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## Morphology and growth of *Alnus incana* x *glutinosa* F<sub>1</sub> hybrids\*

### INTRODUCTION

On an experimental area with 11 provenances of black alder established in 1968 in Kórnik (Mejnartowicz 1980a) besides the plots with black alder from Czeszewo on the Warta a hybrid full sib progeny was planted obtained from controlled pollination of *Alnus incana* with *Alnus glutinosa*. Such hybrids, sometimes found in nature, have usually a luxuriant growth and as such have drawn the attention of foresters long ago. Already in 1854 data was published on interspecific hybrids of alders. These were most probably the first controlled crosses in trees that have yielded a progeny with heterosis (Klotsch 1854 after Svoboda 1957). After that for almost 100 years publications are not known on controlled hybrids between the black and gray alders. In 1969 Vaclav reported that 12 years old hybrids *A. incana* × *glutinosa* have a height of 6.1 m while the hybrids of *A. glutinosa* × *incana* only 3.3 m. This data has indicated the importance of the choice of mother, and have also shown that a higher number of fertile seeds is obtained when we use for pollination a mixture of pollen from several trees of black alder. From the studies of Chiba (1966) it appears that interspecific hybrids of alder do not have heterosis and that only occasionally one observes in the F<sub>1</sub> generation a greater height growth.

### METHODS

When selecting stands for the establishment of an experiment on the genetic variability of black alder a single tree of gray alder was found in the surround of a seed stand of black alder in Comp. 111 of Range

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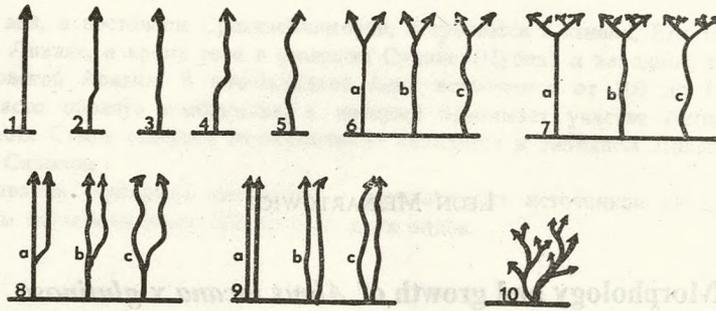


Fig 1. Form classification of alder (Verweij 1977)

1, 2 — straight, 3, 4 — slightly curved, 5 — heavily curved, 6 pitchfork, 7 — widely spreading, 8 — heavy lateral branches starting under crown, 9 — double stem, 10 — bush tree

Splawilk, Forest District Czeszewo on the Warta (Mejnartowicz 1972). From this tree all male flowers were removed and the female flowers were covered with isolation bags made from wide dialysis tubes. The flowers were later pollinated with a pollen mixture from 12 black alder trees growing in the adjacent seed stand. From this same stand seed was collected for the provenance study of black alder (Mejnartowicz 1980a).

Hybrid seed and seed from the paternal population have been sown in the same nursery of Zwierzyniec Range near Kórnik. After one year the seedlings were transplanted at a spacing of  $10 \times 30$  cm. Two years old seedlings were planted out onto three experimental areas in Forest Range Zwierzyniec nr. Kórnik, onto a fertile sandy-clayey soil rich in water, in Forest Range Budwiecie of Forest District Gołdap and on plot I-2a in a sand pit of the Szczakowa Mine-filling Sand Quarry. In all the experimental areas the hybrids were planted only on the plots with trees of provenance Czeszewo and in the surround of the experiment but always besides trees of black alder of the same provenance. Below the results presented concern only the measurements and observations made in the Zwierzyniec experimental area.

## RESULTS

The maternal tree *Alnus incana*, had a height of 6m and a diameter of 7 cm measured at 1.3 m above the ground. The tree was 15 years old. The stem was crooked with many tops, which according to the scale shown in fig. 1 can be designated with the symbol 7b. The crown was positioned at mid length of the stem. It was therefore a typically „negative” tree. Around the stem there occurred numerous root sprouts characteristic for many trees of this species. The leaves were grayish-green, dull, without a lustre, which according to the Colour Chart RHS (1966)

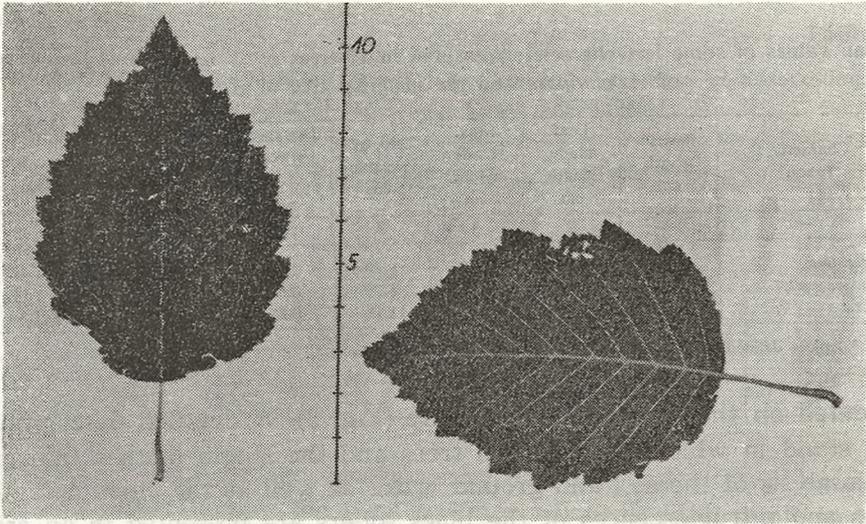


Fig. 2. Leaf shape of the maternal tree *Alnus incana*.  
Phot. K. Jakusz

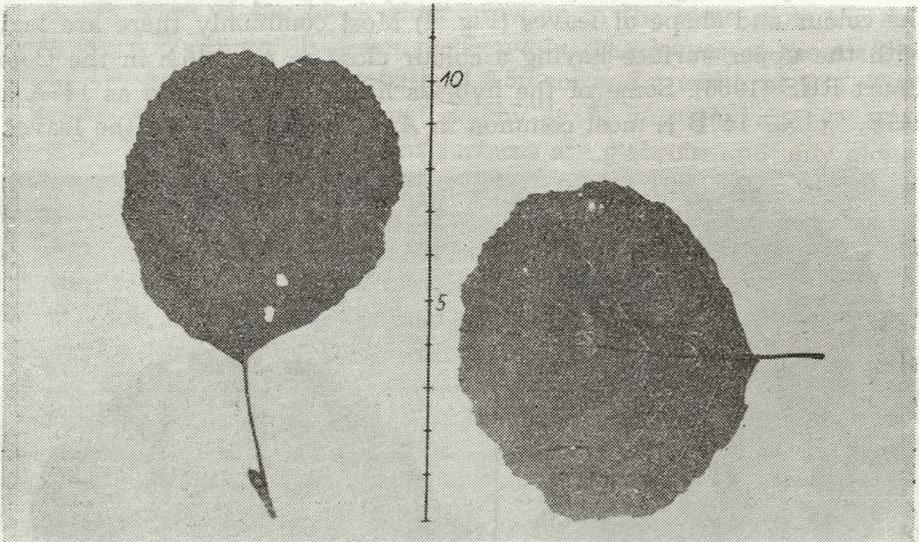


Fig. 3. Leaves of *A. glutinosa*, provenance Czeszewo. Phot. K. Jakusz

could be defined as having a 147 A colour on the upper leaf surface and 147 B on the lower. The leaf shape is shown in Figure 2 and other data in Table 1.

Paternal trees, *A. glutinosa*, have had a height of 24 - 26 m, a diameter of 26 - 38 cm and an age of 60 - 75 years. The stems were straight of high technical quality, with a crown covering the upper 1/4 to 1/3 of their length. The leaves were dark green with a lustre on the upper surface,

Table 1

Mean values of some leaf characters measured in 10 trees of *A. incana* × *glutinosa*, 10 trees of *A. glutinosa* and the maternal tree of *A. incana*

Character Taxon	Petiole length cm	Leaf blade length cm	Max. blade width cm	No. of vein pairs cm	Distance between 2 - 3 vein cm	Down	Apex type*	2 : 1	2 : 4	2 : 5
	1	2	3	4	5	6	7	8	9	10
<i>A. glutinosa</i>	1.98	6.25	5.56	6.40	0.82	1.0	1.25	3.28	1.12	0.98
<i>A. incana</i> × <i>gluti.</i>	2.32	8.96	8.21	8.77	0.59	0	2.90	3.89	1.09	1.06
<i>A. incana</i>	2.44	8.54	6.41	11.16	0.51	0	3.00	4.96	1.34	0.76

\* Apices defined as 1 - retuse, 2 - obtuse, 3 - acuminate

intended on the top distinctly downy (Fig. 3). A detailed description of the stand in which the paternal trees and the single mother tree grew, an analysis of the soil and ground water as well as the characters of leaves and infructescences of the black alders are presented in an earlier paper (Mejnartowicz 1972).

The  $F_1$  hybrids *A. incana* × *glutinosa* have leaves with characters that clearly distinguish them from the paternal species. They differ in the colour and shape of leaves (Fig. 4) Most commonly there are leaves with the upper surface having a colour close to no. 146A in the Colour Chart RHS (1966). Some of the hybrids have leaves classed as 147A and 147B. Colour 147B is most common in *A. glutinosa* however the leaves of

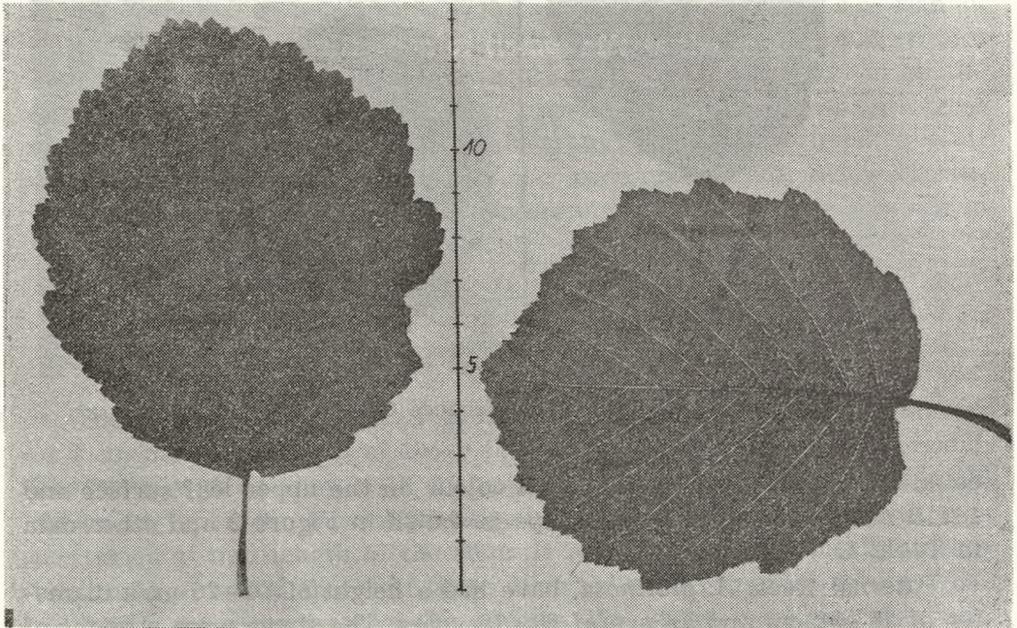


Fig. 4. Shape and dimensions of leaves from the  $F_1$  hybrids *A. incana* × *glutinosa*.

Phot. K. Jakusz

Table 2

Colour of bark and leaves in 4 years old trees of *A. glutinosa* and *A. incana* × *glutinosa* estimated on the basis of the Colour Chart RHS (1966)

Tree no.	Bark		Upper leaf surface		Lower leaf surface	
	<i>A. incana</i> × <i>gluti.</i>	<i>A. gluti.</i>	<i>A. incana</i> × <i>gluti.</i>	<i>A. gluti.</i>	<i>A. incana</i> × <i>gluti.</i>	<i>A. gluti.</i>
1	199 A	177 A	146 A	137 A	147 C	146 B
2	200 C	201 A	146 A	147 B	146 B	147 C
3	199 A	201 A	146 A	147 B	148 B	147 C
4	200 C	201 A	147 B	147 B	147 C	147 C
5	200 C	200 C	146 A	148 A	146 B	148 B
6	200 C	200 D	147 B	147 B	146 B	147 C
7	201 A	201 A	147 A	147 B	147 B	147 C
8	177 A	177 A	147 A	146 B	147 B	146 C
9	199 A	197 A	146 A	147 B	146 B	147 C

the hybrids do not have the characteristic lustre of the paternal species. On the lower leaf surface the most common colour is 146B while in the black alder it is 147B (Tab. 2). In terms of dimension the leaves of the hybrids exceed substantially those of the parental forms. Their mean length (measured on 10 trees) amounts to 8.96 cm and width 8.21 cm while in the trees of the black alder growing in the same plots the dimension are 6.25 cm and 5.56 cm respectively. The leaves of the maternal tree have had an average length of 8.56 cm and a width of 6.41. The leaf surface of the hybrids are not downy as *A. glutinosa* and not pubescent as *A. incana*. Both the leaf surfaces are glabrous and only along the main vein there occur hairs of creamy colour. The leaf is apiculate or obtuse but it is never retuse as in the black alder nor acuminate as in gray alder. The estimated colour of leaves and bark in 9 hybrid trees and 9 trees of the black alder are presented in Table 2.

Several leaf characters are typical intermediate. For example the characteristic leaf shape (Fig. 4), the number of pairs of veins as the ratio of blade length to petiole length are intermediate between those of *A. glutinosa* and *A. incana* (Tab. 1).

The bark in the young hybrid trees is greenish brown, smooth with a lustre. About the 10th year it becomes dull gray in the lower parts of the stem, the upper ones remaining smooth with an olive green colour.

Infructescences which were formed by some of the hybrids in the 12th year similar in shape to those of the gray alder, however they have somewhat longer peduncles, whereas on the mother species the female catkins are usually sessile. The paternal species has much longer peduncles (Figs 5, 6 and 7). So far we lack data concerning the fertility of seeds developed on the  $F_1$  hybrid trees.

Height and diameter have been measured in hybrids and in the adjacent trees of black alder from provenance Czeszewo. An analysis of data is presented in figures 8 and 9 and in tables 3 and 4. The rapid

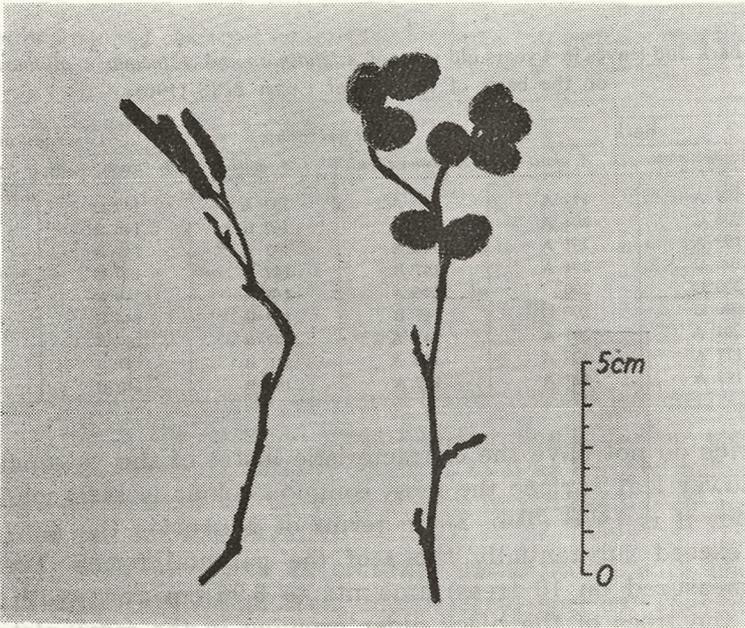


Fig. 5. Inflorescences and the sessile or very shortly pedunculate infructescences of *A. incana*. Phot. K. Jakusz

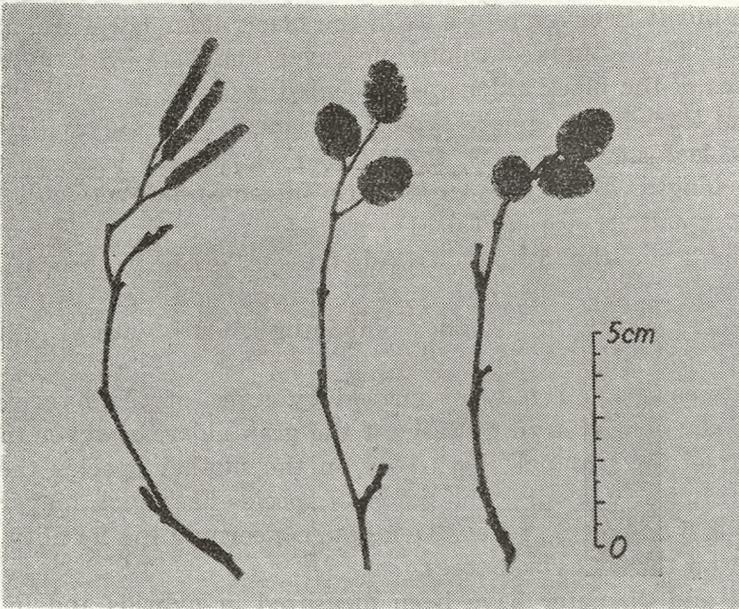


Fig. 6. Inflorescences and infructescences of the hybrids. Peduncles of intermediate length between those for the parents. Phot. K. Jakusz

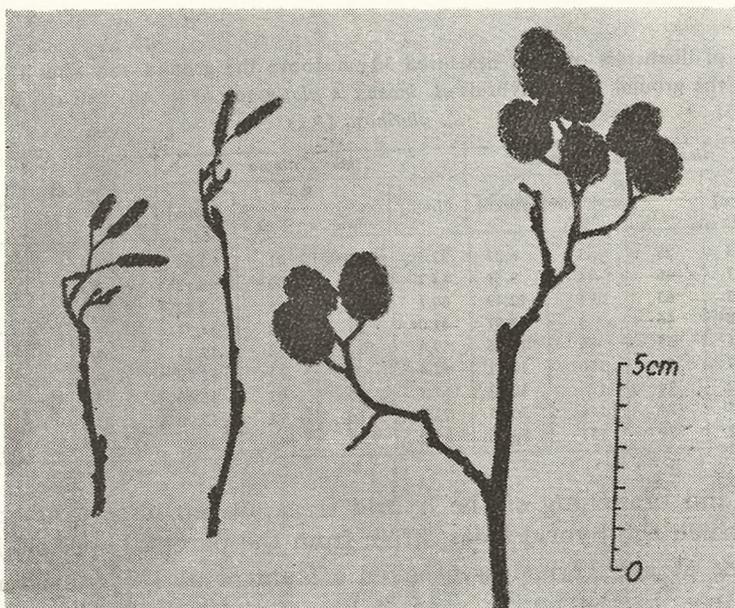


Fig. 7. Inflorescences and infructescences of trees from the paternal population of *A. glutinosa*. Phot. K. Jakusz

growth of the hybrids is particularly manifest between the 4th and 12th year. All the hybrid trees have had at the time a greater height and diameter, though towards the end of the observation period there was a tendency for a decline in the differences. While the height of 3 year old *A. glutinosa* seedlings represented only 67.9% of the height of the hybrids, in the 12th year it was already 89.7% (Tab. 3).

Girth increment of hybrid trees was much greater than that of *A. glutinosa* and the differences here were even greater than in height. In the eleventh year of life diameters of black alder measured at 1.3 m amounted to only 62.4% of the diameters of the hybrids (Tab. 4).

Table 3

Height of *A. incana* × *glutinosa* ( $A_i$  ×  $A_g$ ) trees and those of *A. glutinosa* ( $A_g$ ) of equal age from the paternal population, growing jointly in plots of an experimental area in Kórnik

Age	<i>Alnus incana</i> × <i>glutinosa</i>				<i>Alnus glutinosa</i>				$\frac{A_g}{A_i \times A_g}$ [%]	$t_{0.01} = 2.98$
	$\bar{x}$ [cm]	R		S [cm <sup>2</sup> ]	$\bar{x}$ [cm]	R		S [cm]		
		$x_{min}$	$x_{max}$			$x_{min}$	$x_{max}$			
3	165	26	235	55.5	112.3	30	210	41.9	67.9	8.75
4	328	160	400	66.3	249	130	380	64.8	75.9	9.37
5	460	370	550	56.7	379	250	460	52.3	82.4	11.53
6	579	480	660	57.2	490	370	600	72.3	84.6	11.56
7	643	550	780	80.6	563	480	650	61.8	87.6	6.70
8	761	610	880	93.0	656	550	790	81.4	86.2	5.59
12	1103	900	1400	142.0	990	700	1200	122.8	89.7	9.42

$\bar{x}$  – mean tree height in cm, R – range, S – standard deviation

Table 4

Comparison of diameters of trees measured 30 cm above the ground and after the 6th year 1.3 m above the ground in the hybrids *A. incana* × *glutinosa* (Ai × Ag) and the pure species *A. glutinosa* (Ag)

Age	<i>Alnus incana</i> × <i>glutinosa</i>				<i>Alnus glutinosa</i>				$\frac{Ag}{Ai \times Ag}$ [%]	$t_{0.01} = 2.98$
	$\bar{x}$ [mm]	R		S [mm]	$\bar{x}$ [mm]	R		S [mm]		
		$x_{min}$	$x_{max}$			$x_{min}$	$x_{max}$			
4	42.3	28	53	6.33	32.5	16	41	7.08	76.8	9.25
5	58.5	46	74	9.61	45.2	22	55	9.12	77.3	11.06
6	77.3	63	94	12.49	60.1	34	75	12.82	77.5	11.47
6*	60.0*	46	73	9.57	41.0*	21	60	11.34	68.3	12.93
7	73.1	55	86	12.36	49.4	32	68	12.11	67.6	20.67
8	82.7	61	100	14.11	57.4	38	73	12.30	69.4	6.2
10	106.2	74	126	16.72	67.8	35	92	16.05	63.8	9.81
11	114.5	74	144	20.85	71.5	36	98	17.90	62.4	3.56
12	126.2	79	157	20.06	89.0	49	146	24.79	70.5	3.02

Shape and branching of the hybrid trees are an important characteristic in which the hybrid trees differ from the parental species. None of the hybrids at age 12 had as crooked a stem or as low a crown as the maternal tree. In the fourth year of life of the hybrids the number of branches was counted on 15 hybrid trees and 15 black alder ones. The mean number of first order branches was 38.5 in the hybrids and 35.9

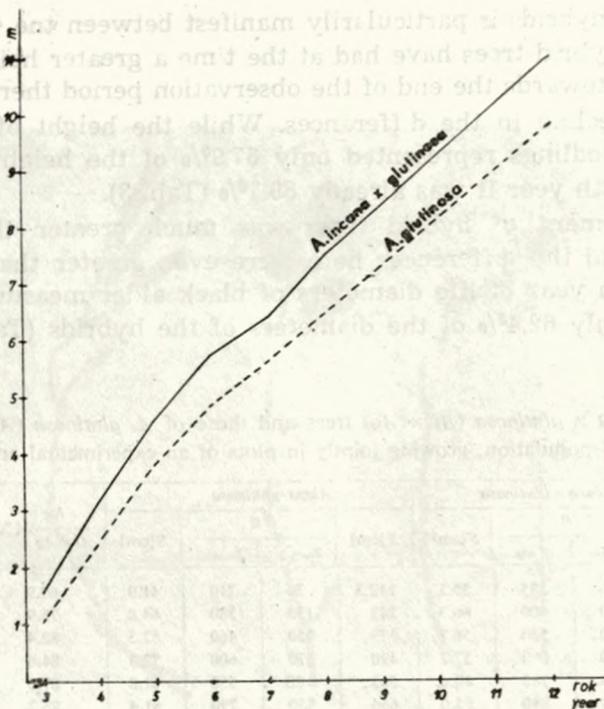


Fig 8. Increase in height of *A. incana* × *glutinosa* and *A. glutinosa* trees during the first 12 years of life

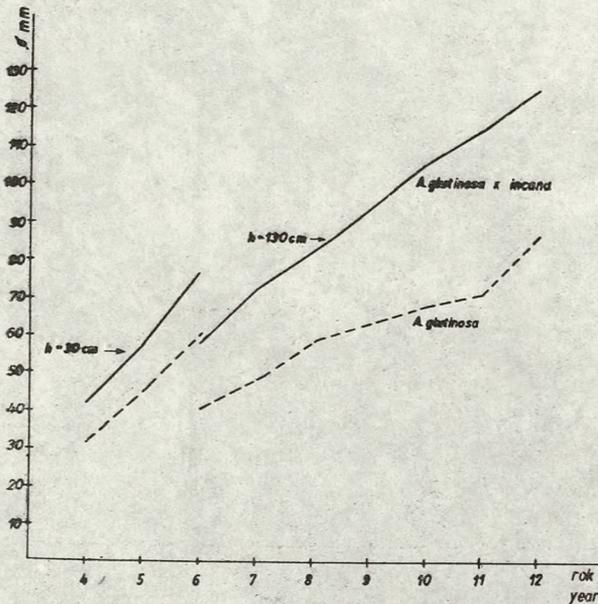


Fig. 9. Increase in diameter of *A. incana* × *glutinosa* and *A. glutinosa* trees measured at 30 cm above the ground till age 6 years and then at 1.3 m from the ground

in *A. glutinosa*. Besides in the hybrids the branches in the lower part of the crown die 2-3 years later than in *A. glutinosa*, and some remain alive even much longer (Fig. 10).

In the first 5-8 years of life the stems of the hybrid trees were straight and did not differ in shape from those of the black alders. Then crooks began to appear in the lower part of the stem, possibly due to the rapid rate of growth (Fig. 11). In the 12th year of life an evaluation was made of the shape of the trees using the scale of estimations presented in Fig. 1. The results are presented in Table 5.

Table 5

Percentage frequency of occurrence of various forms of *A. incana* × *glutinosa* and of *A. glutinosa* estimated on an experimental area in Kórnik according to the scale presented in Fig. 1.

Tree shape type	<i>A. incana</i> × <i>glutinosa</i>	<i>A. glutinosa</i>
1	20	47
2	7	7
3	60	26
5	7	7
6a	6	0
6b	0	7
7a	0	6
Total	100	100

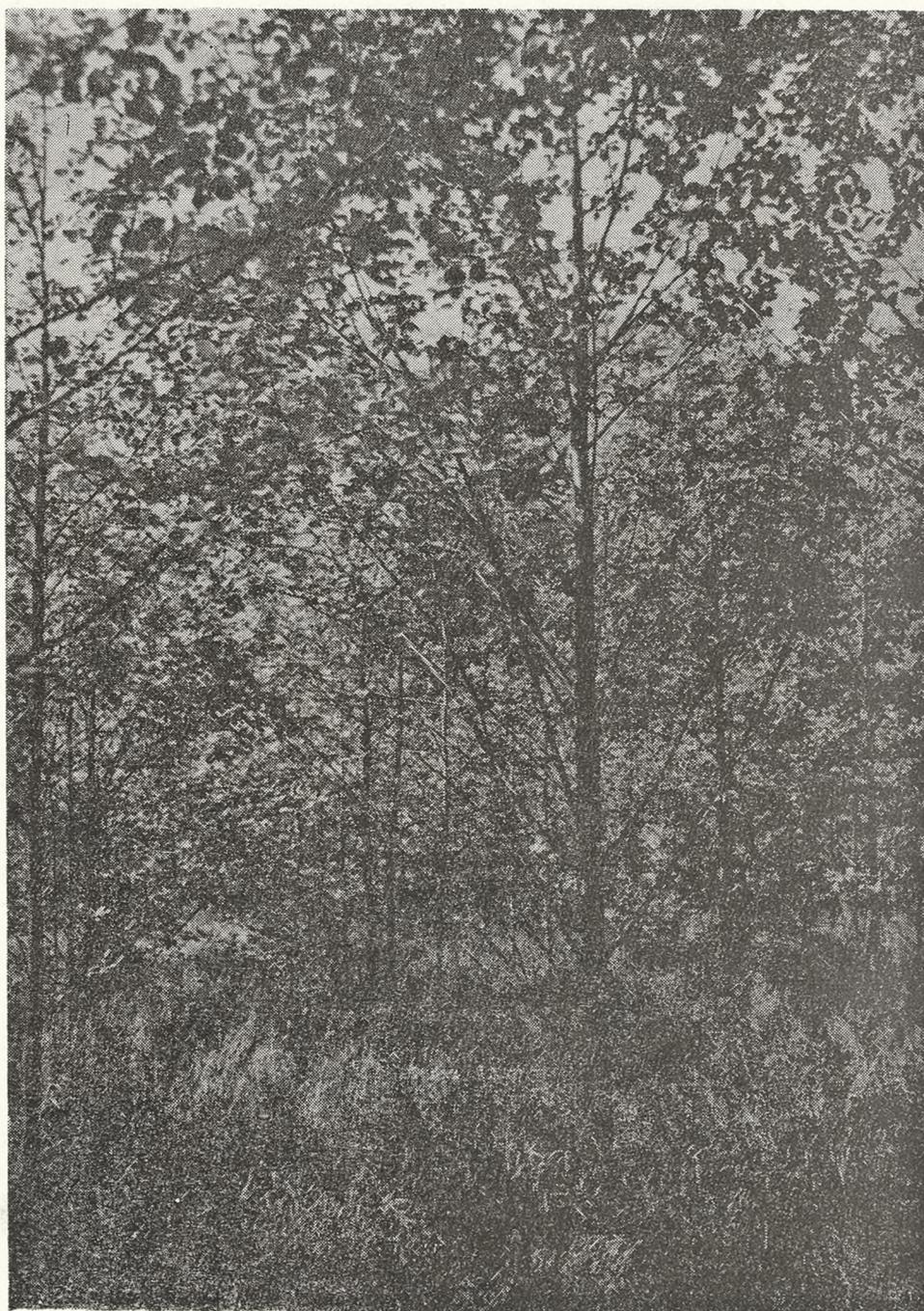


Fig. 10. Eight years old hybrid *A. incana* × *glutinosa* with luxuriant growth but with low set branches at an acute angle. Phot. K. Jakusz



Fig. 11. In the front *A. incana* × *glutinosa* at age 12 years among trees of *A. glutinosa* of the same age from the paternal population, growing on the experimental area in Kórnik. Phot. L. Mejnartowicz

#### DISCUSSION

The leaf characters, and particularly their shapes (Fig. 4), texture and colour, the stem shapes and those of the infructescences on trees raised from artificial cross pollination when compared with the same characters on the paternal trees are intermediate in nature, sometimes with a tendency more in the direction of the paternal form and sometimes towards the mother. This was true for all trees except one, and therefore

can be considered as evidence of hybrid nature of these trees. The single tree in the  $F_1$  progeny which did not have intermediate characters, was clearly close to the maternal form without any paternal features. It had acuminate leaves densely pubescent, leaf and bark colour as in the mother tree, a crooked stem with a smooth bark. This tree may have formed as a result of selfpollination, had the castration been incomplete, or from apomictic development of a seed, which phenomenon is known from the literature to occur in *A. incana* as is pointed out in a review paper (Mejnartowicz 1980c). For this reason in this study this individual was excluded from consideration clearly not being a hybrid. The others are assumed to be proven hybrids.

The obtained measurements of heights and diameters of *A. incana* × *glutinosa* appear to have a clear advantage over the paternal *A. glutinosa* progeny. These differences are significant not only in respect to the Czeszewo provenance which grows on the same plots as the hybrid (results shown in Figures 8 and 9 and Table 3 and 4) but also in relation to the other 10 provenances of the species considered in the Kórnik experiment. Thus for example at the age of 8 years the mean height of trees was 4.7 m for the slowest growing provenance Kętrzyn, 6.3 m for provenance Czeszewo and 7.5 m for provenance Ulanów the fastest growing one (Mejnartowicz 1980b). At the same time the hybrid progeny had an average height of 7.6 m (Tab. 3).

The only known numerical data concerning *A. incana* × *glutinosa* hybrids published by Vaclav (1969) differ surprisingly from those presented here. Trees that were 12 years old in Vaclav's experiment had only a height of 6.1 m that is less than the majority of trees in the 11 provenances studied here at an age of only 8 years (Mejnartowicz 1980b), and less than 7 years old hybrids in this experiment. Perhaps these differences could be assigned to unfavourable site conditions, about which there is no information in Vaclav's paper, or to the fact of using in my study of a father tree with an exceptional breeding value giving a double mean deviation of the  $F_1$  progeny from the mean for the Czeszewo paternal population (Falconer 1974).

The rapid growth of hybrids may be the result of the phenomenon known as heterosis. Since *A. incana* in Czeszewo is several hundred kilometers beyond the continuous range of the species it is quite probable that the individual in question is a selfed offspring of a similarly isolated individual. This is further indicated by its poor, „negative” growth. Thus the crossing of an at least partially inbred individual of *A. incana* with genetically distant *A. glutinosa* trees has resulted in heterosis of characters that are unrelated to reproduction such as height and diameter growth and the length and width of leaves.

Comparing the shape of stems in the  $F_1$  progeny with the mother

*A. incana* tree one can say that this character is patroclinal in nature. None of the hybrid trees had such a crooked stem as was observed in the mother.

Some characters of the hybrids are matroclinal in nature. One can include here the persistence of branches which die much later than in the paternal species, the acute angle at which they are set on the trunk and the texture and colour of bark.

#### SUMMARY

A 15 years old negative individual of *A. incana* has been pollinated with a mixture of pollen collected from 12 *A. glutinosa* trees of great silvicultural value aged about 60 years. The *A. incana* × *glutinosa* hybrids were planted in plots next to *A. glutinosa* trees from open pollination in the paternal stand. Measurements of heights and diameters till the 12th year have shown very significant differences between the mean values for the hybrids and for the trees from the paternal population. At the age of 12 years the mean height was 11.03 m and mean diameter 126 mm while the means for trees from the paternal population of equal age were 9.90 m and 89.0 mm respectively. Leaves of the hybrids have larger areas than those of the paternal species and are not downy. The shape of the leaves, the number of vein pairs, the ratio of blade length to petiole length are intermediate characters, while the petiole length, the branching angle and the viability of branches are matroclinal characters.

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### LEON MEJNARTOWICZ

#### *Morfologia i wzrost mieszańców $F_1$ *Alnus incana* × *glutinosa**

##### Streszczenie

Piętnastoletnie negatywne drzewo *Alnus incana* zapylono mieszaniną pyłków zebraną z 12 drzew *A. glutinosa* o dużej wartości hodowlanej i mających około 60 lat. Mieszańce *A. incana* × *glutinosa* powstałe w wyniku tego zapylenia posadzono następnie na poletkach doświadczalnych obok drzew wyrosłych z nasion zebranych w drzewostanie ojcowskim.

Pomiary wysokości i średnic w wieku do 12 lat wykazały bardzo istotne różnice między drzewami *A. glutinosa* a mieszańcami *A. incana* × *glutinosa*. Drzewa olszy czarnej z populacji ojcowskiej miały w 12 roku życia 9,90 m wysokości i 89,0 mm średnicy, podczas gdy mieszańce miały odpowiednio 11,03 m i 126 mm. Liście mieszańców były większe niż drzew z populacji ojcowskiej i nie były omszone w kątach nerwów.

Kształt liści, liczba par nerwów, stosunek długości blaszki do długości ogonka są u mieszańców cechami intermedialnymi, podczas gdy długość ogonka, kąt osadzenia gałęzi na pniu oraz żywotność tych gałęzi są cechami o charakterze matroklinalnym.

### ЛЕОН МЕЙНАРТОВИЧ

#### *Морфология и рост гибридов $F_1$ *Alnus incana* × *glutinosa**

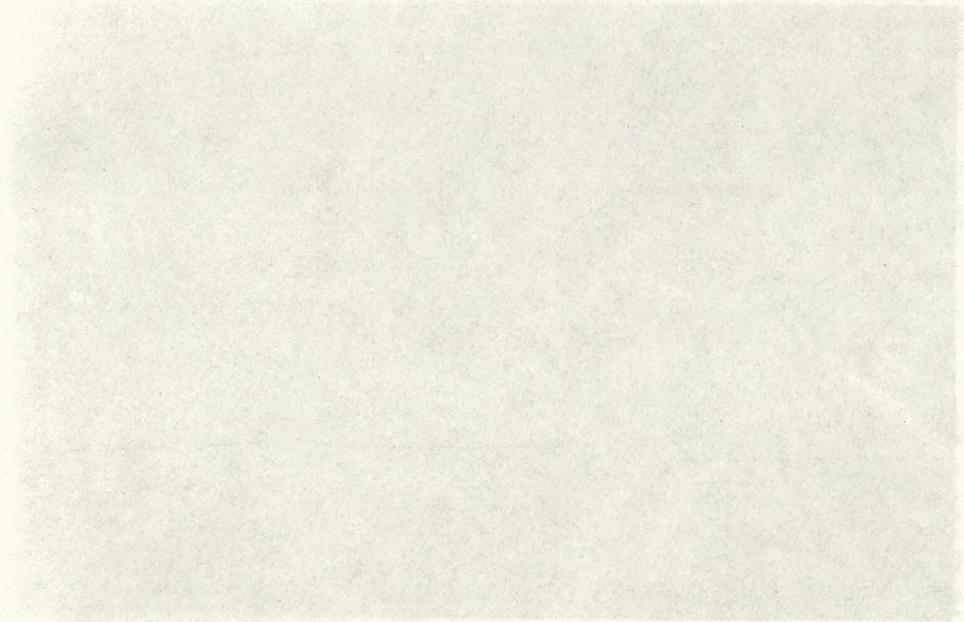
##### Резюме

Пятнадцатилетнее негативное дерево *Alnus incana* опылили смесью пыльцы собранной с 12 деревьев *A. glutinosa* в возрасте около 60 лет, характеризующихся большой хозяйственной ценностью. Возникшие в результате этого опыления гибриды *A. incana* × *glutinosa* были высажены на опытных площадях рядом с деревьями выросшими из семян собранных в отцовском древостое.

Измерения высот и диаметров в возрасте до 12 лет выявили существование значительных различий между деревьями *A. glutinosa* и гибридами *A. incana* × *glutinosa*. Деревья ольхи черной с отцовской популяции достигли к 12 годам 9,90 м высоты и 89,0 мм диаметра, в то время, как гибриды имели соответственно 11,03 м

и 126 мм. Листья гибридов характеризовались большими размерами чем у деревьев отцовской популяции и отсутствием опушения между углами нервов.

Форма листьев, число пар нервов, отношение длины листовой пластинки к длине черешка являются у гибридов интермедияльными чертами, в то время как длина черешка, угол между ветвями и стволом, а также жизнеспособность этих ветвей являются матроклинальными чертами.



...ta sama tablica van Houtte'a. Fot. T. Tytkowski

...szczególną uwagę zasługuje fakt, że w tej...  
...takie spośród krzewów jak *Corylus arbo-*  
...*avellana* Jacq., *Castanea sativa* Mill., *Sy-*  
...*avellana* L., + *Castanea sativa* sp., co...  
...były dotychczas atakowane przez jamio-  
... (1864) stwierdził występowanie jądrowy  
... z wymienionymi przez H. o-