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Growth of hybrid poplars in silviculture at the age of 6 years

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ABSTRACT: Growth and timber production of 28 poplar clones were evaluated. A set of clones was derived from 14 clones newly bred in Forestry and Game Management Research Institute in the Czech Republic, eight well-known cultivars of *Populus* × *euroamericana* planted in Europe and imported to the Czech Republic, two standard cultivars 'I-214' and 'Robusta' (*Populus* × *euroamericana*). Four clones of *Populus deltoides* were added to the test set. Tree spacing was 4 × 4 m. Stem diameter, tree height and stem volume production were evaluated in 6-years-old trees. Based on the results, it was concluded that the yield of four clones was higher than that of standard cultivar 'I-214'. Standing volume of two *P. deltoides* clones and one new Czech *P.* × *euroamericana* clone varied in the range of 77–121 $m^3 \cdot ha^{-1}$.

Keywords: Fluvisol; *Populus* × *euroamericana*; *Populus deltoides*; timber production

Poplars belong to the fastest growing trees in the temperate climate zone and have high biomass production in a relatively very short period. The yield of poplar plantations is effective despite the necessity of demanding establishment. A successful poplar culture depends on planting of proven clones, good site and intensive cultural treatments. All clones, usually hybrid poplars, were proved in tests before their wide use in forestry or for other purposes. Clonal selection for growth rate, yield, pest resistance, site adaptability is the main goal of breeding research programmes (Stanturf et al. 2001).

Many authors investigated anatomical and physiological characteristics, assuming that they have an important influence on biomass productivity. The results showed a high interclonal variability for most parameters. Strong correlations between the number of stomata on the leaf adaxial surface and biomass, thickness of palisade tissue and biomass, leaf area and biomass were described in *Populus* × *euroamericana* and *Populus deltoides* clones. Dry weight of biomass was measured as an indicator of productivity. It can be supposed that it is possible to create genotypes with an optimal structure of vegetative organs (Orlović et al. 1998). Differences among *Populus* × *euroamericana*, *Populus deltoides* and *Populus deltoides* × *balsamifera* clones in some growth parameters were evaluated (Tuskan, Rensema 1992). There were significant differences among clones in diameter at breast height (dbh), total height, live crown length, crown width and weight. Ceulemans et al. (1992) studied the physiology, morphology and genetics of two *Populus* species, *Populus trichocarpa*, *Populus deltoides*, and their hybrids. The growth of selected *Populus* hybrids with the parental species was compared in the study to explore clonal variation within hybrids and parental species and to relate differences in productivity according to differences in morphological and physiological traits. Growth vigour of five new poplar clones (*Populus* × *euroamericana*, *Populus deltoides*) was evaluated in comparative field study with registered cultivars 'I-214' and 'Pannonia' (*Populus* × *euroamericana*) and parameters of new candidate clones such as height and dbh were measured to select the best clones for poplar wood production (Orlović et al. 2006). Many parameters such as dbh, upper diameter limit outside bark, height, leaf area index, stem and stemwood biomass were measured on three

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poplar clones 'I-69', 'I-72', 'NL-80351' (*Populus* × *euroamericana*) planted at four different spacings. The best design for ground pulp timber production was recommended on the basis of 6-year results (Fang et al. 1999).

The growth and volume production of 22 *Populus* × *euroamericana* clones were intensively assessed in the eastern Slovakia lowland in the unflooded alluvia on medium-heavy clay soil (Kohán 2008). The evaluation of results showed that clones 'OP-223', 'NE-367', 'Quariento' and 'Pannonia' presented high volume production in 5-years-old plantation and they were also the best poplars at the age of 10 years (Kohán 1991, 1999). The poplar 'Pannonia' was also investigated on research plots with different level of groundwater (Kohán 2008).

Poplar breeding started in the Forestry and Game Management Research Institute (FGMRI) in the Czech Republic in 1952. Research plots were established and evaluated in different site conditions and 22 clones were recommended for cultivation. This study had two main goals: (*i*) to compare the growth of newly bred poplar hybrids with standard registered cultivars of *P.* × *euroamericana*, (*ii*) to select the best clones in the test with high timber production for further evaluation.

MATERIAL AND METHODS

Poplar clones for this experiment were selected from the specific poplar breeding programme of the Forestry and Game Management Research Institute (Table 1). The selection was based on significantly good growth vigour in the maintained Czech poplar germplasm collection. The clones were selected from F1 progenies of the species *Populus angulata*, *Populus nigra*, *Populus deltoides* including well-performing clones from the open pollination of those parental species. Clones from this group were labelled as CZ clones. The second group of nine clones included standard registered cultivars planted in the Europe but not tested in the Czech Republic. Two registered cultivars 'I-214' and 'Robusta' (*Populus* × *euroamericana*) were planted as standards of the test and cultivar 'I-214' was then used as a basis for clonal ranking. Four clones of the species *Populus deltoides* were also used.

An experimental plot was established at the Kostelany locality in the southeastern part of the Czech Republic (GPS 49°02'71.658"N, 17°25'32.206"E, elevation 176 m a.s.l.) along the Morava river in 2003. Soil type is Fluvisol with good water supply.

The site was prepared by single pretreatment cultivation with plough, disc and rotary tiller. One-year-old rooted plants were planted at a spacing of 4 × 4 m, each clone in three replications by four plants. The experimental plot had one border row on all sides. Weed control was applied without herbicides with a disc and rotary tiller twice during each growing season. Individual plants were first hoed and then grass was only mowed. Pruning was performed in 2005–2007.

All trees were measured at six years of age. Stem diameter was measured at breast height (dbh at 1.3 m) in the same azimuthal direction. Total tree height was measured to the nearest centimetre with an ex-

Table 1. The list of species and clones of tested poplars

Clone number	Species and clone name
P-335	*P. nigra* × *deltoides* 'CZ-A 011'
P-363	*P. deltoides* × *nigra* 'CZ-301/67'
P-365	*P. deltoides* ssp. missouriensis × *nigra* 'CZ-A 003'
P-390	*P.* × *euroamericana* 'CZ-148'
P-447	*P.* × *euroamericana* 'CZ-144'
P-448	*P.* × *euroamericana* 'CZ-146'
P-528	*P. angulata* 'Törökfay' × *wind* 'CZ-257'
P-535	*P. angulata* 'Törökfay' × *nigra* 'CZ-1047'
P-540	*P. angulata* 'Törökfay' × *nigra* 'CZ-919'
P-608	*P. angulata* 'Törökfay' × *nigra* 'CZ-584'
P-629	*P.* × *euroamericana* 'I-214' × *wind* 'CZ-702'
P-645	*P.* × *euroamericana* × *wind* 'CZ-00794'
P-738	*P. nigra* × *deltoides* ssp. monilifera 'CZ-245/58'
P-740	*P. angulata* 'Törökfay' × *nigra* 'CZ-390'
P-755	*P. angulata* 'Törökfay' × *nigra* 'CZ-352'
P-756	*P. angulata* 'Törökfay' × *nigra* 'CZ-846'
P-788	*P. angulata* 'Törökfay' × *wind* 'CZ-384'
P-187	*P.* × *euroamericana* 'Bietigheim'
P-188	*P.* × *euroamericana* 'Blanc du Poitou'
P-231	*P.* × *euroamericana* 'H-381/5'
P-234	*P.* × *euroamericana* 'I-154'
P-385	*P.* × *euroamericana* 'NE-237'
P-657	*P.* × *euroamericana* 'I-214'
P-716	*P.* × *euroamericana* 'Pannonia'
P-758	*P.* × *euroamericana* 'Gigant'
P-778	*P.* × *euroamericana* 'Boccalari'
P-781	*P.* × *euroamericana* 'Koltay'
P-786	*P.* × *euroamericana* 'Robusta'
P-581	*P. deltoides* 'BT'
P-779	*P. deltoides* 'Bellotto'
P-789	*P. deltoides*
P-798	*P. deltoides*

tensible telescopic pole. Stem volume was estimated according to volume tables for poplars (Fröhlich, Grosscurth 1973). Mean annual increment of tree height was worked out for five growing seasons. Standing volume was estimated for a stand with a spacing of 4 × 4 m. All data were statistically evaluated using the analysis of variance (nested design ANOVA) and differences among clones were investigated. Tukey's multiple range test (at $P = 0.05$) was used because of the imbalance of plant numbers among clones. Dunnett's test was used for a comparison of each clone with standard clone P-657 ('I-214'). All statistical analyses were performed by STATISTICA 8.0. (StatSoft 2007)

RESULTS

The research plot Kostelany is a typical Central European site type of poplar plantation. The first results showed significant differences (ANOVA, $P < 0.05$) among newly tested clones in diameter, height, estimated stem volume and mean annual increment (Table 2). Survival of clones was very high: 100% of planted trees were measured on 18 clones (= 64.3% of all clones) at the age of 6 years. Survival rate of 11 clones was 91.6% of individuals and survival rate of only 2 clones was 83.3%. Trees in border rows derived from 4 clones (P-363, P-365, P-608, P-581) were not included in clonal ranking while 28 clones were examined in detail. The evaluation of clones was based on a comparison with the standard registered cultivar 'I-214' (P-657, *Populus* × *euroamericana*). Clones with the same or better growth were evaluated as the best clones of the tested group of clones. Clones were more variable in diameter than in tree height (Table 3). The second standard cultivar 'Robusta' was not used for the comparison due to worse growth parameters than the most of tested clones.

The diameter overbark varied in the range of (7.25)9.60–19.86 cm, the mean of the group of clones was 14.80 cm. The best results were recorded

Table 2. Nested design ANOVA for height (*h*), diameter (dbh), stem volume (*V*), mean annual increment of height (MAI), at $P = 0.05$

	Effect (F/R)	SS	df	MS	Den. syn. error df	Den. syn. error MS	*F*	*P*
h								
Intercept	Fixed	70,342.55	1	70,342.55	56.2602	11.91170	5,905.333	0.000000
Clone	Fixed	2,128.36	27	78.83	56.1195	11.94366	6.600	0.000000
Rep2(clone)	Random	670.38	56	11.97	240	3.79948	3.151	0.000000
Error	Fixed	911.87	240	3.80				
dbh								
Intercept	Fixed	52,569.14	1	52,569.14	56.1655	4.495346	11,694.12	0.000000
Clone	Fixed	657.01	27	24.33	56.0760	4.509462	5.40	0.000000
Rep2(clone)	Random	253.21	56	4.52	240	0.913021	4.95	0.000000
Error	Fixed	219.13	240	0.91				
V								
Intercept	Fixed	2.835262	1	2.835262	56.2268	0.003113	910.7527	0.000000
Clone	Fixed	0.487611	27	0.018060	56.1042	0.003122	5.7847	0.000000
Rep2(clone)	Random	0.175254	56	0.003130	240	0.000866	3.6135	0.000000
Error	Fixed	0.207855	240	0.000866				
MAI								
Intercept	Fixed	1,517.952	1	1,517.952	56.2155	0.178786	8,490.311	0.000000
Clone	Fixed	21.386	27	0.792	56.099	0.179305	4.417	0.000001
Rep2(Clone)	Random	10.066	56	0.18	240	0.047267	3.803	0.000000
Error	Fixed	11.344	240	0.047				

df – degree of freedom, den. syn. error – denominator synthesis error, *F* – *F*-value, *P* – *P*-value, SS – sum of squares, MS – mean square

Table 3. Means (x) and standard deviations (SD) of diameter (dbh), height (h), estimated stem volume (V) and mean annual increment of height (MAI) of 28 poplar clones at the end of their 6th year of growth. Means in vertical sequence not followed by the same letter are significantly different at $P = 0.05$ according to Tukey's test

Clone		dbh (cm)	h (m)	V (m^3)	MAI (m)
P-187	x	14.16^{cde}	13.25^{efghi}	0.084^{bcdef}	2.26^{defgh}
	SD	2.38	1.32	0.034	0.24
P-188	x	16.95^{efg}	$12.87^{cdefghi}$	0.102^{def}	2.19^{cdefg}
	SD	1.71	1.28	0.041	0.25
P-231	x	9.60^{ab}	10.05^{ab}	0.031^{ab}	1.68^{ab}
	SD	3.44	2.46	0.029	0.80
P-234	x	15.25^{de}	13.08^{defghi}	0.095^{cdef}	2.16^{cdefg}
	SD	2.08	1.31	0.032	0.27
P-335	x	14.29^{cde}	13.16^{efghi}	0.084^{bcdef}	2.27^{defgh}
	SD	2.18	1.02	0.029	0.21
P-385	x	13.87^{cde}	11.12^{bc}	0.064^{abcde}	1.85^{bc}
	SD	2.68	1.26	0.029	0.24
P-390	x	14.18^{cde}	$11.90^{bcdefgh}$	0.072^{bcdef}	2.11^{bcdefg}
	SD	2.52	1.15	0.030	0.19
P-447	x	19.16^{fg}	13.87^{ghij}	0.161^{ghi}	2.30^{efgh}
	SD	2.60	1.08	0.054	0.23
P-448	x	15.68^{def}	$12.09^{bcdefgh}$	0.091^{bcdef}	2.05^{bcdef}
	SD	2.36	1.35	0.036	0.29
P-528	x	12.36^{bc}	11.31^{bcde}	0.051^{abcd}	1.92^{bcde}
	SD	2.07	1.45	0.026	0.29
P-535	x	16.33^{efg}	14.12^{ij}	0.117^{efg}	2.41^{fgh}
	SD	1.33	1.13	0.020	0.23
P-540	x	14.66^{de}	13.58^{fghij}	0.089^{bcdef}	2.31^{efgh}
	SD	0.91	0.87	0.015	0.16
P-629	x	10.95^{abc}	11.13^{bcd}	0.039^{abc}	1.87^{bcd}
	SD	2.57	1.22	0.019	0.25
P-645	x	7.25^{a}	8.01^{a}	0.011^{a}	1.26^{a}
	SD	2.13	1.89	0.012	0.43
P-657	x	16.50^{efg}	13.87^{ghij}	0.121^{fgh}	2.33^{efgh}
	SD	2.42	0.97	0.044	0.18
P-716	x	16.08^{ef}	14.16^{ij}	0.119^{efg}	2.31^{efgh}
	SD	3.02	1.21	0.050	0.24
P-738	x	13.50^{cde}	$12.12^{bcdefgh}$	0.066^{abcdef}	2.07^{bcdef}
	SD	2.08	0.80	0.027	0.14
P-740	x	15.36^{de}	14.18^{ij}	0.107^{defg}	2.35^{fgh}
	SD	1.92	0.98	0.035	0.23
P-755	x	14.66^{de}	14.16^{ij}	0.098^{def}	2.50^{gh}
	SD	2.09	1.46	0.040	0.30
P-756	x	14.13^{cde}	13.27^{efghi}	0.082^{bcdef}	2.28^{defgh}
	SD	2.13	0.81	0.029	0.15

Table 3 to be continued

Clone		dbh (cm)	*h* (m)	*V* (m^3)	MAI (m)
P-758	*x*	14.66^{de}	12.62^{cdefghi}	0.084^{bcdef}	2.10^{bcdefg}
	SD	2.40	1.04	0.030	0.24
P-778	*x*	15.75^{def}	13.08^{defghi}	0.099^{def}	2.18^{cdefg}
	SD	1.57	0.51	0.023	0.13
P-779	*x*	14.33^{cde}	11.91^{bcdef}	0.082^{bcdef}	2.07^{bcdef}
	SD	3.57	2.15	0.051	0.46
P-781	*x*	19.86^{g}	14.27^{ij}	0.180^{hi}	2.41^{fgh}
	SD	2.90	1.00	0.058	0.21
P-786	*x*	14.00^{cde}	13.45^{fghij}	0.082^{bcdef}	2.34^{fgh}
	SD	1.74	0.94	0.025	0.20
P-788	*x*	15.33^{de}	12.83^{cdefghi}	0.091^{bcdef}	2.18^{cdefg}
	SD	1.57	0.74	0.020	0.16
P-789	*x*	16.63^{efg}	13.95^{hij}	0.124^{fgh}	2.40^{fgh}
	SD	2.23	1.36	0.047	0.23
P-798	*x*	19.70^{g}	15.29^{j}	0.193^{i}	2.65^{h}
	SD	2.27	1.03	0.054	0.26

in clones of *P.* × *euroamericana* (P-781: 19.86 cm; P-447: 19.16 cm; P-716: 16.08 cm), *Populus deltoides* (P-798: 19.70 cm; P-789: 16.63 cm) and in the standard cultivar 'I-214' (= P-657): 16.50 cm (Fig. 1).

Tree height varied in the range of (8.1) 10.05–15.29 m in the group of clones (the mean of the group was 12.86 m). The best results were measured in clones of *Populus deltoides* (P-798: *H* = 15.29 m; P-789: *H* = 13.95 m), *Populus* × *euroamericana* (P-781: 14.27 m; P-716: 14.16 m; P-447: 13.87 m). The standard cultivar P-657 (= 'I-214') was 13.87 m high (Fig. 2).

The mean annual increment of height (MAI) varied in the range of (1.26) 1.68–2.65 m, the mean of the group of clones was 2.18 m. Real variance was relatively small, MAI of 57.14% of 28 clones was

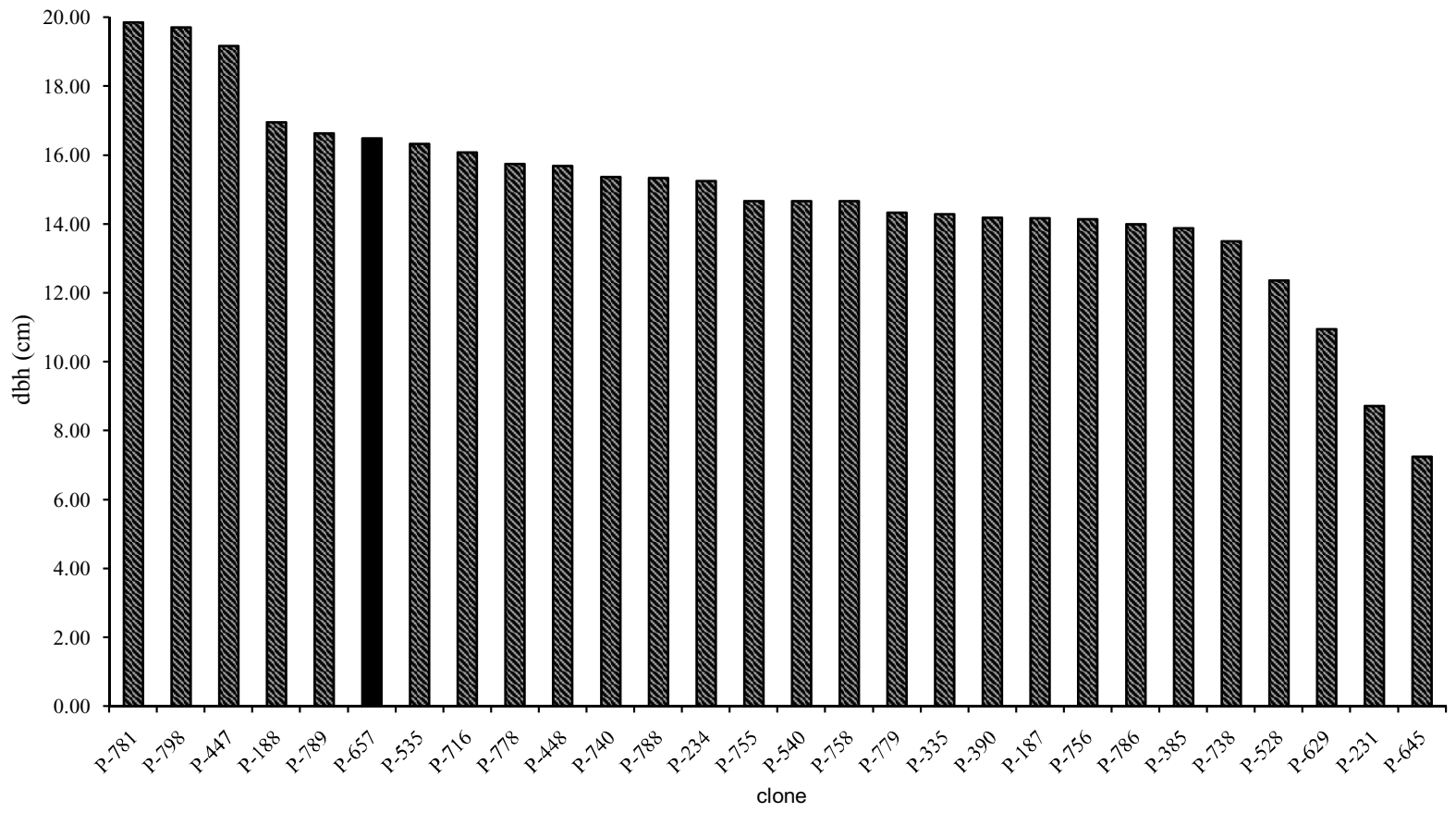

Fig. 1. Mean diameter (dbh) of tested poplar clones at age of 6 years

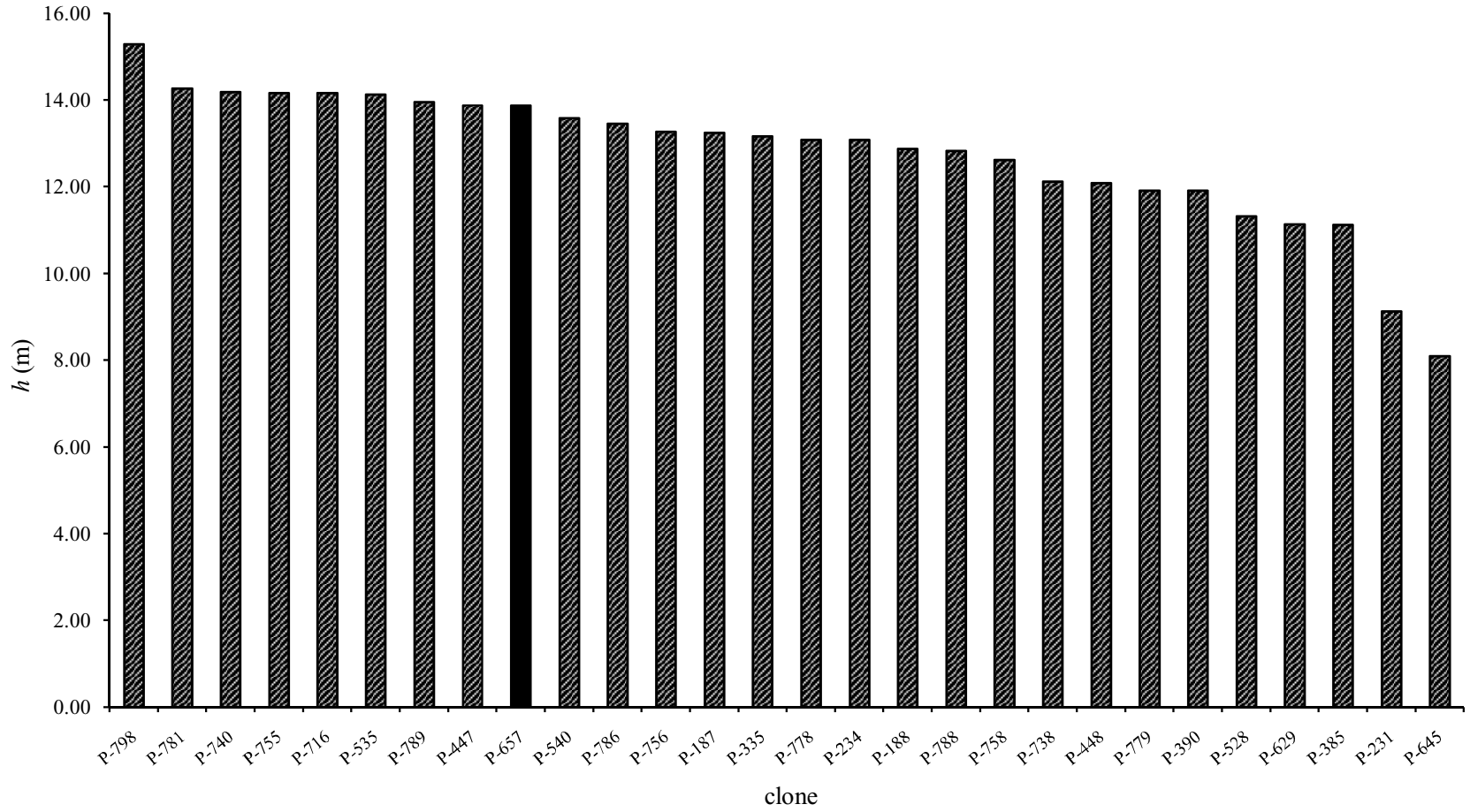

Fig. 2. Mean tree height (*h*) of tested poplar clones at age of 6 years

higher than the mean of the group and 10 clones (= 35.7%) showed MAI in the range of 2.30–2.50 m. Only 1 clone with MAI 2.65 m was observed (*Populus deltoides* P-798).

The main quantitative parameter, estimated stem volume overbark, varied in the range of (0.11) 0.031–0.193 m^3, the mean of the group of clones was 0.094 m^3 (Fig. 3). The best results were obtained in *Populus deltoides*, clone P-798: 0.193 m^3 and *P.* × *euroamericana* 'Koltay' (P-781: 0.180 m^3) followed by a new hybrid clone of *P.* × *euroamericana* 'CZ-144' (P-447: 0.161 m^3). *Populus deltoides*, clone P-789 (0.124 m^3) and *P.* × *euroamericana* 'Pannonia' (P-716: 0.119 m^3) were comparable with *P.* × *euroamericana* 'I-214' (P-657: 0.121 m^3). Three clones were much greater, the respective stem volume increment of clone P-798 and P-781 was 159.5% and 148.8% of that of cultivar 'I-214'. The stem volume of the new hybrid clone P-447 was 133.9% of that of cultivar 'I-214' (Table 4).

The following 11 clones, representing a compact group, did not significantly differ from each

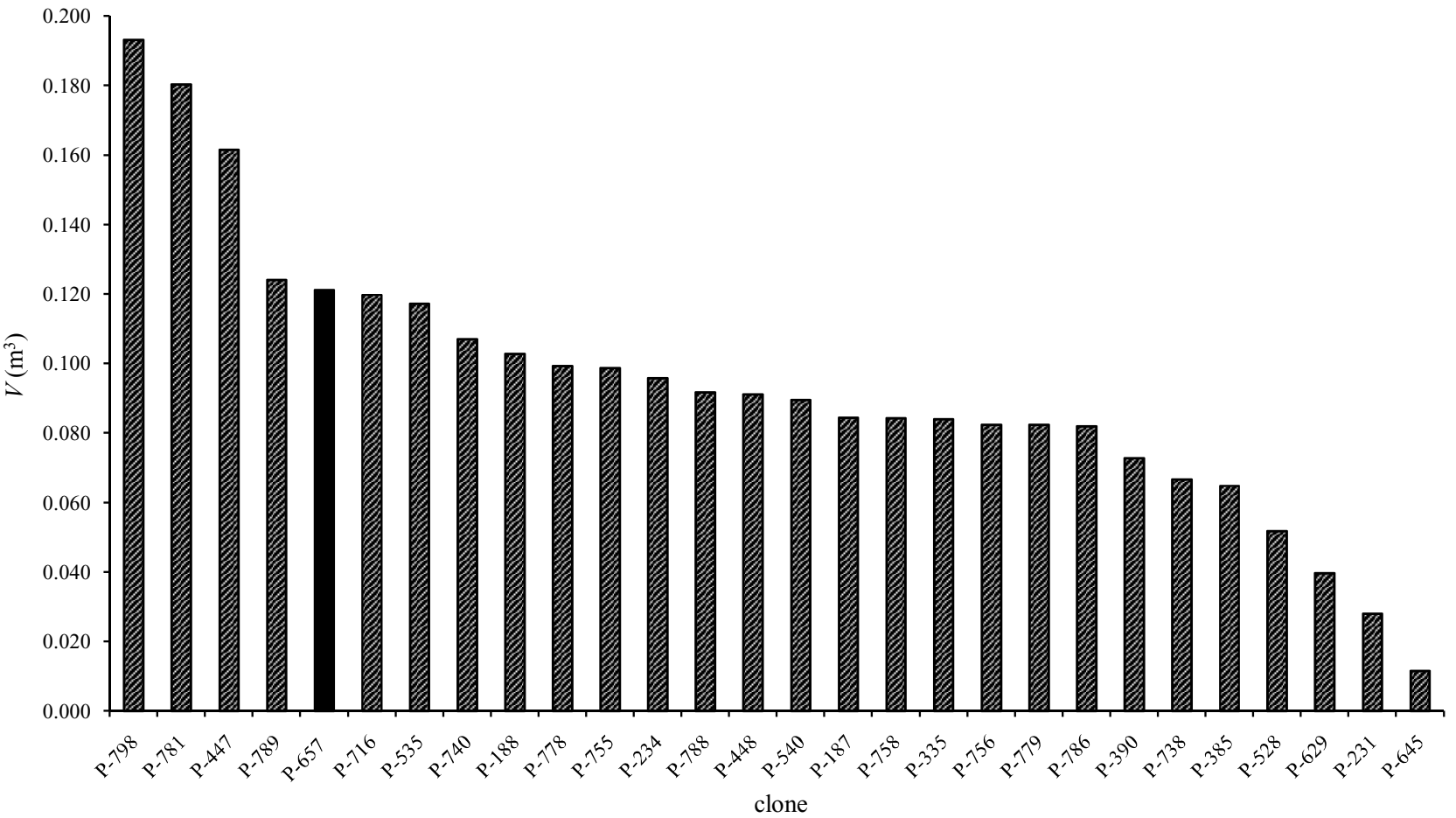

Fig. 3. Mean stem volume (*V*) of tested poplar clones at age of 6 years

Table 4. The percentage of the increment of tree height, diameter and stem volume, clonal ranking by standard cultivar 'I-214' (P-657). A. **group of candidate clones, B. *group of promising clones

Clone	Height (%)	Clone	Diameter (%)	Clone	Stem volume (%)
P-798**	110.2	P-781**	120.4	P-798**	159.5
P-781**	102.8	P-798**	119.5	P-781**	148.8
P-740*	102.2	P-447**	116.2	P-447**	133.9
P-755	102.1	P-188*	102.8	P-789**	102.5
P-716*	102.1	P-789**	100.8	P-657**	100.0
P-533	101.8	P-657**	100.0	–	–
P-789**	100.5	–	–	–	–
P-447**	100.0	–	–	–	–
P-657**	100.0	–	–	–	–
P-540	97.8	P-535	98.9*	P-716*	99.2
P-786	96.9	P-716	97.5 *	P-535*	96.7
P-756	95.6	P-778	95.5 *	–	–
P-187	95.5	P-448	95.0 *	–	–
P-335	94.8	P-740	93.1 *	–	–
P-778	94.2	P-788	92.9 *	–	–
P-234	94.2	P-234	92.4 *	–	–
P-188	92.7	–	–	–	–
P-788	92.4	–	–	–	–
P-758	90.9	–	–	–	–

other (P = 0.05), their stem volumes ranged from 0.072 to 0.095 m^3: P-187 ('Bietigheim'), P-234 ('I-154'), P-335 ('CZ-A011'), P-390 ('CZ-148'), P-448 ('CZ-146'), P-540 ('CZ-919'), P-756 ('CZ-846'), P-758 ('Gigant'), P-779 ('Bellotto'), P-786 ('Robusta') and P-788 ('CZ-384').

With the above-mentioned compact group and with the best group of 5 clones a group of 6 clones with stem volume 0.098–0.119 m^3 ranged, showing small significant differences among the clones: P-188 ('Blanc du Poitou'), P-535 ('CZ-1047'), P-716 ('Pannonia'), P-740 ('CZ-390'), P-755 ('CZ-352'), P-788 ('CZ-384'). The stand yield of the two of them, clone P-535 (0.117 m^3) and P-716 (0.120 m^3), was close to that of cultivar 'I-214' (0.121 m^3).

The stem volume 0.667 m^3 and less was typical of the last group of 6 clones: P-231 ('H-381/5'), P-385 ('NE-237'), P-528 ('CZ-257'), P-629 ('CZ-702'), P-645 ('CZ-007/94'), P-738 ('CZ-245/58'). These clones are not probably promising from the production aspect.

The comparison of all clones with standard clone ('I-214') was performed by Dunnett's test (Table 5).

Due to the low age of poplar plantation, the evaluated clones were divided into two groups:

– A. group of candidate clones yielding more than cultivar 'I-214' at the age of 6 years in all parameters including cultivar 'I-214',
– B. group of promising clones comparable with cultivar 'I-214' which can have a high yield during the next growing period, their growth reached more than 90% of the growth of standard cultivar 'I-214'. Clonal ranking was based on a comparison of diameter and stem volume (Table 4). Tree height in the range of 90–100% of that of cultivar 'I-214' was observed in a very wide group of clones (Fig. 2).

Volume production was chosen as an important criterion of clonal evaluation. Yield per ha was illustrated by the estimation of standing volume. The group of the best clones was represented by standing volume 101–121 $m^3 \cdot ha^{-1}$ at the age of 6 years (Table 6). The yield of the new clone *P.* × *euroamericana* 'CZ-144' was higher than the yield of cultivars 'Pannonia' and 'I-214' (*P.* × *euroamericana*).

DISCUSSION

An experimental hybrid poplar plantation was evaluated at the age of 6 years. Recommended cul-

Table 5. Comparison of all clones with standard clone (P-657), significant differences marked at $P = 0.05$ according to Dunnett's test

Clone	dbh	*h*	*V*	MAI
P-187	0.999989	0.738642	0.769844	1.000000
P-188	0.980412	1.000000	1.000000	0.999695
P-231	**0.002098**	**0.000476**	**0.008577**	**0.013568**
P-234	0.998800	0.999218	0.986777	0.996879
P-335	0.999767	0.801587	0.756726	1.000000
P-385	**0.042159**	0.581286	0.210626	0.210300
P-390	0.336361	0.772577	0.427717	0.951298
P-447	1.000000	0.558895	0.652360	1.000000
P-448	0.469151	1.000000	0.946135	0.764696
P-528	0.085581	0.089044	0.068648	0.264074
P-535	1.000000	1.000000	1.000000	1.000000
P-540	1.000000	0.942596	0.907322	1.000000
P-629	0.052000	**0.006431**	**0.017706**	0.153154
P-645	**0.000009**	**0.000010**	**0.000620**	**0.000014**
P-657	–	–	–	–
P-716	1.000000	1.000000	1.000000	1.000000
P-738	0.464987	0.392357	0.246266	0.817569
P-740	1.000000	0.999950	1.000000	1.000000
P-755	1.000000	0.942596	0.996824	0.998487
P-756	0.999997	0.749894	0.734438	1.000000
P-758	0.877797	0.942596	0.767237	0.927404
P-778	0.998800	1.000000	0.997738	0.998850
P-779	0.312939	0.821253	0.705305	0.827596
P-781	1.000000	0.274179	0.183470	1.000000
P-786	1.000000	0.649226	0.691470	1.000000
P-788	0.970942	0.999719	0.946105	0.999448
P-789	1.000000	1.000000	1.000000	1.000000
P-798	0.753137	0.304556	**0.043528**	0.631761

dbh – diameter at breast height, *h* – tree height, *V*– stem volume, MAI – mean annual increment of height

tivation techniques such as ploughing and weed control in rows were performed and had a positive influence on fast growth of poplars in the initial growth period (FAO 1979). The evaluated groups of poplars represented hybrids of *Populus angulata*, *Populus deltoides*, *P. nigra* and four clones of *P. deltoides*. Some authors compared *P. deltoides* as a parent species with its hybrids due to the common presumption of better growth of hybrids (Ceulemans et al. 1992). This idea was not included in this research; the investigated clones of *P. deltoides* were not actual parents of hybrids, so the comparative study was not performed. The pure species of

Table 6. Estimated standing volume of poplar clones at the age of 6 years

Clone number	Species and clone name	Standing volume ($m^3 \cdot ha^{-1}$)
P-447	*P.* × *euroamericana* 'CZ-144'	101
P-657	*P.* × *euroamericana* 'I-214'	76
P-781	*P.* × *euroamericana* 'Koltay'	112
P-789	*P. deltoides*	77
P-798	*P. deltoides*	121
P-716	*P.* × *euroamericana* 'Pannonia'	75

P. deltoides, clone P-798, had the best results in all measured parameters. Tree height, stem volume and mean annual increment of clone P-798 significantly differed from the rest of hybrid clones.

P. deltoides clone P-798 was followed by *Populus* × *euroamericana*, clones 'Koltay' and 'CZ-144'. Similar results were published in Serbia (Orlović et al. 2006). The experiments were established for the testing of *P. deltoides* clones and *P.* × *euroamericana* 'Pannonia' with a spacing of 4.25 × 4.25 m. Tree heights of *P. deltoides* clones varied in the range of 14.23–14.90 m (*P.* × *euroamericana* 'Pannonia' 15.60 m) and diameters were in the range of 16.47–17.20 cm (*P.* × *euroamericana* 'Pannonia' 15.37 cm) on Humofluvisol, in the 5-years-old plantation. These results are in agreement with the present study.

In the warm wet temperate climate other three clones of *P.* × *euroamericana* ('I-69', 'I-72', 'NL-80351') reached mean dbh 17.0–18.0 cm and mean tree height 16.6–18.08 m at different planting densities (Fang et al. 1999). The diameter over three clones was 18.2 cm for a spacing of 4 × 4 m. These results show the influence of climate conditions on rapid growth of *P.* × *euroamericana* and are comparable with presented results.

CONCLUSIONS

Clones of *Populus* × *euroamericana* and *Populus deltoides* planted at a spacing of 4 × 4 m were evaluated for dbh, tree height, mean annual increment of height, stem volume and standing volume at the age of 6 years. Clones P-798 (*P. deltoides*), P-781 (*P.* × *euroamericana* 'Koltay'), P-447 (*P.* × *euroamericana* 'CZ-144') originating from open pollination and P-789 (*P. deltoides*) maintained in the Czech poplar germplasm collection were included in the group of candidate clones with estimated mean stem volume higher than that of standard registered cultivar 'I-214' (*P.* × *euroamericana*). The cultivar 'I-214' was also included in this group. Mean dbh of the top five clones varied in the range of 16.50–19.86 cm, mean tree height was in the range of 13.87–15.29 m, mean annual increment 2.30–2.65 m, mean stem volume 0.121–0.196 m^3, estimated standing volume 76–121 $m^3 \cdot ha^{-1}$.

In the group of promising clones were ranked clones comparable with cultivar 'I-214' which can promise a high yield in the next growing period and the growth of which reached more than 90% of the growth of standard cultivar 'I-214'. Results attained for clone 'Pannonia' were somewhat worse than those of cultivar 'I-214'. Clonal ranking was based on a comparison of diameters and stem volumes. Five new clones from a breeding programme (four clones from progenies *P. angulata* 'Törökfay' × *nigra*, one clone from open pollination *P. angulata* 'Törökfay' × wind) and three registered cultivars of *P.* × *euroamericana* ('Blanc du Poitou', 'I-154', 'Boccalari') were included in this group. It is supposed that the growth of 8 promising clones with stem volume 0.098–0.119 m^3 will significantly increase in the next 5 years but clones with stem volume lower than 0.667 m^3 will be eliminated from further evaluation.

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