Analysis of Inheritance and Growth of Curly Birch Progenies from Controlled Hybridisation and Possibilities of their Utilisation for Timber Production in Agricultural Landscape

Viera PAGANOVÁ

Department of Biotechnics of Verdure, Slovak Agricultural University in Nitra, Nitra, Slovak Republic

Abstract: The influence of habit form on progeny growth was studied within the evaluation of the height growth of curly birch hybrid progenies. In all years 1998, 1999 and 2001 statistically significant differences in height were found between progenies in dependence on the hybrid combination of their parents. A large variability of heights was recorded in particular hybrid combinations nearly in all evaluated years. The effect of distant hybridisation can occur within the combination of the parents with different habit forms and their progenies reach excellent growth rate. The qualitative characteristics – rhytidome colour, occurrence of curly grain (decorative timber) on the trunk and branches and habit form were evaluated in 2001. The results confirmed statistical significance of the relationship between hybrid combination and occurrence of the studied qualitative characteristics in their progeny. The curly grain on trunk was found in all evaluated progenies, in four of them the ratio of individuals with curly grain and individuals without it was 2:1, in one progeny it was in 1:1. The proportion of birches with decorative timber will possibly increase because especially fine types of curly grain can be correctly identified at higher age.

Keywords: curly birch; crossing; decorative timber; hybridisation; inheritance; timber production

The curly birch (*Betula pendula* Roth. f. *carelica* Sok.) is a rare plant, but of high commercial value. More than two centuries the attention has been paid to this woody plant with respect to its decorative timber with brown coloured drawing (Figure 1): in cross-section the decorative drawing of timber looks like letter "V", in longitudinal section it looks like many waving strips, which recalls marble. In areas with more abundant occurrence of this plant its timber is used for the facing of representative rooms and ship interiors, for production of valuable veneers and furniture, in woodcarving and for making souvenirs. In addition curly birch has characteristics of the typical pioneer woody-plant, decorative habit, extraordinary curly grain on the trunk and branches, which makes this plant an interesting element of the landscape.

In 1975–1985 detailed study of the birch was carried out with special regard to its valuable technical forms in Slovakia. The curly birch was

Figure 1. Curly birch timber – the surface of the trunk without bark (left) and longitudinal section of the trunk with decorative brown pattern (right)

found in nearly 80 localities. About 330 curly birch individuals were propagated xenovegetatively (by grafting) and also generative progenies from seed collection were obtained in several localities for conservation of this valuable gene pool. This material was used for establishing a seed orchard and for plantings in Borova hora Arboretum of the Technical University in Zvolen. Material that is the object of evaluation in this paper was obtained from the mentioned base in the course of subsequent work.

The most frequent and known occurrence of curly birch is in the north-eastern area of Russia, in Baltic countries and in the southern part of Scandinavia. The scattered occurrence of this plant is mentioned from northern Ukraine, eastern parts of Germany and Poland. The whole area of its distribution lies between 48°40′and 63° of northern latitude and between 10° and 39° of eastern longitude. Especially in the last decade several new localities with curly birch were found (Ljubavskaja 1978; Jevdokimov 1989; Pagan & Paganová 1994).

Several authors (Kořínek 1956; Hejtmánek 1957; Václav 1961; Košút 1977; Pagan 1985) reported the occurrence of curly birch in the territory of the Czechoslovak Republic.

The curly birch is a polymorphic taxon whose individuals can be different in growth characteristics (tree or shrub forms), habit, branching, morphological characteristics of leaves, beginning and periodicity of fructification, richness of fruits, shape, size and multiplicity of curly grain, structure of its timber, etc. Therefore different classification systems were elaborated according to the mentioned basis. The Russian author Ljubavskaja (1978) elaborated one of the most detailed classifications. She distinguished seven growth forms of curly birch and took into account also the type of curly grain that is connected with timber texture. In addition, tree and shrub forms of birch with dark bark (*Betula obscura* Kotula) with various shapes and intensity of curly grain (Pagan 1980) were also found in the territory of Slovakia.

A considerable geographic variability of curly birch was found. The particular ecotypes are different in growth rate, length of vegetation period, representation of growth forms and various types of curly grain, etc. (Jevdokimov 1989).

The opinions concerning the origin of decorative timber of curly birch were different and they developed gradually. Several authors supposed that the occurrence of curly grain was conditioned by external environmental impacts, by mechanical influence on the cambium or by pathogenic process following various diseases (Ruden 1954; Vailinois 1935; Sokolov 1948; Jakovlev 1949; Aleksejeva 1964; Saks-Bander 1974 and others).

The hypothesis about the inheritance of decorative timber and systematic relationship of curly birch to *Betula pendula* became predominant gradually (Heikinheimo 1933, 1951; Sokolov 1950, 1959; Jablokov 1952; Lindquist 1947; Václav 1961; Bagajev 1963; Ljubavskaja 1975; Jermakov 1986; Jevdokimov 1989 and others in Paganová 1996).

Ryynänen and Ryynänen (1986) mentioned that the decorative structure of timber was hereditary, however its background was not described so far.

Ruden (1954) considered the occurrence of curly grain and decorative timber of curly birch to be a monogenic and lethal character. Ljubavskaja (1975) worked out a hypothesis according to which curly birch progeny was the generation of tree individuals – heterozygotes (*Aa*), shrubs – recessive homozygotes (*aa*) and dominant homozygotes (*AA*). Dominant homozygotes have a common type of timber (without decorative texture). Ljubavskaja (1978) and Jevdokimov (1989) proved that the typical drawing of timber was inherited according to the rule of incomplete dominance. Jermakov (1986) considered decorative drawing of timber as a synthetic character that was the composition of many characters, mainly genetically conditioned ones. In connection with his own hypothesis he refused the theory of single recessive gene (*a*) as the carrier of decorative drawing of timber and dominant gene (*A*) that controls the creation of common timber. According to this author, in such a case all heterozygotes (*Aa*) would have the common type of timber, but there are individuals with decorative timber among them.

According to Jevdokimov (1989), curly grain is considered to be a recessive character and he considered individuals with curly grain to be homozygotes. The author described scarce occurrence of plants with decorative timber in birch populations as well as their lower vitality. However both Jermakov (1975) and Jevdokimov (1989) mentioned a possibility of the occurrence of a gene controlling decorative timber among heterozygotes with common timber.

The genetic origin of curly grain and typical timber drawing was confirmed by progeny testing and also by experiments with curly birch introduction (Sokolov & Suchdoľskij 1969; Aleksan-

drova-Kuznecova 1975; Litvak & Jevdokimov 1977; Etholen 1978; Ljubavskaja 1978 in Pagan & Paganová 1994). At present it is evident that curly grain and decorative timber are regularly inherited within open pollinated progenies in different ecological conditions (Jevdokimov 1989).

In the last decade several evaluations of hybrid curly birch progenies from open and controlled pollination were carried out. They were focused on understanding the inheritance mechanism as well as on obtaining the seed material for conservation of this valuable gene pool. The production of this noble and high-valuated decorative timber comes into the foreground of scientific interest.

Curly birch has high requirements for light. It grows naturally on various soils except soils with abundance of moisture, with a high level of stagnant groundwater. It is considered to be a pioneer woody plant with low requirements for environmental conditions, very suitable for landscape restoration on non-forest soils that are difficult to use for agricultural production.

Curly birch grows as solitary plant, alternatively in small groups. Curly birch retreats from stands in consequence of shading. Its natural regeneration appears on glades, on margins of forest stands and on abandoned agricultural lands, so everywhere where it has sufficient light. The creation of curly grain indicating decorative timber is also very frequent in conditions of full light while in stands with higher density of plants it is reduced (Ljubavskaja 1978; Reďko & Jevdokimov 1979).

Mainly stands outside woodlands are suitable for successful growing and timber production of this valuable technical form of birch. The utilisation of abandoned agricultural lands or degraded areas is a chance for successful establishment and planting of curly birch. The growing of curly birch can be an alternative of the effective land exploitation (considering quite a short production period – approximately 30 years) and it can also become an eco-stabilisation element in the landscape.

MATERIAL AND METHODS

We evaluated the height growth of full-sib progenies of curly birch and qualitative characteristics that are typical of this technical form of birch. The progenies are planted in the area of the University Forest Enterprise of Technical University in Zvolen, experimental base Tale. The site is almost a plain with moderate west exposure at an altitude of 800 m. The individuals are planted at a regular spacing of 2 m. The characteristics of the parent individuals are given in Table 1. The outline of hybrid combinations of the analysed progenies is given in Table 2.

The parent individuals come from different localities (mainly from the area of eastern Slovakia) and they represent various habit forms of curly birch (shrub, tree, mono-stem, multi-stem, with black or white colour of bark) as it is seen from Table 1. Maternal plants that were used within controlled hybridisation are planted in Borova hora Arboretum of the Technical University in Zvolen. This material is only a part of the large archive of the most valuable plants of curly birch from Slovakia.

The first evaluation was done in 1998, in a period when progenies reached the age of 5 years

Table 1. Characteristics of the parent individuals of curly birch included in controlled hybridisation

Clone	Form	Origin	Characteristics of the parent individual
35	tree, white bark	Ladomírov	multi-stem tree, massive crown, robust curly grain
176		Becherov (Ondávka)	growth form Ib, globular curly grain, massive crown
237		Kečkovce	mono-stem tree, thick branches, conspicuous nearly continuous (linear) curly grain
47	tree, black bark	Mikulášová	multi-stem tree with thick branches
81		Snakov	mono-stem tree with thin branches
1323	shrub, white bark	Ladomírov	shrub with conspicuous curly grain, generative origin
92	shrub, black bark	Hrabské	twin stem from stock, thicker branches, conspicuous curly grain
2463		Ladomírov	multi-stem shrub with conspicuous curly grain, generative origin

and some stabilisation of growth processes after their planting at the site was expected. Following evaluations were done in 1999 and 2001 (at the age of 6 and 8 years).

Heights of plants were measured to the nearest 0.01 m and their diameter (dbh – diameter at breast height) to the nearest 1 mm. So far, the diameter of the analysed progenies was not evaluated because of irregular occurrence of curly grain on the trunk, which could decrease the detachment of measuring. More accurate measurements of the diameter growth of curly birch progenies can be done at higher age.

The basic statistical characteristics (mean, standard deviation and coefficient of variation) were calculated for each hybrid combination. One-way analysis of variance and Tukey's test were used to evaluate statistical significance of height differences between progenies of the particular hybrid combinations. Statistical significance of the influence of parent individuals on differences in the height of progenies was evaluated by the multifactor analysis of variance.

Besides the quantitative characteristics attention was also paid to other progeny characteristics that represent the inheritance of the characteristics of parent plants within the particular hybrid combinations. These characteristics are: colour of bark, occurrence of curly grain on the stem and branches, and plant habit. The first evaluation of the qualitative characteristics was done in 2001, when they were already identified on several individuals within the progenies. The representation of the qualitative characteristics was evaluated in percentage for each hybrid combination and χ^2-test was used to evaluate statistical significance of the relationship between hybrid combinations and particular qualitative characteristics.

RESULTS AND DISCUSSION

In 1998, at the age of 5 years the first evaluation of the heights of hybrid progenies of curly birch from controlled hybridisation was done. The basic statistical characteristics for particular combinations are given in Table 2.

The height values of the progenies were different in dependence on the hybrid combination of curly birch forms as it is seen from these data. In 1998 the highest mean value of height (1.51 m) was recorded in combination 3 of the shrub and tree form of curly birch with black bark. On the other hand, the lowest mean value of height (1.16 m) was found in combination 2 of the shrub form with black bark and tree form of curly birch with white bark.

A very high coefficient of variation (nearly 42%) was found in combination 2, which had the lowest mean value of height. The range of height values within this progeny was from 0.1 m to 2.1 m. Only two hybrid combinations (3 and 5) had the values of coefficient of variation below 25%, which suggests rather aligned height values within these progenies.

Table 2. Basic statistical characteristics of height of the hybrid progenies of curly birch

Combination		N	1998			1999			2001		
			X	S_x	$S_{x\%}$	X	S_x	$S_{x\%}$	X	S_x	$S_{x\%}$
1	47 (TB) × 81 (TB)	16	1.26	0.45	35.23	1.73	0.36	20.55	2.85	0.67	23.38
2	2463 (SB) × 176 (TW)	80	1.16	0.48	41.50	1.53	0.60	39.06	2.21	1.00	45.24
3	2463 (SB) × 81 (TB)	45	1.51	0.34	22.61	1.99	0.36	17.86	2.93	0.67	23.06
4	2463 (SB) × 92 (SB)	59	1.17	0.42	35.90	1.55	0.53	34.32	2.08	1.00	48.01
5	47 (TB) × 237 (TW)	24	1.47	0.29	19.47	1.98	0.33	16.70	2.89	0.61	21.19
8	92 (SB) × 237 (TW)	64	1.18	0.41	34.55	1.55	0.48	31.12	2.01	0.76	37.64
9	1323 (SW) × 92 (SB)	51	1.44	0.45	31.54	1.83	0.55	30.19	2.30	0.92	40.08
12	47 (TB) × 35 (TW)	4	1.46	0.49	33.92	2.07	0.58	28.12	3,06	0.94	30.62
Total		343	1.28	0.44	34.56	1.69	0.53	31.65	2.34	0.93	39.60

TB – tree form with black bark, SB – shrub form with black bark, TW – tree with white bark, SW – shrub with white bark

In all analysed years high variability of plant heights within particular hybrid combinations was found. Especially in the last analysed year (2001) the coefficients of variation were about 45–48% in some cases (hybrid combination 2 and 4). These data correspond to findings of Ljubavskaja (1978), who mentioned evident differences in height and diameter values between the generative progenies of curly birch forms. The distinctive differentiation of curly birch seedlings according to their height is evident in nurseries already in the first year of their growing and there is possible to identify shrub and tree forms among them.

In 1999 the highest mean value of height (2.07 m) was found in combination 12 of the two tree forms of curly birch where the maternal plant had black colour of bark and the pollen donor was a plant with white bark. Considering the low number of plants in this progeny, combination 3 of the tree and shrub form of curly birch, both with black colour of bark, is more representative. The average value of height in this progeny was 1.99 m. The progenies of both mentioned hybrid combinations had the highest values of height also in 2001. In 1999 as well as in 1998 the lowest mean value of height (1.53 m) was found in the progeny of combination 2. In 2001 the lowest mean value of height (2.01 m) was measured in progeny 8, which represents the same combination of curly birch forms as progeny 2 (shrub form with black bark × tree form with white bark).

The influence of the combination of parent plants on progeny height is evident already from the comparison of their basic statistical characteristics. This assumption was verified by one-way analysis of variance; its results are given in Table 3.

The results of one-way analysis of variance confirmed statistically significant differences in the values of progeny height between various hybrid combinations in the whole analysed period of 1998, 1999 and 2001.

The significance of differences in mean values of height between the analysed hybrid progenies was verified by Tukey's test on 95% significance level (Table 4).

In 1998 statistically significant differences were confirmed between the following progenies: 2–3, 2–5, 2–9, 3–4, 3-8, 4–9 and 8–9. These progenies come from various combinations of different forms of parent plants and differences between them show interesting continuities. For example progeny 5 from the combination of two tree forms of curly birch with different colour of bark with mean value of height (1.51 m) is significantly different from progeny 2, with mean value of height (1.16 m) from the combination of shrub and tree form of curly birch with different colour of bark. Although progenies 4 and 9 come from the combination of plants with similar habit form (both are shrubs), they have significantly different mean values of height. Hybrid progeny 9 of two shrub forms of curly birch with black colour of bark with mean value of height (1.17 m) is significantly different from progeny 4 of two shrub forms with white and black colour of bark (1.44 m). The differences between progenies 9 and 8 are also interesting, when plants from the combination of two shrub forms with different colour of bark reached higher

Table 3. The results of one-way analysis of variance of height of the curly birch progenies from controlled hybridisation

Year	Source of variation	Sum of squares	DF	Mean square MS	*F*-value	Significance α
	Combination	7175166	7	1025023.8	5.729	0.0000
1998	Residual	59941130	335	178928.7		
	Total	67116296	342			
	Combination	12114621	7	1730660.2	6.763	0.0000
1999	Residual	85989076	335	255919.9		
	Total	98103697	342			
	Combination	$4.1491 \cdot E^{7}$	7	5927219.4	7.845	0.0000
2001	Residual	$2.5387 \cdot E^{8}$	335	755559.5		
	Total	2.9536·E8	342			

Table 4. Tukey's test for mean values of height of the curly birch progenies from controlled hybridisation.

Hybrid combination		Mean value of progeny height (m)		
		1998	1999	2001
1	47 (TB) × 81 (TB)	1.26abc	1.73abc	2.85bcd
2	2463 (SB) × 176 (TW)	1.16a	1.53a	2.21ab
3	2463 (SB) × 81 (TB)	1.51c	1.99c	2.93d
4	2463 (SB) × 92 (SB)	1.17ab	1.55ab	2.08a
5	47 (TB) × 237 (TW)	1.47bc	1.98c	2.89cd
8	92 (SB) × 237 (TW)	1.18ab	1.56ab	2.01a
9	1323 (SW) × 92 (SB)	1.44c	1.83bc	2.30abc
12	47 (TB) × 35 (TW)	1.46abc	2.07abc	3.06abcd
Total		1.28	1.69	2.34

TB – tree form with black bark, SB – shrub form with black bark, TW – tree with white bark, SW – shrub with white bark
The statistically significant differences are not between values with the same character

mean value of height (1.41 m) than plants from the combination of shrub form with black bark and tree form with white bark (1.18 m).

While in 1998 and 1999 significant differences in mean values of height were found between the progenies of 7 hybrid combinations, in 2001 they were found already between the progenies of 9 combinations. However, only in four cases were significant differences found always between the same progenies during the whole evaluated period. As it results from data in Table 4, the mentioned progenies are: 2–3, 2–5, 3–4 and 3–8.

During all three years one of the highest mean values of height was found in progeny 3 of the hybrid combination of curly birch shrub form (clone 2463) and tree form of curly birch (clone 81), both with black colour of bark. It is possibly the effect of distant hybridisation when parent plants with different habit were crossed.

This assumption is also supported by information given by Ljubavskaja (1978), who compared identical forms of curly birch originating from various hybrid combinations and found their influence on the growth rate of progenies. The larger the differences between parent plants (taxonomic and form difference, respective distant origin of parent plants or different environmental conditions in which they were grown), the more intensive the growth of their hybrid progeny.

It was found by the evaluation for example that in dependence on the habit form of pollen donor (paternal plant) clone 2463 (shrub form with black bark) had progenies with higher or significantly lower mean value of height. Its progeny from the hybrid combination with clone 81 (tree form with black bark) had the highest mean value of height. On the other hand, its progeny from the hybrid combination with clone 176 (tree form of curly birch with white bark) had very low (even the lowest) mean values of height during the studied years. Such a comparison shows the different influence of the particular parent plants on the growth of their progenies.

These findings are also confirmed by the results of multifactor analysis of variance (Table 5). The statistically significant influence of parent plants (representing different habit forms) on the height of curly birch hybrid progenies was found in all evaluations in 1998, 1999 and 2001.

The significance of differences between the mean values of the progenies of particular parent plants was verified by Tukey's test (Table 6).

In 1998 and 1999 significant differences were confirmed between the progenies of identical pairs of parent plants. Statistically significant differences were found between the progenies of five pairs of maternal plants: 47–92, 47–1323, 2463–92, 1323–2463, 1323–92, as well as between the progenies of four pairs of paternal plants (pollen donors): 81–92, 81–176, 237–92, 237–176.

The habit form of parent plants affects height growth of their progenies as it results from the

Table 5. Multifactor analysis of variance of height of the curly birch progenies from controlled hybridisation

Year	Source of variation	Sum of squares	DF	Mean square MS	*F*-value	Significance α
1998	A Mother	4185460.8	3	1395153.6	7.797	0.0000
	B Father	4490110.3	4	1122527.6	6.274	0.0001
	Residual	59941130.0	335	178928.74		
	Total	67116296.0	342			
1999	A Mother	6112051.4	3	2037350.5	7.961	0.0000
	B Father	7760982.7	4	1940245.7	73581	0.0000
	Residual	85989076	335	255919.87		
	Total	98103697	342			
2001	A Mother	14956318	3	4985439.2	6.598	0.0002
	B Father	20897611	4	5224402.7	6.915	0.0000
	Residual	$2.5387 \cdot E^8$	335	755559.55		
	Total	$2.9536 \cdot E^8$	342			

Table 6. Tukey's test for mean values of height of the curly birch progenies from controlled hybridisation

Source of variation	Mean height of progenies (mm)		
	1998	1999	2001
A Mother			
47 (TB)	1203.98b	1667.30b	2589.05b
2463 (SB)	1449.25b	1929.97b	2661.03b
92 (SB)	917.84a	1240.59a	1705.29a
1323 (SW)	1722.75c	2208.32c	2873.95b
B Father			
35 (TW)	1574.47ab	2164.24ab	2923.29ab
81 (TB)	1383.10b	1824.24b	2721.41b
92 (SB)	1040.31a	1381.07a	1879.53a
176 (TW)	1034.08a	1362.69a	2002.88a
237 (TW)	1585.31b	2075.49b	2759.54ab
Total	1323.45	1761.55	2457.33

TB – tree form with black bark, SB – shrub form with black bark, TW – tree with white bark, SW – shrub with white bark

detailed analysis of differences between the progenies of the above-mentioned parent plants. The progenies of the parents with tree habit form had significantly higher mean values of height than progenies of the parents with shrub habit form. For example in all the analysed years the progeny of maternal tree 47 (with black bark) had significantly different mean values of height in comparison with progenies of maternal plants 92 and 2463, which have shrub habit. Also according to Ljubavskaja (1978) tree forms of curly birch with fine curly grain have relatively fast growth rate, while shrub forms grow slowly. Other forms (with larger curly grain on the trunk and forms with low stem) take a medium position within the scale of growth rate.

Besides the analysis of heights there is an interesting evaluation of some qualitative characteristics within the hybrid progenies of various curly birch forms. The results (Table 7) should be considered

as informative with respect to the evaluation of very young progenies where colour of rhytidome, curly grain on the trunk and habit form appeared just at the age of 8 years (in 2001).

The highest proportion of plants with black bark (87.5%) was found in the progeny from the combination of maternal tree (47) with black bark and tree form (237) with white bark. The lowest proportion of plants with black bark was in progeny from the combination of shrub form with dark bark (2463) and tree form with white bark (176). In this progeny the ratio of plants with dark and white bark was approximately 1:3. The low proportion of plants with black bark (1:2) was also in the progeny of hybrid combination 2463 × 92 of two shrub curly birch forms with black colour of bark. The proportion of plants with black bark will probably increase with age not only in this progeny.

The bark colour was impossible to be identified on all plants. However, the results of χ^2-test confirmed a statistically significant relationship between bark colour and hybrid combination of parent plants (Table 8).

The occurrence of curly grain on the trunk, which indicates decorative texture of timber in progeny, was evaluated (Table 7). The curly grain is noticeable on plants at higher age, therefore the first evaluation at the age of 8 years is considered to be just informative and in the next period the proportion of the plants with curly grain may increase.

The typical characteristic – occurrence of curly grain on the trunk or on branches was found in all 8 progenies (Figure 2). The highest percent proportion of plants with curly grain (75%) was found in hybrid combination 12, where parents had the tree habit and maternal tree had black colour of bark. However, there is a reference to the low number of plants in this progeny. The ratio of plants with curly grain (they have decorative timber) to plants without curly grain was 2:1 within four hybrid combinations (8, 5 and 9).

The highest percentage (68.8%) of plants with curly grain was found in the progeny of curly

Table 7. Percentage of the qualitative characteristics in hybrid progenies of curly birch

Hybrid combination		Rhytidome colour		Curly grain		Habit		
		white	black	appeared	missing	shrub	low-stem	tree
1	47 (TB) × 81 (TB)	56.30	43.70	93.80	6.30	0.00	0.00	100.00
2	2463 (SB) × 176 (TW)	78.50	21.50	67.10	32.90	16.40	8.90	74.70
3	2463 (SB) × 81 (TB)	35.60	64.40	44.40	55.60	0.00	15.60	84.40
4	2463 (SB) × 92 (SB)	78.30	21.70	63.30	36.70	26.70	28.30	45.00
5	47 (TB) × 237 (TW)	12.50	87.50	33.30	66.70	0.00	16.70	83.30
8	92 (SB) × 237 (TW)	46.90	53.10	31.30	68.80	9.40	34.40	56.30
9	1323 (SW) × 92 (SB)	55.80	44.20	38.50	61.50	17.30	25.00	57.70
12	47 (TB) × 35 (TW)	25.00	75.00	25.00	75.00	0.00	25.00	75.00

TB – tree form with black bark, SB – shrub form with black bark, TW – tree with white bark, SW – shrub with white bark

Table 8. Chi-square test of the relationship between the hybrid combination of curly birch progenies and selected qualitative characteristics

Characteristics	χ^2 value	DF	Probability α	Statistical significance
Rhytidome colour	58.3119	7	$3.27710 \times E^{-10}$	$\alpha < 0,05$ ***
Decorative timber (curly grain)	41.6440	7	$6.08857 \times E^{-7}$	$\alpha < 0,05$ ***
Habit form	52.6211	14	$2.20658 \times E^{-6}$	$\alpha < 0,05$ ***

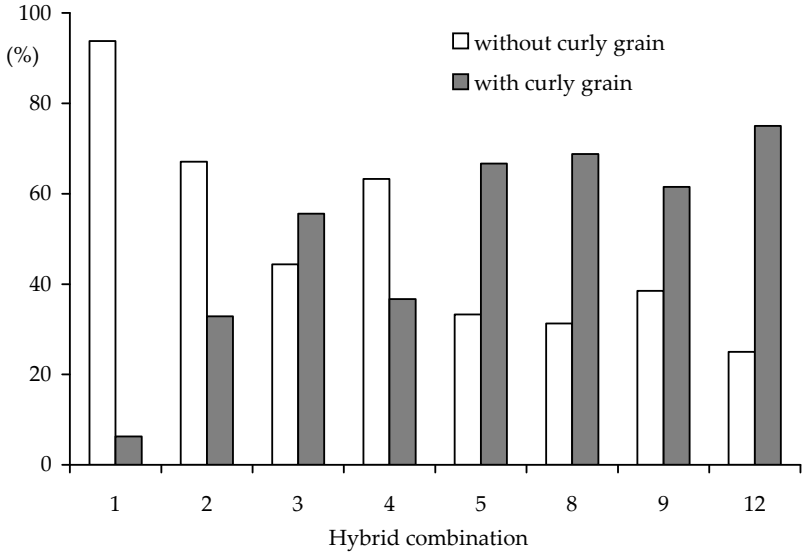

Figure 2. Percentage of plants with decorative timber (curly grain) in the progenies of various hybrid combinations of curly birch forms (2001)

birch shrub form with black bark (clone 92) and tree form with white bark (clone 237). The next two progenies come from the combination of tree form with dark bark (clone 47) and tree form with white bark (237) as well as from the combination of two shrub forms with white (clone 1323) and black (clone 92) colour of the bark.

The ratio of plants with curly grain to plants without it was 1:1 within the progeny from hybrid combination 3 of the shrub form with dark bark (clone 2463) and tree form with dark bark (clone 81).

The obtained results show a higher proportion of plants with decorative timber in progenies from hybrid combinations of the shrub and tree forms of curly birch. The contrary findings of some authors are known from literature in connection with these results.

According to Sokolov (1950) the tree form of curly birch with low stem does not apparently have a higher proportion of plants with decorative timber in progeny; on the contrary such parent plants reduce their quality. On the other hand, Bagajev (1963) reported a high proportion of plants with decorative timber (75%) within the progenies from the crossing of curly birch tree forms with curly birch individuals with low stem and also within the progenies whose both parents had just the low-stem habit form as well as within the self-pollinated progenies of the tree and low-stem forms of curly birch. The author evaluated 10 and 20 years old plantings of curly birch. In his opinion during hereditary transfer the highest proportion of plants with curly grain (and decorative timber) appeared in the progenies of maternal plants with low stem (56%). The proportion of plants with mentioned characteristics in progenies of shrub maternal plants was 37% and within the progenies of tree maternal plants it was 35%. The mean proportion

Figure 3. A young curly birch plant with low stem and large curly grain on the trunk and branches

Figure 4. A curly birch individual with black bark

of plants with curly grain on the trunk was 43% within the whole evaluated planting.

The proportion of plants with decorative timber will possibly increase in curly birch progenies in subsequent years because especially fine curly grain can be identified with higher reliability just at higher age. In 6 years old planting of curly birch in favourable environmental conditions Reďko and Jevdokimov (1979) found about 36% of the plants with evident characteristics of decorative timber, while in unfavourable conditions the proportion of such plants was only 1%. These authors also mentioned that early diagnostics of 1–3 years old curly birch plants was often subjective and provided only approximate information about the presence of plants with decorative timber in the planting. For example according to the results of early diagnostics there should be only 38% of the plants with decorative timber, but the anatomical analysis (method of trunk cross-section) showed 56% proportion of these plants in the analysed progeny. The intensive formation of curly grain takes place at the age of 10–20 years.

According to Ljubavskaja (1978) quickly growing plants without evident curly grain predominate in the progeny of curly birch with *Betula pendula*. Within the hybrid progeny of various curly birch forms the presence of slowly growing plants increases, but they have the characteristic curly grain on their trunk and branches.

The results of chi-square test (Table 8) confirmed a statistically significant relationship between the hybrid combination and occurrence of curly grain on the trunk in its progeny.

The curly birch individuals with different habit forms were used for controlled hybridisation, therefore the evaluation of inheritance of this characteristic was interesting within their progenies. Particular progenies were evaluated for the proportion of plants with tree, shrub and low-stem habit (the plant has a straight stem approximately to the height of 0.5 m, where it creates the more or less bushy crown).

Within the progenies of the parents with tree habit (progenies 1, 5 and 12) (Table 7) only or mainly individuals with tree habit occur.

The dominance of tree individuals was also recorded in other progenies where at least one parent had the tree habit form (progenies 2 and 3). Exceptionally the progeny of hybrid combination 8, where parents are shrub form with dark-brown bark (clone 92) and tree form with white bark (237), has the highest proportion of tree individuals (56.3%) but the representation of plants with low stem is also relatively high (34.4%). The proportion of shrubs in this progeny was 9.4%. The highest proportion of shrub individuals (26.7%) was found in the progeny of hybrid combination 4, where the parents are two shrub plants with black bark 2463 × 92. The ratio of shrub to low-stem to tree form in this progeny is approximately 1:1:2 and it had the highest proportion (45.0%) of tree habit individuals.

The dominance of tree habit form was recorded in all hybrid progenies, also in those where the parents had shrub habit. The highest presence of tree individuals was in the progenies where both parents, or at least one parent, had the tree habit form. Ljubavskaja (1978) evaluated the growth of curly birch progenies from controlled hybridisation, where maternal plants of IIA form with low stem were crossed with various paternal plants. During the whole studied period she found the best height growth in the progenies obtained from crossing with *Betula pendula* and progenies from crossing with pollen mixture of the various curly

birch forms were at the second place. The lowest values of height were found in progenies from hybridisation with curly birch shrub form and those that were obtained from self-pollination.

It can be declared that to achieve the highest proportion of tree individuals in the progeny is to cross the parents with tree habit form in controlled hybridisation. However, the proportion of tree individuals is also relatively high in the progenies where at least one of the parents has the tree habit form, the statistical significance of the relationship between hybrid combination and representation of the particular habit form within the progeny was also confirmed by the results of χ^2-test (Table 8).

Conclusion

According to the results mentioned above, it is possible to draw the following conclusions:

Curly birch progenies of the parents with tree habit have significantly higher mean values of height than progenies of the parents with shrub habit.

The effect of distant hybridisation can appear in the combination of parents with different habit forms and their progenies reach excellent growth rate as it is found in progeny 3, where curly birch forms with different habits (shrub and tree) were crossed.

There is a statistically significant relationship between the hybrid combination and the occurrence of the studied qualitative characteristics (habit form, decorative timber bark colour) in their progeny.

Decorative timber (indicated by curly grain on the trunk) is indicated in all evaluated progenies. In four of them the ratio of individuals with curly grain to individuals without it was 2:1 and in one progeny it was 1:1. The proportion of birches with decorative timber will possibly increase because especially the fine type of curly grain can be correctly identified at higher age.

The dominance of tree habit form exists in all hybrid progenies and also in those where parent individuals had the shrub habit. The highest proportion of tree individuals is in the progenies where both parents, alternatively at least one of them, have the tree habit form.

Full-sib curly birch progenies can be successfully used for timber production in the open landscape on abandoned agricultural lands. They have a high proportion of plants with decorative timber and appropriate tree habit, which is necessary for production of valuable timber.

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Súhrn

Paganová V. (2004): **Analýza dedičnosti a výšky potomstiev brezy svalcovitej z kontrolovanej hybridizácie a možnosti ich produkčného využitia v poľnohospodárskej krajine.** Czech J. Genet. Plant Breed., **40**: 51–62.

Pri hodnotení rastu hybridných potomstiev rôznych foriem brezy svalcovitej sa skúmal vplyv formy habitu na rast potomstiev. Vo všetkých rokoch 1998, 1999 a 2001 sa zaznamenali štatisticky významné rozdiely vo výškach potomstiev podľa hybridnej kombinácie rodičov. Takmer vo všetkých hodnotených rokoch sa zaznamenala vysoká variabilita výšok aj v rámci jednotlivých hybridných kombinácií. Pri kombinácii rodičov s odlišnou formou habitu však môže dochádzať ku efektu tzv. vzdialenej hybridizácie a ich potomstvá dosahujú výborný výškový rast. Kvalitatívne znaky – farba borky, výskyt zhrubnutí (dekoratívna textúra dreva) a forma habitu sa hodnotili len v roku 2001. Výsledky potvrdili štatisticky vysoko významný vzťah medzi hybridnými kombináciami a prejavom skúmaných kvalitatívnych znakov v ich potomstvách. Zhrubnutia na kmeni – svalce sa zaznamenali vo všetkých hodnotených potomstvách, pričom v štyroch potomstvách sa podiel jedincov so zhrubnutiami k jedincom bez ich prejavu pohyboval v pomere 2 : 1 a v jednom potomstve bol ich podiel približne v pomere 1:1. Je možné, že podiel svalcovitých jedincov sa bude v ďalšom období zvyšovať, lebo najmä jemné zhrubnutia sa dajú spoľahlivo identifikovať až vo vyššom veku.

Kľúčové slová: breza svalcovitá; dekoratívne drevo; hybridizácia; dedičnosť; produkcia dreva

Corresponding author:

Dr. Ing. Viera Paganová, Slovenská poľnohospodárska univerzita v Nitre, Fakulta záhradníctva a krajinného inžinierstva, Katedra biotechniky zelene, Tulipánová 7, 949 01 Nitra, Slovenská republika
tel.: + 421 376 522 745, fax: + 421 376 522 741, e-mail: viera.paganova@uniag.sk