ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Hortorum Cultus 12(4) 2013, 85-94*

TESTING OF HYBRID PROGENIES AND VARIOUS SPECIES OF GENUS *Abies* FOR FORESTRY, DECORATING HORTICULTURE AND CHRISTMAS TREE PRODUCTION

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Abstract. The paper evaluated dendrometric parameters of hybrid progenies of various *Abies* species obtained during measurements in the spring 2010 on the research plot in Kostelec nad Černými lesy. Data were processed and compared to the measurement taken in 2004. Results show that all hybrid progenies within the plot exceeded *A. alba* in investigated parameters. Only two of the progenies achieved worse results in mean height – *A. koreana* × (*A. cilicica* × *A. cephalonica*) and progeny of spontaneous hybrid no. 2. Considering height and diameter *A. nordmanniana* was evaluated as the most productive. On the contrary *A. gracilis* is considered unsuitable for further culture and research due to the mortality of 100%.

Key words: hybridization, breeding, progeny testing

INTRODUCTION

Silver fir (*Abies alba* Mill.) was one of our most important forest trees in the past and its occurrence in natural tree species composition of the Czech Republic was up to 20%. Nowadays, its occurrence decreased to 1% under the changing environmental conditions. Silver fir deserves more attention with regard to potential productivity (Silver fir is our most productive coniferous tree) and favorable influence of litter. It is more than advisable to increase its share in forest. In the CR as well as in abroad there were not many research activities carrying out on the genus *Abies* comparing to economic important genus *Pinus* and *Picea*. This may be partly caused by problems related to the planting of the fir [Mergen et al 1964].

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From a population genetics viewpoint we cannot rely only on a gradual adaptation of domestic forest tree populations with respect to great rapidity of ecological conditions changes. Genetic adaptation of domestic forest tree populations on the basis of selection and mutation processes lasts minimally ten or more generations with sudden changes [Kobliha and Janeček 2005]. Increase in fir representation in our forests can be achieved using introduction of foreign tree species adapted to similar climatic conditions or interspecific hybridization of various fir species in order to improve general fir resistance. Therefore this fact does not allow breeding with the target to increase resistance against particular factors. It is necessary to focus on increase of general viability via interspecific hybrids [Greguss 1988a, b]. Using interspecific hybridization for breeding within genus *Abies* originated from spontaneous natural hybrids occurring in the ranges of neighboring fir species [Mergen et al 1964, Mergen and Gregoire 1988].

Today 40–50 fir species and 126 interspecific hybrids are known [Liu 1971, Schütt 1994, Greguss 1995, Musil and Hamerník 2007]. *A. concolor* × *A. grandis* [Larsen 1934], *A. veitchii* × *A. alba* and *A. concolor* × *A cephalonica* are the most commonly known hybrids [Rohmeder 1961, Rohmeder and Eisenhut 1961]. The hybrids within genus *Abies* are characteristic of heterosis not only in vigour but also in enhanced resistance to pollutants, diseases and unfavorable climatic factors – e.g. drought. Establishment of research plots within forest stands is a crucial part of genetic testing and forest trees breeding programs. Comparative plantations are especially used for a research where evaluation of hybrid plants variability is performed [Šindelář 2004].

Hybrid tree progenies as long-living organism are difficult to testing. There are long-term measurements of investigated traits. On the basis of this investigation plant with required qualities can be chosen. Nevertheless misinterpreting of the results acquired from young plants (cca 15–20 years old) could be expected. Only long-term investigation could reveal genetic quality of the plant [Eriksson et al 2006].

The target of the field experiments is investigation of various traits and characteristics of chosen tree species or set of trees. Traits such as volume production, height and thickness increments, qualitative characteristics of the stem and crown, fitness and resistance to abiotic (drought, frost) as well as biotic factors (insects, fungal diseases) are the most often examined. Mortality is the first trait occurring immediately within the initial phase of the experiment. The unsuitable species or hybrids combination can be revealed using this trait. An appropriate statistic evaluation method should be chosen according to the character of the trait. Usually more than one trait is considered from the bulk of traits investigated in the plot (e.g. selection indexes) [Paule 1992, Šindelář 2004].

Testing of hybrid progenies and especially testing of parents with desired genetic-dependent traits plays an important role in forest genetics. If we have the selection of suitable parents originating from progenies measurement we deal with back selection.

Variance estimation is the target of the hybrid testing and it is used for prediction of possible gains resulting from selected individuals. These results are source for new trees selection establishing a new generation [Eriksson et al 2006, White et al 2007].

Testing of selected hybrids was accomplished by Kobliha [1988, 1989], resp. Kobliha and Janeček [2005, 2007], Janeček and Kobliha [2007]. *Abies cephalonica* showed excellent results from intraspecific breeding among others using pollen exposed to γ radiation. Trees of *Abies alba* from control plot with open pollination were sur-

passed by intra- and interspecific hybrid combinations with genetic substitution of *Abies alba* [Kobliha 1989, Kobliha and Pokorný 1990, Kobliha and Snášelová 1991, Snášelová and Kobliha 1990, Kobliha and Králík 1992, Kobliha 1993a, b].

In Slovak Republic Greguss [1984, 1986, 1988a, b, 1992, 1995], Kormuťák [1984, 1985, 1992, 2004], Galgóci et al [2008], Galgóci et al [2011] were engaged in hybridization and testing of fir hybrids. According to their results Silver fir lags behind significantly comparing to hybrids and the differentiation among hybrid progenies and progenies of particular species from open pollination grows simultaneously [Greguss 1986]. Such results are important not only for forestry purposes but also for Christmas tree production and decorating horticulture.

Nowadays USA has the biggest interest on investigation of genus *Abies* hybrids which is aimed at *Abies fraseri* (Pursh) breeding. The target of this breeding program is to obtain species resistant to pathogenic root funghi *Phytophthora cinnamomi* [Kobliha and Stejskal 2009, Stejskal et al 2011] causing considerable economic damages in the Christmas tree plantations.

Similarly in the CR there is an increasing interest in planting of various fir species on the Christmas tree plantations. Farmers here as well as in the USA prefer vigor, resistance and aesthetic features of hybrids. There is an international cooperation between the USA and Czech Republic on the field of fir breeding. This issue is solved within the partnership between Czech University of Life Sciences in Prague (Faculty of Forestry and Wood Sciences, project-coordinator Prof. J. Kobliha) and North Carolina State University in Raleigh (project-coordinator Prof. J. Frampton).

The goal of this study was testing of hybrid progenies planted on experimental and comparative plots in Forest Establishment Kostelec n.C.l. Following objectives of interspecific and complex hybrids of genus *Abies* were evaluated: 1. Level of resistance to abiotic and biotic factors, 2. higher growing potential and 3. identification of species appropriate for Christmas tree production.

MATERIAL AND METHODS

The investigated area with size of 0.46 ha is located in Forest Establishment Kostelec n.Č.l. about 300 m westward from Tree Breeding Station Truba near Kostelec nad Černými Lesy (50°00’ N and 14°49’ E) in Central Bohemian Region, district Prag-East (Forest Natural Region 10 – Central Bohemia Upland). The altitude of the investigated area is 380 m a.s.l. According to Quitt [1971] the area belongs under moderate climatic region type 9 (MT9). Total amount of precipitation is 682 mm, average year temperature 7.8°C. The geological bedrock is Mesozoic rock (sandstone, slate).

According to Kobliha and Janeček [2001] seeds of 21 spontaneous hybrids of genus *Abies* were collected in arboretum Kysihýbel near Banská Štiavnica in the Slovak Republic. Considering phenotype these hybrids incline to *Abies cephalonica*, *A. cilicica* and *A. numidica*. The seeds were sown as individual progenies in Tree Breeding Station Truba in 1991. Plants of 21 investigated progenies plus additional species of genus *Abies* were used for establishment of comparative plantation with spontaneous fir hybrids in 1996. There were 25 individuals in 1.20 × 1.20 m spacing planted in following composition (tab. 1).

Table 1: Composition of tested individuals

Species	Number of replication
Abies alba	9
Abies balsamea	4
Progenies of spontaneous hybrids	3
Abies gracilis	3
Abies grandis	2
*Abies koreana*x (*A. cicilica* × *A. cephalonica*)	2
Abies nordmaniana	1
Abies procera	1
Abies concolor	1

During the spring 2010 the total height of all trees was measured. Hypsometer Vertex III (Haglöf Sweden AB, Sweden) or range pole for smaller trees were used. Diameter of trees (DBH) was measured at breast height (130 cm above the ground) using caliper (Preisser UK Ltd, United Kingdom). Together 1170 individuals were measured.

Statistica 9 software (StatSoft Inc., Tulsa, OK, USA) was used for basic statistic evaluation of the acquired data. One-way ANOVA was carried out to detect statistically significant differences in height and diameter parameters.

RESULTS

Height evaluation. Total mean height was 4.9 m for all progenies. Overview of all tree heights together with mean height is given in Figure 1. According to investigated data *A. gracilis* suffered from 100% mortality on the plot. Progenies no. 2 and *A. koreana* × (*A. cilicica* × *A. cephalonica*) showed the smallest height (3,6 m which is 91% of the *A. alba* height). *A. procera* showed the same mean height as *A. alba*. The height of all other progenies was bigger than *A. alba*.

Table 2. Overview of descriptic statistics

Mean	N	Mean	Minimum	Maximum	Variance	Standard deviation	Variation coefficient
Mean tree height	1144	4.9	1.4	18.7	3.8	1.9	39.2
Mean breast height diameter	1152	57.0	4.0	141.0	825.8	28.7	49.2

Height of progenies of spontaneous hybrids no. 1, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, *A. balsamea*, *A. concolor* and *A. grandis* were within the range from 4.2 to 5.6 m which was from 108 to 144% of *A. alba* height. Progenies no. 8, 9,

A. concolor, *A. nordmanniana* with height from 5.9 to 7.6 m (151 to 195% height of *A. alba*) succeed to above mentioned progenies. The mean height of these progenies was (expressed in percent of *A. alba* mean height): 151% in *A. concolor* and progenies of spontaneous hybrids no. 9, 162% in progenies no. 8 and 194% in *A. nordmanniana* showing the biggest height of 7.6 m. Description statistic is outlined in Table 2.

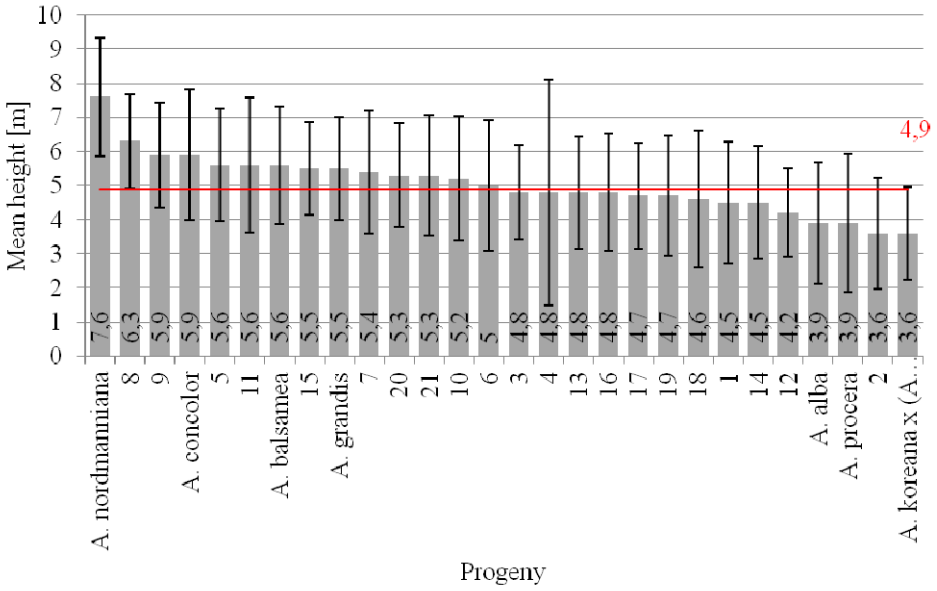

Fig. 1. Mean heights of progenies with error bars

As the data showed out normal distribution ANOVA and Duncan post-hoc test could be used. Null hypothesis of no difference between heights of particular provenances was denied on the level $\alpha = 0.05$ (tab. 3).

Table 3. Results of one-tailed test of significance

Mean		SS	Degree of freedom	NS	F	p
Mean tree height	Intercept	24824	1	24824	7.8	0
	Progeny	683	27	25		
	Error	3603	1116	3		
Mean breast height diameter	Intercept	3630537	1	3630537	6.2	0
	Progeny	122675	27	4544		
	Error	827820	1124	736		

Diameter evaluation. *A. alba* showed the smallest DBH comparing to other progenies (fig. 2).

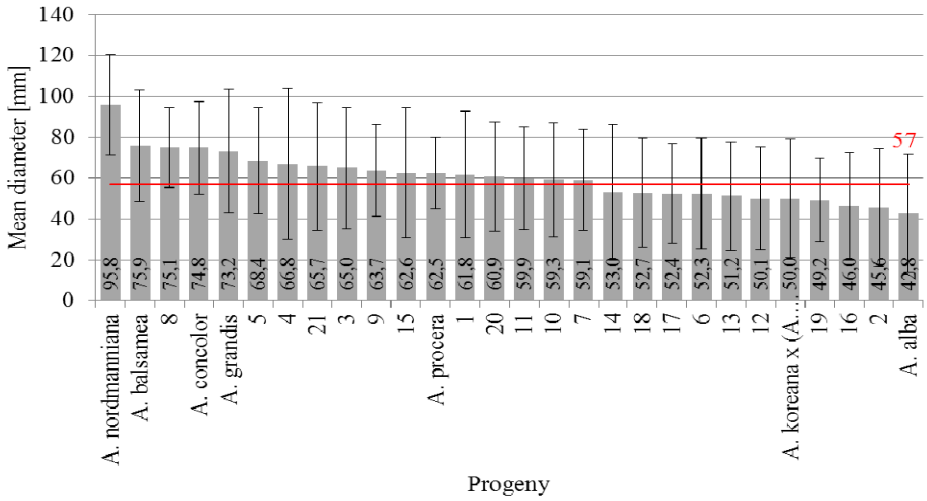

Fig. 2. Mean breast heights diameters of progenies with error bars

Table 4. Overview of mean values of heights and diameter in particular progenies

Progeny	Number of individuals	DBH (mm)	Variation coefficient	Height (m)	Variation coefficient
1	32	62	50	4.5	39.0
2	32	46	63	3.6	38.7
3	33	65	46	4.8	32.1
4	33	68	55	4.8	38.8
5	44	68	38	5.6	29.4
6	47	52	52	5.0	39.5
7	47	60	42	5.4	31.7
8	44	75	26	6.3	21.6
9	51	64	36	5.9	25.5
10	45	59	47	5.2	34.2
11	60	60	42	5.6	27.0
12	42	50	50	4.2	42.0
13	56	51	52	4.8	38.3
14	40	53	63	4.5	43.1
15	33	63	50	5.5	179.3
16	48	46	57	4.8	68.9
17	39	52	47	4.7	35.1
18	46	53	50	4.6	37.6
19	31	49	41	4.7	33.2
20	49	61	44	5.3	33.3
21	29	67	48	5.3	38.1
A. alba	123	45	68	3.9	47.2
A. balsamea	52	76	36	5.6	29.5
A. concolor	17	75	30	5.9	21.7
A. gracilis	0	0	0	0.0	0.0
A. grandis	24	73	42	5.5	36.8
A. koreana × (*A. cilicica* × *A. cephalonica*)	36	49	58	3.6	44.9
A. nordmanniana	13	96	26	7.6	17.9
A. procera	24	62	28	3.9	26.0

The DBH of 45 mm was surpassed by spontaneous hybrids no. 1, 2, 3, 6, 7, 9, 10, 11, 12, 13, 14, 15, 16,17, 18, 19, 20, 21, *A. koreana* × (*A. cilicica* × *A. cephalonica*) and *A. procera.* Their DBH ranged from 46 to 67 mm which was from 102% to 149% of *A. alba* mean DBH. DBH of progenies no. 5, 4, 8, *A. balsamea*, *A. concolor*, *A. grandis* and *A. nordmanniana* ranged from 68 to 96 mm (151–213% of *A. alba* mean DBH). The mean DBH of these progenies expressed in percent of *A. alba* value was: 151% in spontaneous hybrids no. 5 a 4, 162% in *A. grandis*, 167% in *A. concolor* and in progeny no. 8, 169% in *A. balsamea* and *A. nordmanniana*. *A. nordmanniana* showed with values of 96 mm the biggest mean DBH (213% of *A. alba* mean DBH) (tab. 4).

Table 5. One-tailed test of significance

		Sum of squares	Degree of freedom	Mean square	F	p
For tree heights	Intercept	1527	1	1527		
	Replication	94	8	12	3.2	0
	Error	4193	1135	4		
For breast height diameter	Intercept	202485	1	202485		
	Replication	17303	8	2163	2.6	0
	Error	933192	1143	816		

Basic statistic parameters for particular progenies are shown in Table 2. Using Kolmogorov-Smirnov test data normality was confirmed. ANOVA evaluated differences in growth of particular progenies. No differences in DBH values of all progenies were tested within null hypothesis. After rejecting of null hypothesis Duncan's test was performed (tab. 5).

DISCUSSION

It was found that most of the progenies showed better height increment than our domestic *A. alba*. Only in two of the progenies worse height increment was recorded – no. 2 and *A. koreana* × (*A. cilicica* × *A. cephalonica*). This result differs from the previous measurement on the plot in 2004 where the heights of the progenies no. 16 and *A. gracilis* were smaller than in *A. alba*. On the contrary progenies no. 2 and *A. koreana* × (*A. cilicica* × *A. cephalonica*) were ranked above *A. alba*. *A. gracilis* was regarded as the most unsuitable species for further culture and testing [Kobliha and Janeček 2001]. According to the height and diameter traits *A. gracilis* was markedly behind the other progenies. Progenies no. 23 and *A. nordmanniana* were evaluated as the progenies with the biggest height in 1999, 2004 as well as in 2010. In 2004 the mean height of *A. nordmanniana* was 330% of *A. alba* mean height [Oborný 2006]. After six years the height of *A. nordmanniana* was 194% of *A. alba* mean height – thus height increase of *A. nordmanniana* is slowing down with increasing age. Our results are in agreement

with conclusions of Kobliha and Janeček [2001] obtained on the same investigation area in 1999. According to this measurement the height of *A. nordmanniana* was 385% of mean height of *A. alba*. Progeny of *A. nordmanniana* was considered as the most perspective of all. On the other hand *A. nordmanniana* at age of 10 years was evaluated as the weakest progeny in the whole set according to results from Greguss [1992] obtained on Slovakian research plot. Low number of progenies replication could be the reason of results discrepancy. In our case *A. nordmanniana* was represented on one plot only. On the other hand results concerning *A. alba* have high reliability due to the high number of replication.

Similarly diameter increment of *A. alba* control population was surpassed by all progenies. There was measurement of root neck of all progenies on the plot in 2004. *A. gracilis* showed the smallest root-neck diameter on the plot and it was the only progeny with lower values of root-neck diameter comparing to *A. alba* [Oborný 2006]. This investigation confirms the conclusion that *A. gracilis* is not suited for further research. On the other hand *A. nordmanniana* was considered as the progeny with biggest mean DBH (213% of *A. alba* DBH). This result is in coincidence with measurement in 2004. Other three exotic species of genus *Abies* were evaluated positively – *A. balsamea*, *A. concolor* and *A. grandis* – the mean DBH were round 160% of *A. alba*. The mean DBH of all progenies of spontaneous hybrids were round 160% of *A. alba* mean DBH. Exception was the progeny no. 8 where the worst results of all progenies of spontaneous hybrids were recorded. According to Greguss [1992] production of all progenies of spontaneous hybrids was higher comparing to selected species *Abies* in Kysihýbel.

CONCLUSIONS

Abies alba is one of our most important coniferous trees and it is necessary to maintain and increase its distribution in forest stands continuously. On the basis of our research we can conclude that hybrid progenies of genus *Abies* – especially exotic species – grow better than domestic *Abies alba*. The reason could be their growth´s dynamic. This could be illustrated by a slight decrease of height growth in *A. nordmanniana* comparing to previous measurement. Despite of this decrease the best results in both measured parameters in *A. nordmanniana* were recorded. On the contrary *A. gracilis* was found completely inappropriate for further research due to the mortality of 100%.

ACKNOWLEDGEMENT

This work was supported by grant no. QH81160 (NAZV) Economic Efficiency of Tree Breeding and by the platform KONTAKT ME 914 Fir Breeding for Forestry and Christmas Tree Production within research project at Ministry of Education, Youth and Sports.

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TESTOWANIE POTOMSTWA HYBRYDOWEGO I RÓŻNYCH GATUNKÓW RODZAJU *Abies* DLA LEŚNICTWA, OGRODNICTWA OZDOBNEGO ORAZ PRODUKCJI CHOINEK

Streszczenie. Niniejsza praca ocenia parametry dendrometryczne hybrydowego potomstwa różnych gatunków *Abies* otrzymane podczas pomiarów wiosną 2010 na poletku doświadczalnym w Kostelec nad Černými lesy. Otrzymane dane były przetworzone i porównane z pomiarami poczynionymi w roku 2004. Wyniki pokazują, że całe potomstwo hybrydowe na poletku przewyższało *A. alba* pod względem badanych parametrów. Tylko dwa osiągnęły gorsze rezultaty, jeśli chodzi o średnią wysokość – *A. koreana* × (*A. cilicica* × *A. cephalonica*) oraz potomek spontanicznej krzyżówki no. 2. Pod względem wysokości i średnicy, *A. nordmanniana* oceniono jako najbardziej produktywną. Z kolei *A. gracilis* uważa się za nieodpowiednią do dalszej uprawy i badań ze względu na 100% śmiertelność

Słowa kluczowe: krzyżowanie, hodowla, testowanie potomstwa

Accepted for print: 18.01.2013