doi: 10.17221/31/2017-HORTSCI

Long term cropping and selected parameters of 15 apple tree cultivars

Jan Blažek*, Lubor Zelený, Jana Křelinová

Research and Breeding Institute of Pomology Holovousy Ltd., Holovousy, Czech Republic

**Corresponding author: jan.blazek@vsuo.cz*

Abstract

Blažek J., Zelený L., Křelinová J. (2018): Long term cropping and selected parameters of 15 apple tree cultivars. Hort. Sci. (Prague), 45: 11–17.

Fifteen apple cultivars registered in the Czech Republic were included in this comparative study. The most productive after eight years of cropping was 'Rucla', which had a mean yield of 50.9 t/ha. This cultivar was also the most tolerant to late spring frosts. In order of decreasing yields, it was followed by the cultivars 'Rubinstep', 'King Jonagold' and 'Šampion'. The lowest yield was found for the cultivar 'Fuji Nagafu' (23.7 t/ha) followed by 'Golden Delicious' and 'Rubinola'. The largest canopy volume in 2016 was achieved by 'Rubín' at a level of 2.74 m^3, followed in decreasing order by 'Rubinola', 'King Jonagold' and 'Meteor'. According to the final tree canopy volume, the least vigorous was 'Selena' with a mean of 1.50 m^3. The largest canopy of 2.74 m^3 was exhibited by 'Rubín'. The 'Braeburn' cultivar exhibited the highest degree of spur bearing, followed by 'Lady Silvia' and 'Vysočina'. In contrast, the poorest spur patterns were observed in 'Rubín' and 'Fuji Nagafu'. 'Meteor' was characterised by the densest canopy, whereas the 'Rubín' cultivar was the least dense.

Keywords: *Malus domestica* Borkh.; tree vigour; yield efficiency; tree performance; spurring habit

This paper describes the continuation of a study published four years ago (Blažek, Křelinová 2013). From the 22 cultivars bred in Holovousy and described in the original study, we here consider only the eight that we regard as the most important. On the other hand, four well-known cultivars that originated and are presently widely grown in the Czech Republic, two apple cultivars with worldwide importance and one novel domestic cultivar were newly included in the present study. Besides cropping and tree vigour, some tree canopy characteristics were also evaluated.

Previously, the vigour of apple trees on M9 rootstock was evaluated in 35 orchards located in different climatic conditions of the Czech Republic during the period 1996–2000. In total, 31 commonly grown or novel cultivars were ranged according to their synthetic growth index based on their increases in trunk cross-sectional area, canopy volume and mean shoot length. The cultivar with the lowest degree of tree vigour ('Braeburn') grew more than 50% weaker than the most vigorous cultivar, 'Rubin' (Blažek and Varga 2001).

Cumulative yield and yield efficiency of the 'Topaz' cultivar on M9 was recently studied using different slender spindle forms and pruning (Mészáros et al. 2015). The increase in tree canopy was highest on a slender spindle with additional summer pruning. The lowest increase in crown volume was observed on modified spindle without summer pruning.

Very significant differences in a range of growth and yield characteristics were found in a large-scale trial of 23 apple cultivars that was carried out in the period 1999–2004 in the USA (Crassweller et al. 2007).

The effects of dwarfing and semi-dwarfing apple rootstocks on canopy size and tree cropping were studied in two experimental orchards established in the Research and Breeding Institute of Pomol-

doi: 10.17221/31/2017-HORTSCI

ogy, Holovousy, using the 'Golden Delicious', 'Melrose', 'Jonagold', 'Rubin' and 'Florina' cultivars. A strong negative correlation was observed between tree size and yield efficiency (Kosina 2010).

Lauri and Laurens (2006) realised basic architectural studies on apple tree canopies with a special emphasis on the relationships between vegetative architecture and fruiting. This classification is based upon the "basitony" – "acrotony" canopy gradient and the bottom angle of scaffolds that were used by Lespinasse and Delort (1986).

In a trial of four supported apple orchard systems (Tatura Trellis, Güttingen V, Double-row and HY-TEC), 'Fuji' was tested on M9 and 'Braeburn' on M26 rootstock in Wenatchee, USA. There, the cumulative yield efficiency (kg/cm^2) of Tatura Trellis trees was higher than that of the three other orchard systems due to the smaller size of trees (Barritt et al. 2008).

Yield efficiency for nine apple cultivars grafted onto rootstocks was very recently evaluated in Brazil (Fioravanfo et al. 2016). There, the cumulative yield efficiency of the most productive cultivar 'Royal Gala' on M9 was 5.12 kg/cm^2 of trunk cross-sectional area, whereas the lowest efficiency was observed for the 'Mishima' cultivar, which amounted to only 2.78 kg/cm^2.

MATERIAL AND METHODS

All cultivars were evaluated in experimental orchards established in Holovousy in spring 2003 using M9 rootstock and a tree spacing of 4 × 1 m. For each cultivar, a minimum of three trees were planted without replication. Most frequently, however, a greater number of trees per cultivar were planted in two or three replications. The location is characterised by an average yearly temperature of 8.1°C, average rainfall of about 650 mm and altitude of about 300 m. The orchards were maintained with clean herbicide strips under the tree canopies and with mulched grass along the alleyways. Trees were trained as slender spindles and canopies kept at reasonable densities and sizes using pruning, both in winter and summer. In some of the more vigorous cultivars somewhat greater canopy volume was allowed to develop during the last years if necessary. Fertilising and spraying (based on integrated apple orchard protection guidelines) consisted of normal commercial practices.

Every year from 2004 onwards, yield per tree was recorded as a mean of all trees for each cultivar. At the end of the growing season in 2016, trunk cross-sectional area (TCSA) and canopy volume were evaluated. TCSA was calculated from trunk circumference measured at 20 cm above the graft union.

Canopy volume was calculated following the measurement of canopy height, latitude and longitude. Further, three growth characteristics were rated using rating scales ranging from 1 to 9. The measured parameters included spurring habit, canopy density and canopy shape. In the rating scales of spurring habit and canopy density, 1 designated the minimum and 9 the maximal score, whereas for canopy shape 1 was the most upright and 9 the most drooping. The years 2011 and 2016, with very high flower damage caused by late spring frosts, were not included in the evaluation of cultivar productivity.

RESULTS

Overall tree yields

The total apple yield per tree for all years of evaluation is given in Table 1. The most productive cultivar was 'Rucla' with a total yield of 209.5 kg. In descending order, it was followed by the 'Rubinstep', 'King Jonagold', 'Rubín', 'Vysočina' and 'Angold' cultivars. The least productive cultivar, on the other hand, was 'Fuji Nagafu' with a cumulative yield of only 92.6 kg. In increasing order, it was followed by 'Rubinola', 'Golden Delicious' and 'Meteor'.

The most precocious in fruiting was the 'Lady Silvia' cultivar, which produced 20.3 kg of fruits per tree in the first three years, followed by 'Golden Delicious', 'King Jonagold' and 'Rucla'. In the first year, onset of fruiting was most pronounced in 'Rubinstep' and 'Rucla' (above 1 kg/tree). In contrast, the least precocious in this set was 'Šampion', followed by 'Fuji Nagafu', 'Braeburn' and 'Selena'. The highest relative output of fruits in 2016 was exhibited by 'Golden Delicious', with an average output of 10.3 kg per tree. The highest tendency for biennial bearing was found in 'Fuji Nagafu', followed by 'King Jonagold' and 'Topaz'.

Tolerance to late spring frost

The most tolerant cultivar to late spring frost was 'Rucla' with a harvest of 4.2 kg of fruit per tree in the most critical year of 2011 and 9.5 kg in 2016. It was

doi: 10.17221/31/2017-HORTSCI

Table 1. Yields of cultivars (kg/tree) in each year under evaluation

Cultivar	Yields in years of evaluation (kg/tree)													
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Σ
Angold	0.9	0.8	10.0	0.8	14.0	12.8	24.1	0.3	25.7	12.5	26.3	33.4	2.2	163.8
Braeburn	0.0	0.4	7.0	2.0	15.8	7.5	27.4	0.4	6.8	16.9	24.0	31.1	8.1	146.9
Fuji Nagafu	0.0	0	6.4	2.4	16.6	0	14.0	0.3	5.6	15.5	9.9	20.4	1.6	92.6
Golden Delicious	0.8	2.3	14.1	4.5	11.4	6.6	23.0	2.6	11.2	16.0	17.8	19.7	10.3	140.2
King Jonagold	0.2	2.8	12.2	10.0	19.5	10.5	23.9	2.0	14.6	23.6	13.1	38.9	3.8	175.2
Lady Silvia	0.2	4.7	15.4	12.9	9.7	18.1	16.4	2.6	6.7	22.0	17.7	23.6	8.2	158.3
Meteor	0.2	3.4	9.6	10.7	14.3	6.5	21.1	2.4	9.4	9.0	26.2	29.1	0.5	142.4
Rubín	0.7	3.9	7.2	12.4	18.0	12.4	18.5	0.3	18.0	23.2	19.2	29.9	8.9	172.8
Rubinola	0.9	3.6	7.0	6.9	19.1	7.3	24.0	1.3	6.5	18.3	17.9	19.9	2.6	135.3
Rubinstep	1.3	3.9	8.1	10.9	21.6	15.8	28.4	0.4	8.8	22.4	24.5	36.2	1.2	183.5
Rucla	1.1	3.1	10.6	11.5	21.9	16.1	21.5	4.2	17.6	23.5	32.6	36.3	9.5	209.5
Selena	0.8	1.9	7.3	8.0	13.0	6.8	16.1	0.3	20.7	20.7	21.4	29.2	2.6	148.9
Šampion	0.0	0.6	2.3	7.7	18.4	11.7	23.9	0.6	18.9	21.4	19.0	30.7	6.0	163.0
Topaz	1.0	4.2	6.5	9.4	26.0	13.2	19.6	0	9.3	16.6	13.2	20.5	3.8	143.3
Vysočina	0	3.5	9.8	13.8	15.3	14.8	20.4	1.2	8.4	21.7	22.4	30.7	5.0	167.1
Mean	0.6	2.6	8.9	8.4	17.0	10.8	21.3	1.3	12.5	18.9	20.3	28.6	5.0	156.4
LSD; $P \geq 0.05$	0.52	1.73	2.148	3.91	4.25	6.37	3.40	1.34	5.82	3.29	4.84	3.67	1.93	4.92

followed by 'Golden Delicious', 'Lady Silvia' and 'Meteor' that had harvests roughly half that level. Regarding 2016, the highest harvest of 10.4 kg per tree was obtained from 'Golden Delicious', followed in decreasing order by 'Rucla', 'Rubín', 'Lady Silvia' and 'Braeburn'. Trees of the 'Meteor' cultivar were practically without fruits in 2016, but this was probably mainly connected with its biennial habit of fruiting. The most susceptible cultivars to late spring frost were 'Topaz', 'Fuji Nagafu', 'Rubinstep' and 'Selena'.

Tree vigour

The largest canopy volume in 2016, with 2.74 m^3, was attained by 'Rubín' (Table 2). It was followed in decreasing order by 'Rubinola', 'King Jonagold' and 'Meteor'. The least vigorous cultivar was 'Selena', which had a mean volume of only 1.50 m^3, followed in increasing canopy size by 'Vysočina', 'Rucla' and 'Rubinstep'.

The most vigorous cultivar according to the trunk cross-sectional area was 'Rubinola' (58.4 cm^2), closely followed by 'Rubín', 'King Jonagold', and, finally, 'Topaz'.

The smallest trunk cross-sectional area was observed in 'Selena' (28.8 cm^2). In increasing order, it was followed by 'Braeburn', 'Fuji Nagafu' and 'Rucla'.

The greatest difference between these two characteristics of tree vigour was observed in 'Topaz' followed by 'Meteor', 'Braeburn' and 'Angold'. On the contrary, the two characteristics were in good mutual agreement in the case of the 'King Jonagold', 'Rucla', 'Rubín' and 'Šampion' cultivars.

Annual shoot length

This tree growth parameter was largest in 'Rubinola', where it amounted to 40.9 cm on average (Table 2). This cultivar was followed in decreasing order by 'King Jonagold', 'Rubín' and 'Meteor'. The shortest mean shoot length, meanwhile, was observed in 'Selena' (22.0 cm) followed by 'Braeburn', 'Rubinstep' and 'Topaz'.

doi: 10.17221/31/2017-HORTSCI

Table 2. Tree characteristics in 2016

Cultivar	Trunk cross section area (cm^2)	Canopy volume (m^3)	Difference between TCA and CV (%)	Mean length of annual shoots (cm)	Spurring habit (1–9)	Canopy density (1–9)	Canopy shape (1–9)
Angold	40.6	2.18	10.9	26.0	5	6	6
Braeburn	34.7	1.94	12.9	22.7	7	5	6
Fuji Nagafu	36.9	1.92	6.8	32.9	3	4	5
Golden Delicious	41.6	2.06	2.8	28.3	5	5.5	5
King Jonagold	52.4	2.54	0.7	40.4	5	5	7
Lady Silvia	44.4	2.02	–5.4	31.9	6	5.5	5
Meteor	43.6	2.37	13.0	35.4	5	7.5	4
Rubín	57.4	2.74	–1.1	39.8	3	3	6
Rubinola	58.4	2.70	–5.5	40.9	4	4	5
Rubinstep	41.0	1.91	–2.9	23.5	5	5	4
Rucla	38.4	1.83	–0.9	33.5	5	5.5	7
Selena	28.8	1.50	5.5	22.0	5	7	6
Šampion	42.1	2.05	1.2	24.6	6	6	7
Topaz	51.3	1.97	–24.0	23.9	6	6	6
Vysočina	41.7	1.71	–14.2	30.2	6	5.5	5
Mean	43.6	2.10	0	30.4	5.1	5.4	5.6

TCA – trunk cross section area; CV – canopy volume; spuring habit and canopy density scale: 1 – the minimum, 9 – the maximal score; canopy shape scale: 1 – the most upright, 9 – the most drooping 1 designated the minimum and 9 the maximal score, whereas for canopy shape 1 was the most upright and 9 the most drooping.

Tree canopy characteristics

The 'Braeburn' cultivar was distinguished by the most pronounced spurring habit, followed by 'Lady Silvia', 'Vysočina', 'Šampion' and 'Topaz' (Table 2). The 'Rubín' and 'Fuji Nagafu' cultivars exhibited the poorest spurring. The 'Meteor' cultivar had the densest tree canopy, closely followed by 'Selena'. In marked contrast, the 'Rubín' cultivar exhibited the most open canopy corresponding to a score of 3. It was followed by 'Fuji Nagafu' and 'Rubinola', which both received a 4 for canopy density. Regarding canopy shape, the most upright were the 'Meteor' and 'Rubinstep' cultivars, whereas those with the most spreading were 'King Jonagold', 'Rucla' and 'Šampion'.

Selected parameters of cropping

In Fig. 1, cultivars are ranged according to canopy volume (m^3) in 2016. They largest was 'Rubín' with a canopy volume of 2.74 m^3, while the smallest was 'Selena' with a canopy volume of only 1.50 m^3.

The range of the evaluated cultivars according to the total harvest per tree from all the years of cropping is illustrated in Fig. 2. The 'Rucla' cultivar was distinguished by the highest harvest level, which was 209.5 kg, whereas the lowest harvest (92.6 kg) was recorded in 'Fuji Nagafu'.

In Fig. 3, cultivars are ranged according to their mean annual yield efficiency in the period 2013 to 2015. According to this criterion, the most efficient was 'Rucla' with an outstanding total value of 26.1 kg/m^3. The least productive cultivar was 'Fuji Nagafu', with a value of only 10.6 kg/m^3, which is only 43% of the value for 'Rucla'.

Ordering of the evaluated cultivars according to specific yield during the period 2013–2015 is presented in Fig. 4. The highest specific yield per tree was observed in 'King Jonagold' and amounted to 389 kg/m^3), whereas the lowest yield was from 'Golden Delicious' with 19.7 kg/m^3.

doi: 10.17221/31/2017-HORTSCI

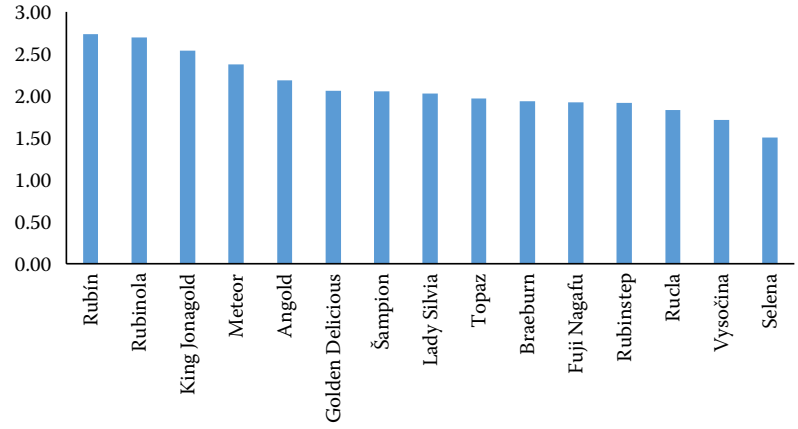

Fig. 1. Cultivars arranged according to canopy volume (m^3) in 2016

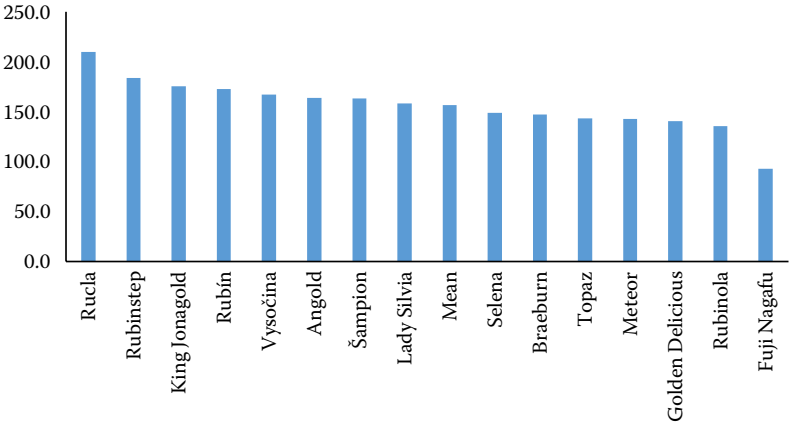

Fig. 2. Cultivars arranged according to the total harvest (kg/tree) from 2004–2016

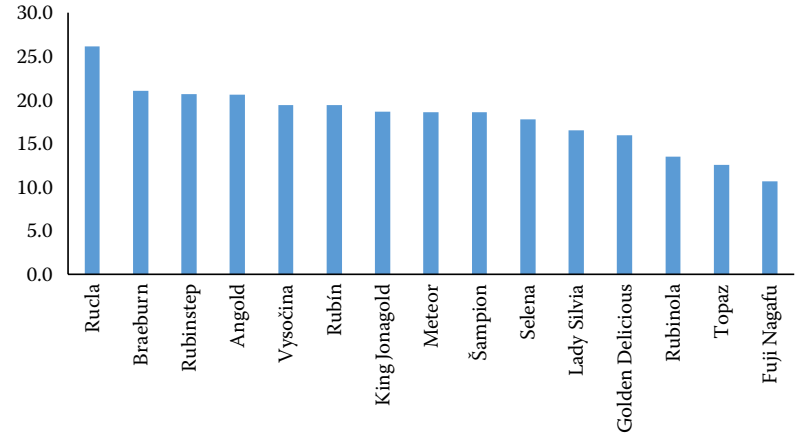

Fig. 3. Cultivars arranged according to the mean annual yield efficiency (kg/m^3) in the period 2013–2015

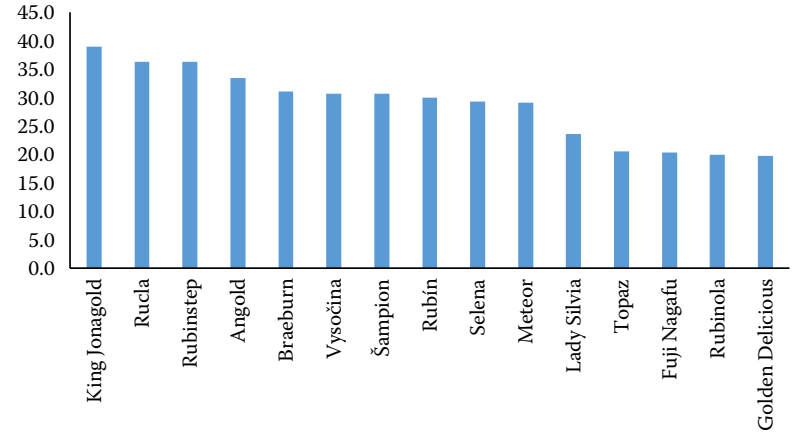

Fig. 4. Cultivars arranged according to the maximal annual yield efficiency (kg/m^3) in the period 2013–2015

doi: 10.17221/31/2017-HORTSCI

DISCUSSION

The present results concerning the productivity of the evaluated cultivars are mostly in agreement with our previous studies (Blažek, Křelinová 2006; Blažek 2013). This was especially true with respect to the most productive cultivars 'Rucla' and 'Topaz' and the least productive cultivar 'Rubín'.

Our data concerning the productivity and tree vigour of 'Topaz' are also in agreement with similar recent findings from Poland (Sosna 2014). Our data concerning the yield efficiency of 'Topaz' are, however, considerably different from those published by Mészáros et al. (2015). This difference can without doubt be explained by the much higher ages of the trees evaluated in our study.

Our finding concerning the tolerance of 'Golden Delicious' to late spring frosts is fully in agreement with a range of previous reports (Aygun et al. 2005; Lipa et al. 2008).

The relationship between trunk cross-sectional area and canopy volume can also be significantly influenced by the method used to calculate the parameter, which was different in this study to procedures described previously (Wright et al. 2006).

Our results concerning the high tendency of 'Fuji Nagafu' toward biennial bearing are fully in agreement with a similar finding from Serbia (Milatovic, Durovic 2012).

The inferior productivity of 'Fuji Nagafu' and 'Golden Delicious', which was found in this study, differs markedly from results from the USA (Crassweller et al. 2007). The discrepancy might be explained by the fact that our colder climatic conditions are not suitable for either of these cultivars.

The mean annual yield efficiency of 'Fuji' was found to be 20.4 in our study, whereas in a study from the US it was described to range from 0.63 to 0.8 (Barrit et al. 2008). In another study from the US, mean annual yield efficiency was reported to be 0.45 for 'Golden Delicious' and 0.37 for 'Fuji Jubilee' (Crassweller et al. 2007). Present results concerning productivity of evaluated cultivars are mostly in agreement to our previous studies (Blažek 2006; Blažek, Křelinová 2006). It is especially in comparison of the most productive ones 'Rucla' and 'Topaz' to the least productive 'Rubín'.

Our data concerning productivity and tree vigour of 'Topaz' are also in agreement to similar recent finding from Poland (Sosna 2014).

References

Aygun A., Sam B., Tarihi G. (2005): The late spring frost hardiness of some apple varieties at various stages of flower buds. Tarin Bilnleri Dergisi, 11: 283–285.

Barritt B.H., Konishi B., Dilley E. (2008): Performance of four high density apple orchard systems with 'Fuji' and 'Braeburn'. Acta Horticulturae (ISHS), 772: 289–294.

Blažek J. (2006): Yields and fruit quality of apple cultivars grown or tested in commercial orchards in Czech Republic. In: Proceeding from International conference International conference of perspectives in European fruit growing. Oct 18–20, 2006, Mendel University of Agriculture and Forestry in Brno: 47–63.

Blažek J. (2013): Comparative study of apple cultivars bred in Holovousy, Czech Republic. Journal of Plant Studies, 2: 1–9.

Blažek J., Křelinová J. (2006): Seven-year orchard performance of eleven new apple cultivars from Holovousy in comparison with some commonly grown ones Horticultural Science (Prague), 33: 131–139.

Blažek J., Křelinová J. (2013): Apple cultivars bred in Holovousy. Part 1 – Characteristics of the orchard. Horticultural Science (Prague), 40: 8–15.

Blažek J., Varga A. (2001): Tree vigour of new apple cultivars grown in the Czech Republic and some factors influencing it. Horticultural Science (Prague), 28: 130–137.

Crassweller R., McNew R., Greene D., Miller S., Cline J., Azarenko A., Barrit B., Barkett T., Brown S., Cowgill W., Fallahi E., Fallahi B., Garcia E., Hampson C., Lindstrom T., Merwin I., Obermiller J.D., Stasiak M., Greene G. (2007): Performance of apple cultivars in the 1999 NE-183 regional project planting. I. Growth and yield characteristics. Journal of American Pomological Society, 61: 84–96.

Fioravanfo J.C., Czermainski A.B.C., Oliveira de P.R.D. (2016): Yield efficiency for nine apple cultivars grafted on two rootstocks. Ciencia Rural, Santa Maria, 46: 1701–1706.

Kosina J. (2010): Effect of dwarfing and semi dwarfing apple rootstocks on growth and productivity of selected apple cultivars. Horticultural Science (Prague), 37:121–126.

Lauri P.E., Laurens F. (2006): Architectural types in apple (*Malus* × *domestica* Borkh.). Growth, Quality and Biotechnology: 1300–1313.

Lipa T., Lipecki J., Janisz A., Dinkiewicz P. (2008): Effects of spring frosts in selected apple and pear orchards in the Lublin region in the years 2005 and 2007. Acta Agronomica, 61: 131–139.

Lespinasse J.M., Delort F. (1986): Apple tree management in vertical axis: appraisal after ten years of experiments. Acta Horticulturae (ISHS), 160: 120–155.

Mészáros N., Sus J., Laňar L., Náměstek J. (2015): Evaluation of slender spindle form in young 'Topaz' apple orchard. Scientia Agriculturae Bohemica, 46: 167–171.

doi: 10.17221/31/2017-HORTSCI

Milatovic D., Durovic D. (2012): Growth and yield characteristics of new apple cultivars. Journal of Pomology, 46: 77–82.

Sosna I. (2014): Estimation of productive value of Czech origin scab-resistant apple cultivars on different rootstocks. Journal of Horticultural Research, 22: 115–121.

Wright H., Nichols D., Embree C. (2006): Evaluating the accountability of trunk size and canopy volume models for determining apple tree production potential across diverse management regimes. In: Proceedings from VII. IS on Modelling in Fruit Research Ed.: P. Braun. Acta Horticulturae (ISHS), 707: 237–243.

Received for publication February 16, 2017
Accepted after corretcions June 2, 2017