3.6 ab	9.5 bc	14.4 c	5.4 a	7.2 ab	15.0 c	55.1 bc
B9	5.2 ab	5.1 ab	14.3 c	7.4 abc	13.3 bc	7.5 ab	52.8 bc
B396	4.6 ab	10.5 bc	17.7 c	10.8 ab	16.9 c	4.6 a	65.1 c
B491	2.8 a	5.2 ab	11.9 bc	4.4 a	7.9 ab	5.6 a	37.8 ab
MTT1	3.0 a	11.1 c	15.4 c	12.3 cd	14.0 bc	14.0 bc	69.8 c
Supporter 1	3.7 ab	1.5 a	4.6 a	2.4 a	6.6 a	9.0 abc	27.8 a
Supporter 2	1.3 a	5.7 ab	5.2 ab	3.2 a	8.3 ab	9.0 abc	32.7 ab
Supporter 3	0.2 a	0.1 a	3.8 a	3.4 a	7.0 ab	7.7 ab	22.2 a
Supporter 4	3.8 ab	4.8 a	10.1 ab	3.9 a	11.4abc	5.4 a	39.4 ab
MM106	8.6 b	19.4 d	34.6 d	15.2 d	28.6 d	12.9 bc	119.3 d

Note: Different letters indicate statistically significant differences in means (Duncan test).

Table 5

THE MEAN FRUIT WEIGHT OF THE APPLE VARIETY 'KRISTA' ON DIFFERENT ROOTSTOCKS

Rootstock	Mean fruit weight (g)						Average fruit weight (g) 2010–2015
	2010	2011	2012	2013	2014	2015	
M.26	137 bc	130 b	13 a	115 a	119 ab	109 a	124 a
M.27	138 bc	135 b	163 bc	137 bc	130 b	106 a	135 ab
P59	136 bc	132 b	132 a	129 ab	115 a	113 ab	126 a
E75	121 ab	125 b	143 ab	148 c	118 ab	104 a	126 a
B9	137 bc	134 b	161 bc	120 a	123 ab	123 b	134 a
B396	149 cd	128 b	135 a	111 a	123 ab	119 ab	127 a
B491	128 ab	125 b	136 a	121 ab	127 b	119 ab	126 a
MTT1	150 cd	130 b	145 ab	127 ab	121 ab	125 b	133 a
Supporter 1	196 e	132 b	124 a	137 bc	115 a	122 b	138 ab
Supporter 2	107 a	130 b	171 bc	147 c	124 ab	120 b	133 a
Supporter 3	101 a	100 a	139 ab	125 ab	149 c	106 a	120 a
Supporter 4	118 ab	137 b	176 c	135 bc	135 bc	123 b	137 ab
MM106	149 cd	125 b	122 a	134 bc	109 a	123 b	127 a

Note: Different letters indicate statistically significant differences in means (Duncan test).

combinations had average or low cropping efficiency (see Table 6 for more details).

DISCUSSION

Haak (2003) found that apple varieties grafted on MM106 are semi-vigorous. Similar results have been reported in Latvia (Skrivele and Dimza, 1997), Lithuania (Kviklys, 2002), and Poland. In different soil and climatic conditions, the combinations on the rootstock MM106 have been shown to be semi-vigorous or semi-dwarfing (Blažek, 1999). Tatarinov (1984) underlines the adaptability of the rootstock and its ability to grow in less fertile soil.

In the present trial, trees of the variety 'Krista' grafted on MM106 were taller and had larger crowns and trunks than the trees grafted on M.26. Haak (2006) found M.26 to be semi-dwarfing. According to Uselis (2002), the size of the trees grown on M.26 depends on the growth vigour of the variety. In our trial, the crowns of the grafting combinations with M.26, B396, E75, and MTT1 were similar in size. However, Kviklys (2002) reported B396 to be semi-dwarfing, and Haak (2006) considered it to be dwarfing or semi-dwarfing.

The rootstock E75, bred in Estonia, is considered to be dwarfing (Haak, 2003). In a series of trials with 16 varieties, the trees grafted on E75 were mainly dwarfing, with the exception of four varieties that grew taller (Univer *et al*,

Table 6

THE ADAPTABILITY OF DIFFERENT ROOTSTOCK COMBINATIONS WITH THE APPLE VARIETY 'KRISTA' TO THE ESTONIAN SOIL AND CLIMATIC CONDITIONS (TREES PERISHED, TOTAL YIELD AND CROPPING EFFICIENCY)

Rootstock	Number of trees perished		Total yield (t/ha)		Cropping efficiency	
					Per trunk cross sectional area (kg/cm^2)	Per crown volume (kg/m^3)
	2008	2010	2005–2009	2005–2015	2005–2015	2005–2015
M.26	1	1	11.2 c	80.03 b	2.02 c	8.76 bc
M.27	1	1	4.35 a	31.03 ab	1.58 b	7.32 ab
P59	1	1	10.65 bc	56.79 b	2.67 d	13.39 d
E75	0	1	7.50 b	70.59 b	1.15 a	5.93 a
B9	1	2	9.39 b	64.37 b	1.63 b	8.87 bc
B396	0	2	12.25 c	80.03 b	2.05 c	8.53 b
B491	1	5	6.50 ab	34.05 ab	2.10 c	6.53 a
MTT1	0	3	10.12 bc	75.56 b	2.63 d	9.53 bc
Supporter 1	10	10	1.14 a	6.94 a	1.51 ab	4.78 a
Supporter 2	9	9	1.81 a	12.03 a	1.93 b	7.94 b
Supporter 3	8	9	2.06 a	8.99 a	1.31 a	5.46 a
Supporter 4	0	9	9.25 b	21.56 a	1.41 ab	11.88 d
MM106	1	1	11.68 c	148.28 c	2.45 d	10.14 cd

Note: Different letters indicate statistically significant differences in means (Duncan test).

2012). In the present trial with 'Krista', the trees of the grafting combinations with M.27 and P59 were significantly shorter, had thinner trunks and smaller crown volume. Similar results have been reported in Poland (Piestrzeniewicze *et al.,* 2006). The other rootstock combinations in our trial were dwarfing.

The crown diameter of apple trees depends on the type of the crown and on the rootstock. In our trial we used a free spindle crown. In the 11-year-old orchard, the crown diameter varied between 192 and 290 cm. Depending on the rootstock, different planting densities should be used. Trees grafted on MM106 should be planted at 5 × 3 m but trees grafted on semi-dwarfing and dwarfing rootstocks may be planted at 4 × 2 m, and on very dwarfing rootstocks at 4 × 1.5 m. In Germany it has been recommended to plant trees grafted on rootstocks P59, M27, and B491 at 3.5–4 m × 1 m.

The start of bearing fruit depends on the variety and rootstock. 'Krista' is a variety that starts bearing fruit early. It may bloom already in the nursery (Kask, 2010). Our trial confirms the report of the breeder. The number of inflorescences depends on the rootstock. The combination with P59 developed significantly more and the combinations with M26, B9 and B396 significantly fewer inflorescences. Similar results were reported for the variety 'Elise' in Poland (Slowinsky and Sadowsky, 1999). Trials with the variety 'Rubin' in combinations with 19 rootstocks showed that the combination with B491 developed significantly more inflorescences than the combination with P59 and M.27 (Piestrzeniewicze *et al.,* 2007). Šabajevienė (2009) found that combinations of the variety 'Auksis' with clonal rootstocks M.26, B396, and B491 developed flower buds on 100% of the shoots' apical meristems but with B9 only on 58% of the apical meristems. Apparently the combination of the variety and rootstock combined with abiotic factors have effect on the efficiency of forming the inflorescences.

Factors such as weather conditions during blooming and the number of pollinating insects can be important in the formation of the yield. In the young orchard, the number of inflorescences was similar across different grafting combinations. The fact that the same number of inflorescences on the combination with E75 led to significantly smaller number of fruits may be caused by the characteristics of the nectar, which would require further biochemical tests. Other studies have also found differences in fertilisation of inflorescences. A comparison trial of 20 apple varieties on the rootstock M26 in Lithuania found that the yield of trees of the same variety with similar inflorescence counts began to vary already in the 5th or 6th year in the orchard (Uselis 2002). In our trial, the difference in the yields of different grafting combinations was small in the young orchard. The difference became more significant in the 5th year. The cumulative yield was significantly higher for grafting combinations with MM106, M26, and B396. Similar results were obtained in Poland with the variety 'Jonagold' (Slowinski and Sadowski, 1999) and 'Shampion' (Kurlus and Ugolik, 1999) on rootstocks M.26 and B396.

The effect of the rootstock on the vegetative growth and yield can be best seen in a mature orchard. Trunk diameter, crown volume and cropping efficiency per trunk cross sectional area and crown volume is often larger in the case of trees on dwarfing rootstocks than in the case of trees on semi-vigorous rootstocks. Blažek (2007) has drawn similar conclusions. The cropping efficiency of the trees on dwarfing rootstocks M.27 and P59 was especially remarkable. Similar results were obtained in Poland (Piestrzeniewicze

and Sadowski, 2007). The yield of P59 and M.27 was found to be comparable in Germany (Vercammen *et al.,* 2007). The clonal rootstocks Supporter 1, 2, 3, and 4 were smaller than M.26 in our trial, but in Northern Germany they were reported to be more vigorous than M.9 and comparable to M.26 (Stehr, 2007).

CONCLUSIONS

In our trial, the effect of 13 grafting combinations with the apple variety 'Krista' on the trees' vegetative growth was evaluated based on trunk diameter, crown diameter, tree height and crown volume. It was found that different rootstocks have a significant effect on the vegetative growth and yield of the trees of the apple variety 'Krista' but not such a significant effect on the size of the fruit. In the grafting combination with MM106, the trees of 'Krista' are of medium vigour; in combination with M.26, B396, MTT1, and E75 of semi-dwarfing vigour; in combination with B9, B491, Supporter 1, 2, 3, and 4 of dwarfing vigour; and with P59 and M.27 of very dwarfing growth vigour.

A comparison of different rootstocks revealed that MM106, M.26, M.27, P59, E75, B9, and B396 are sufficiently winter-hardy in Southern Estonian soil and climatic conditions. Dwarfing rootstocks from Germany (Supporter 1, 2, 3, and 4) are not winter-hardy in Estonia.

In addition to the rootstocks that are already well known in the Estonian nurseries (MM106, M.26, and B9), it may be efficient to start using very dwarfing P59, dwarfing B491, and semi-dwarfing B396 and MTT1.

Based on the results of our trial, we would recommend planting a free spindle crown 'Krista' grafted on MM106 and E75 at 5 × 3 m, trees grafted on semi-dwarfing and dwarfing rootstocks at 4 × 2 m, and trees grafted on very dwarfing rootstocks at 4 × 1.5 m.

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Received 16 August 2016
Accepted in the final form 9 June 2017

ĀBEĻU ŠĶIRNES ‘KRISTA’ DAŽĀDU POTĒJUMA KOMBINĀCIJU VEĢETATĪVĀS AUGŠANAS, RAŽAS UN AUGĻU KVALITĀTES PĒTĪJUMA REZULTĀTI

Polli dārzkopības pētījumu centrā (58°07`N, 25°32`E) Igaunijas dienvidos 2005.–2015. g. tika veikti ilgstoši lauka izmēģinājumi ar ābeļu šķirni ‘Krista’ uz dažādiem veģetatīvi pavairojamiem potcelmiem. Koki bija uzpotēti uz 13 potcelmiem: M26, M27, P59, E75, B9, B396, B491, MMT1, Supporter 1, Supporter 2, Supporter 3, Supporter 4, un MM106. Ābeļu šķirne ‘Krista’ ir piemērota audzēšanai Igaunijas augsnes un klimata apstākļos. Vislabākie rezultāti šķirnei iegūti uz tiem potcelmiem, kas labi pielāgoti Igaunijas klimatam: MM106, E75, B396, M26, M27 un P59. Potcelmi Supporter 1, Supporter 2 un Supporter 3 neizrādījās piemēroti audzēšanai Igaunijā. Koki, kas bija potēti uz potcelmiem MM106, E75, MTT1 un M26 bija lielāka auguma, ar plašākiem vainagiem un lielāku vainaga tilpumu. Sabiezinātos dārzos ar stādījuma shēmu 4 × 1,5 m var audzēt kokus ar mazāku vainaga diametru uz potcelmiem MM27, P59 un Supporter 4. Izmēģinājuma laikā vislielākās ražas iegūtas no kokiem, kas potēti uz MM106, MTT1, B396, M26, E75 un B9. Dažas potcelmu kombinācijas atsevišķos gados uzrādīja pozitīvu ietekmi uz augļu vidējo masu, taču to nevar secināt attiecībā uz visu izmēģinājuma laiku.