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Comparison of growth of maiden trees of cultivars and genotypes of Cornelian cherry (*Cornus mas* L.) in a nursery

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Abstract. Cornelian cherry (*Cornus mas* L.) is still not a very popular fruit plant in Poland. Fruit growers have been recently increasingly interested in the cultivation of plants with fruits that can be widely used in processing. Fruits of Cornelian cherry can be eaten raw, and processed in various ways: for tinctures, juices, jams, silage, candied, etc. Both the fruits and preserves are characterised by high pro-health properties due to the content of vitamins, anthocyanins, and loganic acid. *Cornus mas* adapts well to the climate and soil conditions in Poland. The only limitation of its broader cultivation is lack of good planting material. The experiment investigated the efficiency of budding on two-year-old seedlings (*Cornus mas* L.) of several cultivars and genotypes of Cornelian cherry. Moreover, the height of plants, stem diameter, average number of shoots, number of leaves on selected shoots, and quality of roots were determined. The cornelian cherry maidens obtained by budding with dormant bud in August on two-year-old seedlings of Cornelian cherry (*Cornus mas* L.) constitutes high quality material suitable for establishing commercial plantations. Maiden trees of particular cultivars and genotypes of cornelian cherry significantly differ in height, diameter, number of branches and leaves, as well as the size of the root system. The diameter of the trunk is a good indicator of the quality of Cornelian cherry maiden, because it is closely positively correlated with the height of plants and the number of shoots.

Key words: growth correlations, stem diameter, T-budding, quality of cornelian cherry maiden trees.

INTRODUCTION

Fruit production is a very important branch of human economy, because fruit is a significant ingredient of human diet. It is well known that the optimal diet should be varied. Only then can it provide the body with necessary nutrients used for growth, energy production, and repair processes. Cornelian cherry fruit can provide variety to human diet, and even serve as a protection against diseases. Especially when they are processed in a modern way using e.g. dehydration, which does not cause loss of vitamin C and flavonoids (Strizhevskaya et al., 2019).

Intensification of agriculture leads to the creation of monocultures. This simplifies the landscape, threatens the biodiversity of flora and fauna, and may cause soil and water pollution. Therefore, it has recently been emphasised that the maintainance of high biodiversity permits obtaining higher and more stable yields with high fruit quality, and reduction or elimination of the use of pesticides by farmers (Fedosova & D'Antuono, 2012). Cornelian cherry (*Cornus mas* L.) is an example of a fruit species that is not widely distributed in cultivation. Cornelian cherry comes from Little Asia and Eastern Europe. In the natural state, it also occurs in the south of Europe, near the Mediterranean – Turkey, Italy, Spain, Portugal, and Greece. It grows naturally in bushes, in oak and hornbeam forests, and river valleys. It prefers sunny positions, and can often be found in the mountains, therefore it is very resistant to difficult conditions such as drought and strong winds. It grows well on any type of soil as long as it is permeable, and shows high tolerance for the pH of the substrate (Bijelić et al., 2012). Larger crops are harvested from wild plants in countries such as Iran, Turkey, and Serbia. Nonetheless, raw material obtained from seedlings from free pollination is very diverse in terms of quality. They are small, of various shapes and colours. Moreover, they are often less juicy and tart. Most importantly, the fruits show no uniform pattern of ripening, which makes harvesting difficult. The harvest is one of the most labours and expensive practices in the orchard. However, due to its similarity to olives, mechanical harvesting can be optimized here (Bernardi et al., 2016).

Many countries, including Ukraine, Poland, Iran, the Czech Republic, Austria, Serbia, Turkey, and others, breeding works have started to select cultivars. In the case of cornelian cherry, breeding is carried out towards faster and more abundant yield, and production of fruit of larger sizes, with a high share of flesh and a small stone (Magdhradze et al., 2009). During selection, cultivars interesting in terms of shape and colour are distinguished. The date of fruit ripening, duration of the ripening period, strength of tree growth, resistance to drought, and self-fertility are also important.

Choosing a cultivar for a commercial plantation should depend on the planned fruit management. Fruits intended for direct consumption as a dessert should have the largest mass (it is worth reaching for the Ukrainian variety with the largest weight of over 7g), or be distinguished by the colour of the skin, i.e. yellow ('Bukovinskij', 'Flava', 'Jantarnyj', 'Neżnyj' and 'Pervenets'). Red fruit varieties suitable for processing have fruits with the smallest proportion of stone in the mass of the fruit (9–10% on average), i.e. 'Jelena', 'Grienadier', 'Ekzotycznyj' from Ukrainian cultivars (Klimienko, 2004). Among Polish cultivars, the smallest share of the stone in total mass of fruit was found for the 'Florianka' and 'Dublany' cultivars (11%). Cultivars with a large stone can be used to produce oil rich in unsaturated fatty acids, with the highest share of linoleic acid (70–75%) and oleic acid (15–16.7%). Valuable cornelian seed oil can be used as a dietary supplement. Some Polish cultivars are characterised by a large proportion of the stone in the total weight of the fruit (15–16.5%), e.g. 'Kotula', 'Kresowiak', 'Bolestraszycki', 'Paczoski' and 'Kresowiak' (Kucharska et. al, 2011).

The condition for the establishment of intense cornelian cherry orchards is the availability of high-quality planting material. Cornelian cherry can be propagated from seeds, but generative propagation does not ensure the same characteristics as the mother plant (Bosančić, 2009). Moreover, plants harvested this way have a long juvenile period. Individual cornelian cherry cultivars are reproduced exclusively vegetatively. Difficulties with effective rooting of cornelian cherry necessitate the use of more effective methods (Bijelić et al., 2016). One of them is propagation by budding or grafting on cornelian cherry seedlings.

The objective of this experiment was to investigate differences in the growth of selected cultivars and genotypes of cornelian cherry at the end of the technology of production of maiden trees.

MATERIALS AND METHODS

The experiment was carried out in the period 2016–2017 in a private nursery in Dąbrowica (near Lublin) in Poland (22,454 N; 51,270 E).

In both studied years, the mean annual air temperature and annual precipitation were higher than the multi-annual mean/total (Table 1).

Table 1. Mean monthly air temperature and precipitation in the study years against the multi-annual mean/total (1951–2012)

Month	Air temperature (°C)			Precipitation (mm)		
	Monthly mean			Monthly total		
	2016	2017	Multi-annual mean (1951–2012)	2016	2017	Multi-annual total (1951–2012)
April	8.8	7.1	7.4	42.92	54.6	39.0
May	14.4	13.6	13.0	30.49	41.7	60.7
June	18.3	17.7	16.3	58.16	30.2	65.9
July	18.9	18.1	18.0	130.04	87.9	82.0
August	17.8	19.2	17.2	61.97	56.1	70.7
September	15.1	13.6	12.6	11.93	88.4	53.7
October	6.7	8.8	7.6	111.74	91.4	40.1
Mean/total for the year	8.7	8.5	7.3	876.7	819.2	558.9

In the experiment, two hundred two-year-old generative cornelian cherry rootstocks with a diameter of 12–15 mm were used in both seasons of the study. In August 2016, budding was performed by means of the 'T' method. Buds of selected cornelian cherry genotypes: Gruszkowy, Okazały, Roch, Za bankiem S_1, and Za bankiem S_2 were collected from mother plants growing in Dąbrowica. The buds of cultivars 'Paczoski', 'Raciborski', 'Dublany', 'Bolestraszycki', 'Szafer' came from the Arboretum and Institute of Physiography in Bolestraszyce, near Przemyśl, Poland. Buds were taken only from hardwood shoots. Shield pieces containing a bud wood were inserted in a 'T' shaped incision made on the stock, always on the western side. The rootstock and bud were tied together

Figure 1. Measuring the height of Cornelian cherry maiden plant.

with polythene tape to make the entire cutting surface adhere to the place on the rootstock. During attachment, care was taken not to break the bud. At the end of the 2016 season, manual weeding was carried out. At the beginning of the 2017 season, parts of the stock were cut off above the place of budding. The cut was made at a right angle in the place of the upper cut with the budding method in the letter 'T'. The place of cutting was protected with a mixture of emulsion and Funaben Plus 03 PA. Immediately after cutting, nitrogen fertilisation was applied with 'Mocznik' fertiliser. Soil fertilisation with multi-ingredient 'Fructus truskawka' (concentrated, granular multi-component: N 9%, P 9%, K 16%, Mg 2%, s 24,5%) fertiliser was applied on 2 dates, namely 10.05 and 20.06. Sprouting of the buds began in mid-April 2017. Plants were also foliar supplied with the 'Ekolist Standard' fertiliser from the end of June to mid-August, after 2 days, every 2 weeks. A potassium preparation was also used to accelerate the growth of plants. During the season, mechanical weeding and soil tillage were carried out. In August, the formation of maiden trunks was performed through cutting strongly growing three bottom pairs of shoots that could compete with the leader. One of the final treatments was manual defoliation.

Figure 2. Measuring of stem diameter of Cornelian cherry maiden plant.

During the experiment, the height of plants was determined (from the ground surface to the tip of the leader Fig. 1), as well as the diameter of the plant (just above the place of budding Fig. 2), average number of shoots, and number of leaves on selected shoots. The measurements were made at monthly intervals on four dates, namely: 21.06.2017, 27.07.2017, 29.08.2017, and 10.10.2017. The last step was removing plants from the nursery (at the end of October), and determining the number and length of roots (Fig. 3).

Figure 3. Preparation of maiden plants for assessing the quality of the root system.

Data Analysis

Statistical calculations were performed in STATISTICA for Windows Version 5.5A. The obtained results were subject to statistical analysis by means of analysis of variance (ANOVA). The significance of the differences among the characteristics was assessed based on confidence intervals calculated by means of a Tukey's test, with a significance level of 5%.

RESULTS AND DISCUSSION

Because of its very valuable fruit, Cornelian cherry is bred in many countries, including Ukraine, the Czech Republic, Slovakia, Iran, Turkey, Serbia, France, Austria, and Poland. Polish cultivars, bred in the Arboretum in Bolestraszyce near Przemyśl, include: 'Bolestraszycki', 'Dublany', 'Florianka', 'Juliusz', 'Kresowiak', 'Paczoski', 'Podolski', 'Raciborski', 'Słowianin', and 'Szafer'. They differ in terms of fruit ripening, shape, colour, taste, share of the seed in the fruit, as well as chemical properties, e.g. extract, vitamin C, and anthocyanins (Kucharska et al., 2011).

An important factor intensifying production is high quality nursery material. Generative reproduction does not guarantee obtaining high-quality trees, because young plants are very diverse in terms of quality characteristics. Therefore, cornelian cherry should be vegetatively propagated for production purposes. At a small scale, cornelian cherry can be propagated by layering (Ivanicka & Cvopa, 1977; Klimenko, 2004; Fedosova & D'Antuano, 2012). Another way of vegetative propagation is cuttings. Softwood cuttings are very delicate, sensitive, and require the use of mist (Ivanicka, 1989). It is an effective method, but to a large extent dependent on the date of collection of cuttings, and the type of preparation used for rooting (Pirlak, 2000). The ability to root largely depends on genetic traits, but it can be improved by using growth regulators (auxins), as well as proper fertilisation, irrigation, and maintenance of high humidity (Stepanowa et al., 1986; Smykov et al., 1987). Jagła (2011), comparing the reproduction efficiency of several lesser-known fruit species, including cornelian cherry, using cuttings harvested at the end of June and at the turn of July/August, assisted by rooting preparations such Himal and Rhizopon, stated that cornelian cherry was the poorest rooting species. In both dates of obtaining cuttings, the degree of their rooting varied from 0% (cuttings without rooting preparation) to 33% of cuttings treated with rooting preparation Rhizopon. Cornelian cherry can also be propagated *in vitro*. Cornelian cherry is a species relatively easy to replicate, but in tissue cultures, because in the case of cuttings rooting is very poor.

Not many experiments have been conducted comparing the effect of planting material on the growth and yielding of cornelian cherry in orchards. Nonetheless, the assessment of the rate at which fruiting begins suggests that the best method is grafting or budding on *Cornus mas* seedlings (Klimenko, 2004) or *Cornus amomum* seedlings (Ochmian et al., 2019). In addition to repeating the characteristics of the mother plant, it guarantees much faster beginning of fruiting, even compared to plants obtained by cuttings. Approximately 50% of maiden trees flower and yield in the second year after budding, and almost 100% in the third year (Klimenko, 1990). However, plants obtained from seedlings have the first fruit not earlier than after 8 years after planting. Ochmian et al. (2019) found that cornelian cherry cultivars budded on *Cornus amomum* were characterised by weaker tree growth, but the quality of fruit did not decrease compared to trees on their own roots. Fruits of cultivars with dark skin ('Jolico', 'Schönbrunner' and 'Shumen') from budded trees had significantly more anthocyanins. The 'Jolico' fruit from budded trees showed a much larger diameter and mass.

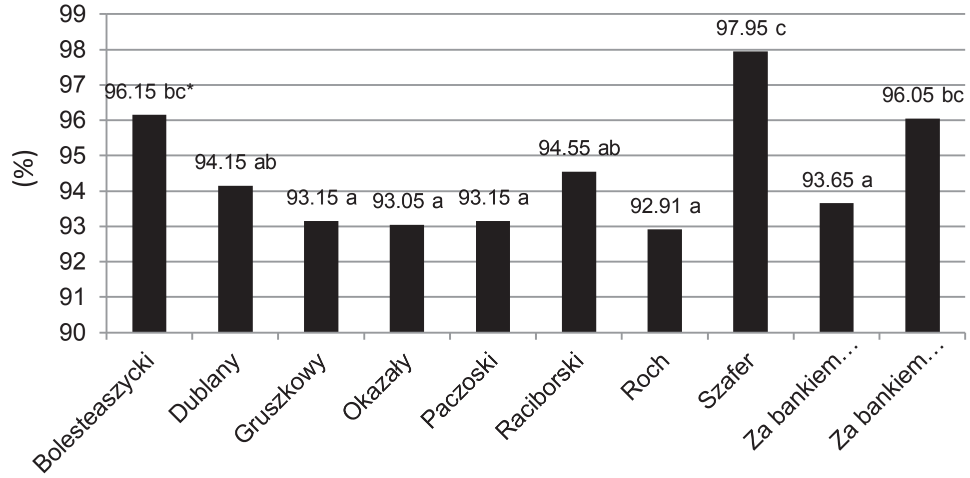

Figure 4. Efficiency of budding (%) of cultivars and genotypes of Cornelian cherry (*Cornus mas* L.).

*Bars with different letters are significantly different at $P < 0.05$.

The rootstock is an important component of the tree, because it determines its strength of growth, adaptation to soil conditions, resistance to disease, size and quality of crops, and tolerance to salinity and drought. In the case of cornelian cherry, a rootstock good in terms of physiological compatibility is cornelian cherry (*Cornus mas* L.). Difficulties with vegetative propagation enforce the use of generative rootstocks, i.e. propagated from seeds. This type of reproduction does not ensure homogeneous quality, although in the case of stone fruits (cherries, cherries, and plums) in the nursery technology, generative rootstocks are also used. The comparative assessment of the method of maiden cornelian cherry production can be referred to the production of two-year-old maiden trees (Sadowski et al., 2006). The root system of such trees is three years old. The trees must be well-grown and branched. The quality features of trees depend on the species. In the case of apple trees, budding trees 20 cm above the ground is most desirable, on dwarf rootstocks with a high-formed crown, at least at a height of 60–80 cm, with not too long lateral shoots (up to 60 cm in length). Based on research by Bielicki et al. (2008) on the quality of obtained young organic trees of apple, pear, cherry, cherry, plum, and quince, the highest number of trees in comparison to budded rootstocks was obtained in the case of apple trees (80.3–91.2%) and pear trees (42.9–87%), and the smallest for sweet cherries (8.4–17.3%). Klimenko (2004) and Fedosova & D'Antuano (2012) reported that the most effective way of propagation of cornelian cherry is budding (efficiency 90–98%) and grafting (efficiency 75–78%). In the present experiment, the efficiency of budding was very high (from 92.1 to 97.95%), suggesting the usefulness of this method for Cornelian cherry propagation (Fig. 4). The quality of rootstocks has considerable influence on the reception of buds. In organic farming, it is difficult to protect against diseases and pests. Due to this, the rootstock is less grown, and the length of cambium activity is reduced. In the absence of monocultures, Cornelian cherry is resistant to diseases and serious pests such as aphids and mites. The growth of maiden trees also to a large extent depends on the time of budding. According to nurseries, the best date for T-budding is the period of intensive division of the cambium. In the conditions of central, south, and east Poland, sour cherry budding should start between the end of July and middle of August (Hołubowicz et al., 1993). In the present experiment, budding was carried out in mid-August, and the high effectiveness of the treatment testifies to good activity of the Cornelian cherry cambium in this period. cv. 'Szafer' was characterised by the highest efficiency of budding (97.95%), while the smallest efficiency of budding concerned genotypes: Roch, Okazały, Gruszkowy, Za bankiem S_1, and cultivar 'Paczoski' (from 92.91 to 93.65%). This confirms results by Bijelić et al. (2016) who in the conditions of Serbia proved that budding in August is a method of reproduction more effective (from 56.67 to 83.62%) than grafting in April (from 21.67 to 30.33%).

The growth of maiden trees in a nursery depends on the genetic characteristics of the species and the variety. Bielicki et al. (2008) found that among the tested species, prune trees were best grown on seedlings, and the variety had a decisive impact on the quality of the obtained maiden trees. Stachowiak & Świerczyński (2004) proved that growth of maiden sweet cherries in the nursery particularly depends on the rootstock, although among the studied cultivars, 'Hardy Giant' and 'Sumit' had the largest trunk diameter and height. According to Jacyna (2004), in the case of pear, the cultivar has a more significant impact on the branching of maiden trees than the rootstock. Jacyna (2004) and Łanczont (2004) evidenced a high correlation between the trunk diameter and number of shoots of maiden trees of apple, pear, and plum trees, which makes the trunk diameter an important quality feature of young trees. Lipecki et al. (2015) found a strong correlation between the diameter of 'Łutówka' maiden trunks and the total length of lateral shoots. The present experiment determined a strong positive correlation of the stem diameter with the height of maiden species and their number of branches (Table 2).

Table 2. Pearson's correlation coefficients (r) between selected measured criteria

Growth parameters	Number of shoots	Tree height	Stem diameter	Number of leaves
Number of shoots	x	0.53*	0.58*	-0.22*
Tree height		x	0.58*	-0.32*
Stem diameter			X	-0.10

Coefficients marked with asterisks (*) are significant at $P < 0.05$.

Meteorological conditions have a strong impact on the quality of nursery material (Baryła, 2005). In the present experiment, maiden trees were damaged by spring frosts in May 2017. Cooling occurred when the plants had 2–3 pairs of leaves (about 10 cm). The frost caused damage to the leaves, manifested in the characteristic scorching of leaf edge, and temporary inhibition of growth. Nonetheless, at the end of the growing season, the height of all dogwood varieties and genotypes exceeded 1,000 mm (Table 3). In the present study, the height of plants was influenced by the cultivar and genotype. The highest values were determined for cv. 'Bolestraszycki', genotype Okazały and cv. 'Dublany' (respectively: 1,493, 1,461, and 1,493 mm), while genotypes Za bankiem S_1

and Roch were the shortest (1,013 and 1,050 mm). The height of maiden trees determined based on Ekaterina (2008) is similar, because in the first year of vegetation maiden trees grow up to 120–150 cm. Bijelić et al. (2016) obtained much lower trees (from 736.7 to 906.8 mm) as a result of budding in August and grafting in April. An important feature that proves the quality of maiden trees is the diameter of the stem. In the present experiment, the stem diameter was similar for more cultivars and genotypes. The largest diameter was reached for cv. 'Dublany' (16.84 mm), and the smallest for cv. 'Raciborski' (12.93 mm). The obtained results confirm the study by Klimenko (1990) in which Cornelian cherry maiden trees had a diameter of 13 to 15 mm, slightly higher than in the case of Bijelić et al. (2016), where the budding genotypes had a diameter of 10 to 13.61 mm.

Table 3. Some above-ground morphometric features of Cornelian cherry cultivars and genotypes

Cultivar/ genotype	Height of plants (mm)	Stem diameter (mm)	Average number of shoots (pieces/plant)	Average number of leaves (pieces/shoot)
Bolestraszycki	1493 c*	16.31 bc	11.4 de	14.8 ab
Dublany	1457 c	16.84 c	11.6 e	14.8 ab
Gruszkowy	1305 bc	15.0 a-c	10.4 b-d	15.8 a-c
Okazały	1461 c	14.71 a-c	9.6 ab	17.7 de
Paczoski	1341 bc	14.75 a-c	11.0 c-e	14.4 a
Raciborski	1182 ab	12.93 a	11.0 c-e	16.3 b-d
Roch	1050.1 a	15.14 a-c	10.0 a-c	18.6 e
Szafer	1103 ab	14.79 a-c	10.4 b-d	15.5 a-c
Za bankiem S_1	1013 a	13.88 ab	9.2 a	17.7 de
Za bankiem S_2	1119 ab	15.11 a-c	10.0 a-c	16.5 cd

*Values in the same column with different letters are significantly different at $P < 0.05$.

The assessment of the effect of the cultivar and genotype on the average number of shoots (Table 3) showed the highest values for cv. 'Dublany', 'Bolestraszycki', 'Paczoski', and 'Raciborski' (respectively: 11.6, 11.4, 11.0, and 11.0 pieces/plant), and the lowest values for genotype Za bankiem S_1 – 9.2 pieces/plant. Cultivars and genotypes. differed significantly in the average number of leaves. The highest number of leaves per shoot was determined for genotypes: Roch, Okazały, and Za bankiem S_1 (respectively: 18.6, 17.7, and 17.7 pieces/shoot), and the lowest for cv. 'Paczoski' (14.4 pieces/shoot)
The results of our study showed that the intense growth of maiden tree height and trunk diameter occurred from June through August, and decreased from September to October (Figs 5, 6). In September and October, intensive formation of leaves on the Cornelian cherry maidens occurred (Fig. 7).

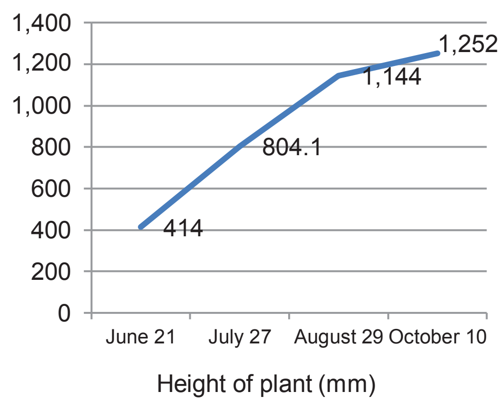

Figure 5. Growth rate in height of Cornelian cherry maiden trees in the growing season.

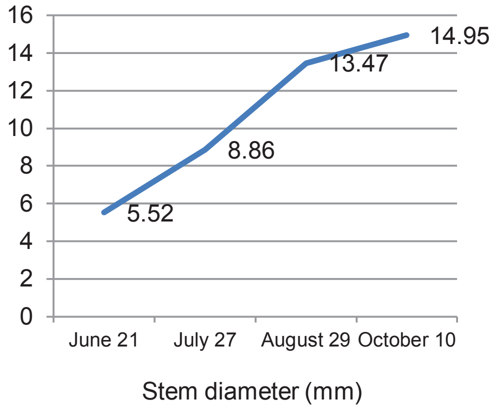

Figure 6. Growth rate in stem diameter of Cornelian cherry maiden trees in the growing season.

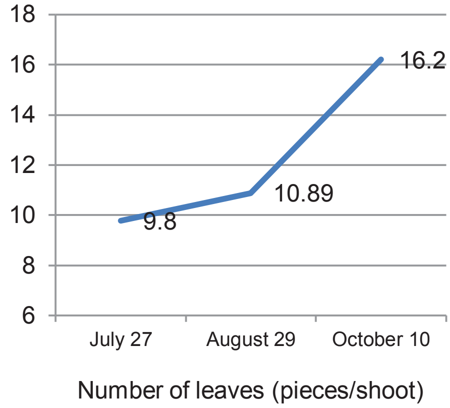

Figure 7. Changes in the number of leaves on maiden shoots in the growing season.

An important element determining correct adoption and commencement of growth on a plantation is a properly developed root system. The Cornelian cherry root system is adapted to grow even in mountainous conditions. It is therefore shallow and very branched, with a high number of very thin roots allowing penetration of the substrate. Cornelian cherry is difficult to root. The number of roots obtained during propagation by cuttings is smaller than during budding. Pirlak et al. (2000) rooting 10–15 cm sections of hardwood shoots recorded from 9.51 to 12.39 roots (depending on the genotype tested), and the root length varied from 4.49 to 5.65 mm. Bijelić et al. (2016) counting roots of Cornelian cherry budded in August recorded from 12 to 19.67 pieces, and their length ranged from 103.34 to 142.38 mm. Klimenko (2004) found a smaller number of maiden roots: from 10.6 to 14.4. In the present study, the most-grown roots were produced in the case of the 'Szafer' cultivar (24.15), and the least-grown ones by genotypes: Roch, Gruszkowy, Za bankien S_1, Za bankiem S_2, and cultivars ‘Dublany’ and ‘Paczoski’ (from 18.10 to 20). Particular cultivars and genotypes substantially differed in the length of roots (Table 4). The longest roots were created by cv. 'Szafer' (160.0 mm), and the shortest by Za bankiem S_1 (127.3 mm).

Table 4. Effect of the cultivar and genotype on selected quality features of roots and efficiency of budding

Cultivar/ genotype	Length of root (mm)	Number of roots (pieces/plant)
Bolestraszycki	149.8 e*	21.00 ab
Dublany	139.0 bc	19.50 a
Gruszkowy	149.6 e	18.10 a
Okazały	142.9 cd	13.15 bc
Paczoski	145.5 de	19.90 a
Raciborski	127.8 a	25.75 c
Roch	144.8 de	18.10 a
Szafer	160.0 f	24.15 c
Za bankiem S_1	127.3 a	20.00 a
Za bankiem S_2	135.3 b	19.20 a

*Values in the same column with different letters are significantly different at $P < 0.05$.

Producing high-quality trees does not guarantee sufficiently rapid growth on a plantation. It is very important not to allow the root system to dry out. In the nursery technology, the method of cultivation needs to be refined: in pots of 2–3 L, or directly in the soil, and then sales with a ‘bare’ but much better developed root system. Propagation by budding is not the easiest and quickest method. It still requires refinement at many stages of nursery production. A minimum period of 2 years is required to obtain rootstocks. Cornelian cherry seeds obtained from harvested fruits require a rest period. This period can be reduced by stratification or scarification. There are many physical and physiological factors, including the fact that the seeds are covered with thick shells. Seeds are stimulated for germination by means of special treatments. Ensuring the continuity of production of rootstocks, followed by proper budding and transport of trees to a permanent place, however, allows for a quick entry into the fruiting period and high fruit quality.

CONCLUSIONS

Cornelian cherry maidens obtained by budding with dormant bud in August on two-year-old seedlings of Cornelian cherry (*Cornus mas* L.) constitute high quality material suitable for establishing commercial plantations. Maiden trees of individual cultivars and genotypes of Cornelian cherry significantly differ in height, diameter, number of branches and leaves, as well as size of the root system. The diameter of the trunk is a good indicator of the quality of Cornelian cherry maiden, because it is closely positively correlated with the height of plants and the number of shoots. The highest quality trees in terms of their height, stem diameter and number of shoots were obtained in the cv. ‘Dublany’. Whereas the weakest growth, the smallest number of shoots and a relatively small diameter of the trunk was characterized by the genotype Za bankiem S_{1}.

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