

Differentiation of some interspecific hybrids of firs (*Abies* sp.) according to the length of primary branches and number of their secondary branches

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Abstract

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During 2011, the length of primary branches was measured in individual seedlings of firs representing 15 crossing variants. Measured branches were divided into separate groups according to the number of secondary twigs. Our data indicate the possibility for differentiation between the hybrid combinations based on length of their primary branches. The interspecific combinations *A. pinsapo* × *A. alba* and *A. alba* × *A. pinsapo* were more similar to mother species in this trait rather than to paternal parent. A given combination of different age differed primarily by the number of primary branches with a higher number of secondary branches in older seedlings. Comparison involving both primary and secondary branches appears to be more efficient in discriminating between hybrid combinations than comparison primary based on secondary branches alone.

Keywords

Abies, branches, differentiation, hybrids, somatic heterosis

Introduction

The genus *Abies* Mill. with its 49 species and about 126 known interspecific hybrids demonstrates the importance and potential opportunities for interspecific hybridization in forest tree breeding (GREGUSS, 1995; KORMUŤÁK, 1994, 2004).

Generally, it is concluded that extensive crossability between representatives of the genus *Abies* is a result of their high genetic relatedness due to specific pattern of speciation (GREGUSS, 1995). KLAEHN and WINIENSKI (1963) consider this to be result of geographic rather than genetic isolation. Recent studies also point to the fact that crossability in the genus is the result of geographical isolation, not genetic isolation (KORMUŤÁK, 2004; KORMUŤÁK et al., 2012; KORMUŤÁK et al., 2013).

A high level of genetic diversity in interspecific hybrids is the result of heterozygous gene loci which leads to various forms of heterosis in hybrids (ROHMEDEK and SCHÖNBACH 1959; MERGEN et al., 1964).

Increased resistance to pests and diseases (MÜLLER, 1989; ROHMEDEK and SCHÖNBACH, 1959) along with increased vitality and adaptability of the hybrids to changing conditions of the environment is generally referred to as adaptive heterosis (GREGUSS, 1995; AUSENAC, 2002). It may also involve a higher proportion of surviving individuals, especially in relation to either immission load of the environment (ČÍTKOVÁ, 1988; RIŠKOVÁ, 1982; EVANS and MÜLLER, 1972) or increasing annual temperature (AUSENAC, 2002).

Reproduction or seed heterosis is the ability of the offspring to produce increased amount of viable seeds

compared to the parental species. This applies in seed orchards and natural sites where adverse environmental conditions reduce the number of viable seeds (ULJUKINA and DERJUŤKIN, 1981; GREGUSS, 1995; KORMUŤÁK, 1994, 2004).

Somatic heterosis of interspecific fir hybrids is the most commonly observed phenomenon which is directly related to the enhanced production potential of forest trees (HAWLWEY and DE HAYES, 1985a, 1985b; KORMUŤÁK, 1994, 2004; ROHMENDER and EISENHUT, 1961; KLAHN and WINIENSKI, 1963; MERGEN et al., 1964).

The papers dealing with somatic heterosis in hybrid firs have been focused preferentially on height growth neglecting other growth characteristics of the hybrids. Considerable variation of morphological traits in fir hybrids makes a problem with their taxonomic identification (GREGUSS, 1995; KORMUŤÁK, 1994, 2004). In present work we have tried to create a system of taxonomic differentiation of selected interspecific fir hybrids based on morphometric features of their primary branches.

Material and methods

In summer 2011, the length of primary branches in seedlings of some interspecific combinations of firs and in control variants of the parental species from open pollination and controlled cross pollination were measured. We used hybrids of the following species: *Abies alba* Mill., *Abies pinsapo* Boiss., *Abies numidica* de Lannoy ex Carrière., *Abies nordmanniana* (Steven) Spach, *Abies procera* Rehder, *Abies holophylla* Maxim. We have analyzed 4-year old seedlings of *A. pinsapo* × *A. numidica*, *A. pinsapo* × *A. alba*, *A. alba* × *A. pinsapo*, *A. alba* – controlled crossing, *A. alba* – open pollination and *A. pinsapo* – open pollination along with 6-year old seedlings of *A. nordmanniana* × *A. numidica*, *A. nordmanniana* × *A. procera*, *A. nordmanniana* × *A. alba*, *A. alba* × *A. numidica*, *A. alba* – open pollination, *A. nordmanniana* – open pollination and 7-year old seedlings of *A. nordmanniana* × *A. holophylla*, *A. nordmanniana* × *A. alba* and *A. nordmanniana* – open pollination. Seedlings were grown in nurseries of Mlyňany Arboretum SAS in spaced 20 × 20 cm. They were also



Fig. 1 Branches of the first and second degree.

grown in standard light conditions without shading. Length measurement was carried out with the help of a ruler Fig. 1. Measured branches of the first degree were divided into groups according to the number of their secondary branches. These groups were statistically evaluated and tested by nested ANOVA (SAS, 1988).

Results and discussion

There were applied various approaches in characterization of intra- and interspecific hybrids of firs involving height growth parameters, morphology and anatomy of needles (LARSEN, 1934; KLAHN and WINIESKI, 1962; CRITCHFIELD, 1988), pollen viability and seed quality (GALGÓCI, 2010), photosynthesing pigments, isoenzymes, terpenes and DNA (GAUDLITZ, 1983; ZAVARIN et al., 1977; WAGNER et al., 1987; DONG and WAGNER, 1994). The length of branches as morphological trait has not been used so far. Using Duncan grouping we were able to differentiate between some crossing variants according to the primary branches length and number of their secondary twigs (Table 1). It is of interest to mention that testing of individual groups of primary branches in 6- and 7-year old seedlings has not affected the descending order of the variants given in Table 1. Even a change of the order has not any statistical impact on differentiation of the crossing variants according to the type of their branches. It follows, therefore, that it does not matter which length parameter is used as a criterion for differentiation. In 6- and 7-year old seedlings both primary and secondary branches length characteristics may be used. It was not possible to discriminate between 7-year old seedlings of the crossing variants on the basis of length characteristics of the first three groups of the primary branches with 0–2 secondary twigs. Efficient in this respect were only the primary branches with three secondary twigs which had clearly differentiated the crossing variant *A. nordmanniana* × *A. alba*. In the category of primary branches with four secondary twigs, we have distinguished crossing variants *A. nordmanniana* × *A. holophylla* and *A. nordmanniana* – open pollination. Similar discrimination was also possible between 6-year old seedlings. The only exceptions in this respect were the variants *A. alba* – open pollination and *A. nordmanniana* × *A. procera* which had not complied discrimination criteria mentioned above (Table 1). Comparison of our data with those published by GALGÓCI et al. (2011) which refer to the height growth characteristics of the 6- and 7-year old progenies of the same crossing variants revealed a high degree of correlation with respect to the 7-year old seedlings only. At the 6-year old seedlings level the authors detected statistically significant differences between the pair of crossings *A. nordmanniana* × *A. numidica* – *A. nordmanniana* × *A. alba* and *A. nordmanniana* × *A. numidica* *A. nordmanniana* – open pollination. Quite different situation was observed at

the stage of 4-year old seedlings. At each group of the analyzed primary branches with corresponding number of twigs, the order of crosses has changed in this case at statistically significant level starting from the longest primary branch to the shortest one. The findings in the 5 groups scale of primary branches were those which had enabled to differentiate the 4 year old seedlings of all the analyzed crossing variants based on their primary branches. Comparison of the length characteristics in two different age categories of *A. nordmanniana* – open pollination seedlings have not revealed statistically significant differences in average lengths of the primary branches in 6- and 7-year old progenies. Both these age categories were represented by the seedlings with primary branch containing maximum 2 twigs. In the crossing variant *A. nordmanniana* × *A. alba* statistical differences between 6- and 7- year old seedlings exist only in the group of primary branches without and/or with one secondary twig. Seven year old seedlings are involved in the group of primary branch with 3 and 4 secondary twigs. Six year old seedlings have not occurred in this group. Among 6- and 4-year old seedlings of *A. alba* – open pollination and controlled crosses of *A. alba* maternal species statistically significant differences were revealed between seedlings of the same age but not between seedlings of different age categories. We have not observed such phenomenon in other groups of primary branches.

Mutual comparison of the growth characteristics in the crossing variants *A. pinsapo* – open pollination 2007, *A. alba* – open pollination 2007, *A. pinsapo* × *A. alba* and *A. alba* × *A. pinsapo* resulted in the conclusion that variants *A. pinsapo* – open pollination and *A. pinsapo* × *A. alba* differ significantly in several groups of the primary branches from the variants *A. alba* – open pollination and *A. alba* × *A. pinsapo*. As a rule, the hybrids have exhibited the tendency to be similar in this respect to mother tree. The phenomenon may be ascribed to the matrilinear inheritance of growth characteristics. A typical feature of crossing variants with arid species *A. numidica* and *A. pinsapo* involved the parental specimen in the formation of secondary twigs in relatively young plants as well as in plants with short primary branches. It is supposed that this feature of the hybrids is related to the ability of the parental species to invade new localities.

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Table 1. The differentiation of interspecific hybrids of firs on the basis of number of secondary twigs on the primary branches

Combining crossing – controlled variant / year of planting	NT	NB0	$\bar{x}0$	DG0	DG1	NB1	$\bar{x}1$	NB2	$\bar{x}2$	DG2	NB3	$\bar{x}3$	DG3	NB4	$\bar{x}4$	DG4
<i>A. nordmanniana</i> × <i>A. holophylla</i> (2004)	40	212	6.54	A	51	13.38	A	48	15.11	A	14	19.19	A	11	22.42	A
<i>A. nordmanniana</i> – open pollination (2004)	12	64	7.23	A	5	13.3	A	10	14.95	A	–	–	–	–	–	–
<i>A. nordmanniana</i> – open pollination (2005)	15	54	7.04	AB	13	12.29	AB	14	14	AB	–	–	–	–	–	–
<i>A. alba</i> – open pollination (2005)	57	152	7.02	AB	71	11.59	AB	83	13.93	AB	32	16.54	BC	9	15.3	B
<i>A. alba</i> × <i>A. alba</i> (2007)	28	130	6.97	AB	15	7.89	DC	–	–	–	–	–	–	–	–	–
<i>A. nordmanniana</i> × <i>A. alba</i> (2004)	29	163	6.78	ABC	58	11.23	AB	73	13.04	ABCD	16	17.43	AB	13	18.55	B
<i>A. pinsapo</i> × <i>A. alba</i> (2007)	33	624	6.46	ABCD	56	11	B	114	13.21	ABCD	9	12.13	EFG	6	15.65	B
<i>A. nordmanniana</i> × <i>A. procera</i> (2005)	47	229	6.08	BCD	78	11.18	AB	117	12.16	BCD	20	16.62	ABC	12	16.51	B
<i>A. pinsapo</i> – open pollination (2007)	28	224	5.8	CDE	27	9.93	BC	41	13.46	ABC	17	16.07	BCD	8	16.22	B
<i>A. alba</i> × <i>A. numidica</i> (2005)	27	134	5.78	DE	41	10	BC	24	11.24	CD	8	13.54	DEF	7	16.14	B
<i>A. nordmanniana</i> × <i>A. numidica</i> (2005)	30	169	5.46	E	34	9.86	BC	11	11.25	CD	6	14.32	CDE	–	–	–
<i>A. nordmanniana</i> × <i>A. alba</i> (2005)	29	189	4.84	FE	29	9.45	C	19	10.98	D	–	–	–	–	–	–
<i>A. alba</i> – open pollination (2007)	18	74	4.43	FG	22	6.17	DE	10	11.25	CD	–	–	–	–	–	–
<i>A. alba</i> × <i>A. pinsapo</i> (2007)	4	26	3.78	GH	9	4.9	E	–	–	–	4	11.4	FG	–	–	–
<i>A. pinsapo</i> × <i>A. numidica</i> (2007)	10	87	3.23	H	4	6.48	D	7	8.12	E	6	9.85	G	–	–	–

NT, number of tree; NB, number of primary branches; \bar{x} mean; DG, Duncan grouping; index 0, branches of the first degree with no secondary twig; index 1, branches of the first degree with one secondary twig; index 2, branches of the first degree with two secondary twigs; index 3, branches of the first degree with three secondary twigs; index 4, branches of the first degree with four secondary twigs.

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