VARIATION AMONG ALNUS PROGENIES GROWN IN OHIO

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Abstract. Seedlings grown in Ohio from seed collected from 12 native seed sources of *Alnus glutinosa* (European black alder) and one seed source of *Alnus cordata* (Italian alder) were outplanted in 1981 in a combination provenance/family planting. Data were collected over a period of 11 years after planting. Results show highly significant variation among provenances in winter injury, time of growth initiation, rate of survival, leaf miner injury, and height and diameter growth. Italian alder seedlings showed the least leafminer injury and the earliest flushing, but showed the poorest survival of all groups tested, primarily because of winter injury. European black alder seedlings grown from seed collected in Iran also sustained major winter dieback and poor survival. Trees from West Germany, France, Denmark, and Yugoslavia seed sources were fastest-growing, whereas seedlings from some sources in southern Europe (Spain, Italy, Bulgaria) were slowest - growing. The genetic variation shown in this study is sufficient to allow for success in breeding for improved insect resistance, cold hardiness, and growth rate in alder.

European alders (both *Alnus glutinosa* (L.) Gaertn. and *A. cordata* Desf.) have been planted throughout the world for reforestation, strip mine reclamation, and, more recently, for urban forestry purposes (1,5,8,9). European black alder (*A. glutinosa*) has the widest range of all alders common to Europe (8). It extends throughout most of Europe into the Mediterranean region and Iraq, south to North Africa. The Italian alder (*A. cordata*) has a more limited distribution, and is confined to Corsica and southern Italy.

Alders are known to increase soil fertility through symbiotic fixation of nitrogen by organisms (such as *Frankia* spp.) residing in root nodules (5,6,9,11). Alders tolerate wet and dry sites, grow rapidly, have dark green, attractive foliage, unique catkins and strobili, and transplant easily. They can attain heights of 23 m under ideal conditions in Europe (8). For these reasons, they have great potential use as street and landscape trees.

This article reports on a study of variation in several traits of European black and Italian alders grown in Ohio from seed collected from 13 European provenances. Evidence for the existence of cold and insect resistance is presented.

Materials and Methods

Seed from 12 provenances of European black alder and one provenance of Italian alder were received in December 1979 from Dr. Richard B. Hall, Iowa State University, Ames, Iowa. Seed were stratified in moist sand at 2°C for four months before planting in flats in the greenhouse. Seedlings were grown for one month in these flats, then inoculated with 800 ml/flat of a slurry containing nitrogen-fixing *Frankia* (Strain ASN1) donated by Dr. Maurice Lelonde (Charles F. Kettering Research Laboratory, Yellow Springs, Ohio). His methodology for slurry preparation and inoculation (11) was followed closely. After inoculation, the soil surface was kept fully moistened for 48 hours.

Several weeks later, seedlings were transplanted to 8 x 8 x 28 cm decomposable, cardboard containers and placed outside for further growth and eventual overwintering. In April, 1980, these seedlings were transplanted to a field site of silt loam soil near Delaware, Ohio (Fig. 1). A randomized complete block, split-plot design was used,

Fig. 1. The alder plantation near Delaware, Ohio in 1993.

with seedlings from each provenance planted together as a "major" plot in each of 5 blocks; open-pollinated families (one family = seedlings grown from seed collected from one tree) within provenances formed cohesive "minor" plots, and varied in number from one to three families per provenance, with three being most common. Depending on availability, from 9 to 12 trees per provenance were planted in each of the 5 blocks.

Data on injury from European alder leaf miner (*Fenusa dohrnii*) were collected in August, 1983. For these data, a visual estimate was made of the percentage of each tree's total foliage showing leaf miner injury. Winter dieback data were collected by estimating the percentage of the entire length of each tree's central leader showing winter injury. This was recorded in June of 1983 and June of 1984. Earliness of growth initiation, or "flushing", recorded in early May, 1984, was based on an index of leaf development and growth from 0 = very late to 100 = very early. Heights (cm) and diameters (mm) 1.4 m above the ground were measured in the autumn of 1987 and 1992, respectively.

Percentage data initially were analyzed using the arcsin transformation. When the data were analyzed subsequently as actual percentages, there was very little difference in the results as compared to the arcsin transformed analyses. Therefore, we chose to present the results as percentages in order to preserve the original units of measurement. All statistical analyses were done using the SAS statistical package (14). Mean separation was performed using the least significant difference (lsd) test at the 5% level of significance.

Results and Discussion

Provenances varied significantly in all traits measured. Significant variation among families within provenances occurred only with time of flushing, however. (Copies of detailed results of statistical analyses are available by request from the authors). The fastest growing trees in height were from former West Germany, France, Denmark, and former Yugoslavia; the slowest growing were from seedlots collected from Iran and parts of southern Europe (Spain, Italy, Bulgaria) (Table 1). It should be noted that seedlings from Iran showed extensive winter dieback of the central leader and might be expected to show less cumulative height growth. Ranking of progenies in diameter growth, measured in 1992, generally followed the same general pattern shown in 1987 for height: Seedlings from Yugoslavia, Denmark, France, and West Germany again were among the largest and those from Iran, Scotland, Spain, and Italy were the smallest.

The Italian alder showed the least leafminer damage, although variation among the other provenances was quite pronounced, following no apparent geographic trend. This is the first report of such large variability in insect resistance in alder; significant gains in resistance possibly could be made with a well- designed breeding program involving crosses within and between both Italian and European black alder (Table 1).

Most of the trees of Italian alder and of European black alder from Iran suffered severely from winter injury and both showed poor survival, with less than 14 percent of the Italian alder and only 42 percent of the Iranian black alder surviving in 1987 (Table 1). Survival in 1992 was lower still; only 7 percent of Italian and 33 percent of Iranian alder survived. Trees from other provenances showed excellent survival and little winter dieback. Hall and Miller (9) also found that trees from near the Mediterranean, Black, and Caspian seas suffer winter dieback when grown in Iowa and Wisconsin.

Whether or not related to winter injury, the Italian alder and Iranian black alder were among the last trees to initiate growth in the spring, with trees from Bulgaria, Yugoslavia, and Estonia the earliest to flush (Table 1). Genys (6,7) found that trees from southeastern Europe (Yugoslavia, Bulgaria, Greece) flushed earliest, and those from northwestern sources (England, Norway, and Ireland) initiated growth last. In our study, the only northerly trees that flushed late were those from Scotland. Genys apparently found more of a geographic pattern of flushing than our results show.

Results presented here confirm patterns from other studies of the wide variation found in European alder. DeWald et al. (4) found the same

Table 1. Characteristics of alder progenies grown from seed at Delaware, Ohio, from different European provenacnes.

Species, Provenance No. and Origin	Winter dieback (% of central leader) 1983	Winter dieback (% of central leader) 1984	Leaf miner injury (%) 1983	Flushing[a] 1984	Survival (%) 1987	Survival (%) 1992	Height (cm) 1987	Diameter (mm) 1992
A. glutinosa								
11 Burdoran, Ireland	0 b[c]	0 b	10 bcd	30 d	99 a	99 a	599 abcde	129 cd
14 Duncon, Scotland	0 b	18 b	15 a	19 efg	100 a	98 ab	510 de	109 ef
22 Saks Kobing, Denmark	1 b	0 b	12 abc	38 bc	100 a	100 a	603 abc	147 ab
28 Tartu, Estonia	0 b	8 b	13 ab	40 b	78 c	78 bc	539 cde	134 bcd
47 Offenburg, Germany	0 b	0 b	8 d	38 bc	95 a	92 abc	619 a	136 bc
54 Breziny, Poland	0 b	0 b	13 ab	32 cd	89 abc	89 abcd	543 bcde	137 bc
65 Luneville, France	0 b	13 b	9 cd	30 d	97 a	97 ab	609 ab	139 bc
70 Kosti, Bulgaria	0 b	8 b	15 a	49 a	96 a	96 ab	489 efg	130 cd
72 Durdevac, Yugoslavia	0 b	5 b	8 d	42 ab	93 ab	92 abc	574 abcd	159 a
80 Astench-Ashrafieh, Iran	85 a	80 a	15 a	18 fg	42 d	33 e	328 i	99 f
91 Zamore, Spain	0 b	0 b	10 bcd	25 def	80 bc	74 cd	423 fgh	191 de
97 Lucca, Italy	0 b	1 b	12 abc	26 de	96 a	69 d	494 ef	124 cde
A. cordata								
98 Avellino, Italy	1 b	68 a	3 e	10 h	14 e	7 f	357 hi	--[b]

a Flushing was visually indexed from 0 = very late to 100 = very early initiation of growth.
b Insufficient data to analyze because of mortality.
c Means followed by the same letter in each column are not significantly different at the 5% level, by the LSD.

Iranian provenances sustained major cold injury at two years of age in Pennsylvania and Canada. In a Canadian plantation, they found superior height growth in several provenances from central Europe, in particular the region from western Hungary through western Germany to northeastern France. However, on the drier Pennsylvania site, a reclaimed coal spoil area, the southern European provenances performed better. DeWald et al. (4) speculated that provenances from southern Europe have evolved to better tolerate summer droughts and therefore perform better than less drought-tolerant northern sources. Borghetti et al. (2) found differences among trees from different provenances of Italian alder in their sensitivity to drought. This variability might be used to select for high drought tolerance in alder.

Sources from central Europe, especially West Germany, have been shown in several studies (3,4,6,7) to yield trees with superior height growth. It appears, therefore, that the use of central European provenances offers the best opportunity of introducing fast-growing black alders to Ohio. However, the relative height rankings could change over time, as they did for Funk (5). Further data on both height and diameter growth should be collected in the future.

Hall and Nyong'o (10) reported serious infestations of the European alder leaf miner in all of their Iowa plantings, and estimated that the leaf miner could cause up to a 40% reduction in leaf dry weight. They also observed individual tree differences. The variation shown in the present study among provenances as well as among species could be capitalized on with a breeding program for leaf miner resistance. Genys (7) found significant variation among individual trees but not among provenances in susceptibility to the aphid *Paraprociphilus tesselatus* Fitch. Increasing insect resistance should be a major goal of an alder breeding program.

Clausen (3) had only 48 percent survival in 5-

year-old seedlings grown in Illinois. The best survivors were from provenances in Holland, northern Italy, Bulgaria, and several central European countries; trees from Norway, Finland, and Poland survived poorly. Merrill et al. (13) found that only alders originating from latitudes north of 53 degrees (e.g., Finland, Norway, northeastern USSR, and Poland) were able to survive four growing seasons near Grand Rapids, Minnesota.

Genetic engineering of *Alnus* has been initiated (12), and that work combined with a stand selection and breeding effort could yield superior *Alnus* clones in the future. Hall and Nyong'o (10) have already developed plans for a seed orchard of European black alder.

The present study shows that variation among provenances is sufficient to directly (through selection of specific seed sources) or indirectly (through breeding and selection) make genetic advances in insect resistance, frost- and cold-hardiness, and growth rate of European black and Italian alders. Because of their nitrogen fixing ability, attractive form and foliage, and adaptability to wet sites, the alders deserve more widespread use and a concerted effort towards genetic improvement.

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Résumé. Des semis croissant en Ohio et qui provenaient de semences recueillies auprès de 12 sources de semences de Alnus glutinosa (aulne européen) et d'une source de Alnus cordata (aulne italien) ont été transplantés en 1981 dans des plantations combinant provenance et famille. Des données ont été recueillies sur une période de 11 années après la transplantation. Les résultats montrent une variation très significative entre les provenances pour ce qui touche les dommages par l'hiver, le moment d'initiation de la croissance, le taux de survie, les dommages par les mineuses et la croissance en hauteur et en diamètre. Les arbres dont les sources de semences étaient d'Allemagne, de France, du Danemark et de Yougoslavie poussaient plus vite, alors que les semis provenant de certaines sources de l'Europe méridionale (Espagne, Italie, Bulgarie) poussaient plus lentement.

Zusammenfassung. Sämlinge, aus den gesammelten Samen von 12 natürlichen Herkünften für Alnus glutinosa (Europäische Schwarzerle) und einer Herkunft für Alnus incana (Italienische Erle) und die in Ohio vorgezogen wurden, wurden 1981 in einer kombinierten Familien- und Herkunftpflanzung ausgepflanzt. Über eine Periode von 11 Jahren wurden die Daten erfasst. Die Ergebnisse zeigen hochsignifikante Unterschiede zwischen den Herkünften bezüglich der Winterschäden, der Anwachszeit, der Überlebensrate, der Schädigung durch Blattbohrer, der Höhe und dem Stammdurchmesser. Bäume mit der Herkunft aus Deutschland, Frankreich, Dänemark und Jugoslavien waren die schnellsten im Wachstum, während die Sämlinge mit der Herkunft aus Südeurope (Spanien Italien und Bulgarien) am langsamsten wuchsen.