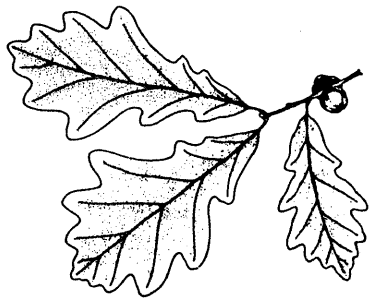
EARLY GROWTH AND FLOWERING OF ALNUS GLUTINOSA PROVENANCES IN SOUTHERN ILLINOIS[1]

Knud E. Clausen[2]



ABSTRACT.--Forty-eight Alnus glutinosa provenances planted in southern Illinois in 1980 differed significantly in survival, height, dbh, and number of stems per tree after the fourth and fifth years in the field. Mean 5-year provenance height ranged from 1.9 to 5.9 m and averaged 4.3 m. So far, provenances from central Europe have performed better than those from either the northern or the southern part of the range. A contour plot technique confirms that for the best performance of A. glutinosa in southern Illinois, seed should come from the central part of the species range. Flowering began during the third year in the field and increased in both frequency and amount in the following years. Two-thirds of the provenances and 41 percent of the trees flowered after 5 years. The fastest growing provenances usually had the most flowering trees.

INTRODUCTION

European black alder (Alnus glutinosa (L.) Gaertn.) has been widely planted in eastern North America on strip mine spoils and other disturbed sites. However, due to its rapid juvenile growth and ability to fix atmospheric nitrogen, the species also shows promise for intensive culture (Hall et al. 1984) and for interplanting with black walnut (Phares et al. 1975) and other forest trees (Plass 1977).

Most of the black alder previously planted in this country is of unknown origin (Maynard and Hall 1981) and probably represents only a small fraction of the genetic variation in the species. To realize the full potential of black alder, we need to identify provenances suitable for different environments and for different silvicultural purposes. Although a few provenance tests of the species have been underway in this country since 1963 (Funk 1979, Kellison and White 1979), these early tests only sampled a limited number of provenances. To provide a better genetic evaluation of this potentially valuable species, Richard B. Hall of Iowa State University began in 1976 to assemble a large collection of A. glutinosa germplasm, which subsequently was used to establish provenance test plantations in Iowa, Wisconsin, Illinois, Pennsylvania, and New Brunswick. In this paper I report the early performance of 48 provenances in the southern Illinois plantation of this test.

MATERIALS AND METHODS

Seedlings of 48 provenances (table 1) representing most of the natural range of A. glutinosa (fig. 1) were grown in containers at Iowa State University, transported to Carbondale, Illinois, on March 11, 1980, and held in a lathhouse until time of planting.

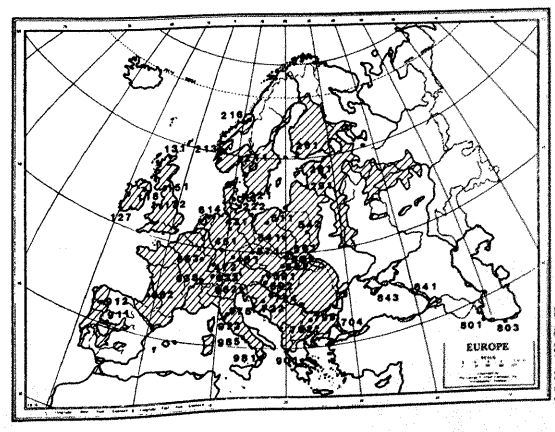


FIGURE 1.--Natural distribution of Alnus glutinosa and locations of provenances studied.

[1]A paper presented at the Fifth Central Hardwood Forest Conference held at the University of Illinois, Urbana-Champaign on April 15-17, 1985.

[2]Principal Plant Geneticist, USDA Forest Service, North Central Forest Experiment Station, Carbondale, IL.

TABLE 1.--Origin of 48 Alnus glutinosa provenances used in test.

Provenance no.	Geographic origin	Latitude °N	Longitude °E (or W)
118	Coote Hill, Ireland	54 05	7 05W
127	Bandon, Ireland	51 46	8 40W
131	Golspie, Scotland	58 15	4 28W
151	Innerleithen, Scotland	55 38	3 06W
172	Wrexham, N. Wales U.K.	52 57	3 02W
211	Oslo, Norway	59 40	10 47
213	Bergen, Norway	60 16	5 27
216	Steinkjer, Norway	64 12	12 14
221	Humlebaek, Denmark	56 00	12 30
222	Sakskobing, Denmark	54 45	11 30
261	Turku, Finland	60 25	22 15
281	Tartu, Estonian SSR	58 10	27 36
291	Riga, Latvian SSR	56 44	24 09
431	Uetze, N. Germany	52 25	10 12
451	Kinzig River, W. Germany	50 00	9 00
472	Offenburg, W. Germany	48 30	8 00
481	Ingolstadt, W. Germany	49 00	11 00
511	Naklo, Poland	53 08	17 24
541	Brzeziny, Poland	51 48	19 50
542	Bialowieza, Poland	52 30	23 50
561	Lezajsk, Poland	50 00	20 30
562	Brzesko, Poland	49 50	20 10
571	Kostelec, Czechoslovakia	50 01	14 51
582	Zvolen, Slovakia	48 35	19 18
591	Gyor, Hungary	47 40	17 00
592	Kormend, Hungary	46 55	16 40
614	Scherpenzeel, Netherlands	52 50	5 50
633	Zurich, Switzerland	47 16	8 20
638	Lausanne, Switzerland	46 32	6 46
653	Nancy, France	48 48	6 16
682	St. Julien en Born, France	44 04	1 16W
704	Kosti, Bulgaria	42 03	27 45
722	Novoselec, Yugoslavia	45 35	16 31
724	Durdevac, Yugoslavia	46 05	17 05
792	Sofia, Bulgaria	43 00	23 00
795	Klisura, Bulgaria	42 45	24 30
801	Hashtpar, Iran	37 30	49 00
803	Noor, Iran	36 35	52 01
841	Sochii, USSR	43 36	39 46
843	Yalti, USSR	44 40	34 20
901	Lamia, Greece	38 54	22 25
911	Zamora, Spain	41 11	6 08W
912	Pontevedra, Spain	41 52	7 30W
962	Pordenone, Italy	46 02	12 29
973	Pinaura di Lucca, Italy	43 49	10 24
975	Villa Basilica, Italy	43 58	10 29
981	Cosenza, Italy	39 10	16 21
985	Forli del Sannio Is, Italy	41 39	14 12

The planting site is located in Pope County about 8 km northwest of Rosiclare, Illinois, on the Shawnee National Forest (latitude 37° 27' N, longitude 88° 26' W). The site, a former agricultural field on Wheeling silt loam, was plowed and disked before planting on April 24-25, 1980. The seedlings were planted in a randomized block design with four blocks and eight trees per plot. Each plot consisted of two four-tree rows with 1.8 m between plants within rows and 3.0 m between the rows. The plantation was mechanically cultivated several times during the first two growing seasons and mowed annually in the following years.

Survival and tree height were recorded after each of the first through fifth growing seasons, dbh was measured after the fourth and fifth years, and number of stems per tree was recorded after the fourth year in the field. Flowering was scored in years 3, 4, and 5 as 0 = none, 1 = light, 2 = moderate, and 3 = heavy. Analysis of variance based on plot means was used to test for differences among provenances in metric traits, survival, and flowering. Percentage values were subjected to arcsin transformation before the analysis, and number of stems per tree was analyzed as $\sqrt{1 + \text{no. of stems}}$. I used stepwise multiple regressions of tree heights against latitude and longitude of seed origins to test how closely height was related to these provenance variables. Seed origin elevations could not be used in the regressions due to incomplete data. Because previous work has shown that polynomial regression models often give a better fit than linear models (Clausen 1984), regression models employing the variables latitude, latitude^2, latitude^3, longitude, longitude^2, longitude^3, and latitude x longitude were also tested and used to construct contour plots.

RESULTS AND DISCUSSION

Survival

Initial establishment of the seedlings was hampered by a severe, prolonged drought during the first growing season. As a result, first-year survival averaged only 54 percent. Precipitation and soil moisture deficiencies throughout the following fall and winter led to additional mortality and a 2-year survival of 48 percent. After the trees had leafed out in the spring of 1983, floodwaters from the nearby Ohio River covered the plantation to a height of 1.5-1.8 m for about 4 weeks and an additional 3 percent of the smallest trees died. At the end of the fifth growing season in the field, provenance survival ranged from 3 to 75 percent and averaged 44 percent (table 2).

Provenance differences in survival were already significant after the first growing season and remained significant in each of the following years. In fact, the provenances changed little in individual rankings after the first year and, except for the minor effects of the flooding, the survival differences probably reflect differential responses to the initial drought stress at the time of planting. DeWald et al. (1983) also reported heavy mortality due to drought in a plantation established in Pennsylvania in 1980 with seedlings of 28 of these provenances. In general, the best survivors in southern Illinois are provenances from Holland, northern Italy, Bulgaria, and several locations in central Europe; provenances from Norway, Finland, the Baltic States, and Poland have survived poorly (table 2).

Growth

Tree height for years 1 through 5 averaged 0.33, 1.19, 2.07, 2.91, and 4.28 m, respectively, and differed significantly (0.001 level) among the 48 provenances in each year. Once the trees were established, annual height growth in this plantation averaged between 0.85 and 0.88 m in years 2-4 and 1.36 m in year 5. For comparison, mean height growth of the five best provenances in years 2-5 was 1.04, 1.27, 1.10, and 1.70 m. Annual height growth of black alder varies according to weather conditions during the growing seasons. Thus, the relatively poor height growth in the fourth year reflects the fact that the summer of 1983 was hot and dry. In contrast, abundant moisture was available during most of the 1984 growing season when many trees grew more than 2 m in height. Similar yearly fluctuations have been reported for companion plantations in Iowa and Wisconsin (Hall et al. 1984).

Five-year height ranged from 1.9 m for Spanish provenance 911 to 5.9 m for provenance 472 from southwestern Germany (table 2). Height of individual trees differed widely and exceeded 7 m in several trees. Except for the Dutch provenance (614), the 10 fastest growing provenances all came from the central part of the species range, an area extending from southwestern France to Crimea and from northern Italy and Yugoslavia to central Germany (fig. 1). In contrast, the slowest growing trees came from either northern Europe (Scotland, Norway, and Finland) or from the southern extremes of the range (Spain, southern Italy, and Iran). Differences between the best and the poorest provenances increased from 75 percent of the plantation mean in year 2 to 93 percent in year 5; that year provenance 472 was 138 percent of the mean height but provenance 911 was only 45 percent of the mean.

Four-year stem diameter (dbh) ranged from 5.8 to 32.3 mm and averaged 21.3 mm; 5-year dbh ranged from 12.0 to 54.1 and averaged 36.0 mm (table 2). Provenance differences were significant (0.001 level) in both years. Because dbh was highly correlated (r = 0.969) with height, the dbh of trees in provenance 472 was 50 percent greater than the plantation mean, and the dbh of trees in Norwegian provenance 216 was only one-third as large as average.

Number of Stems

Although the provenances only varied between an average of 1 and 2.7 stems per tree after 4 years in the field, these differences were statistically significant. Number of stems does not appear to be correlated with growth of the trees but apparently is related to seed origins. Provenances that averaged 2 or more stems per tree were all from the southern part of the species range--Spain, Italy, Greece, and Iran--those with single-stemmed trees all came from northern Europe. The fastest-growing provenances, on the other hand, averaged 1.3 stems per tree. Individual trees had between 1 and 8 stems. Multiple stems were not very common, however; trees with 1 and 2 stems accounted for, respectively, 57 and 32 percent of the trees in the plantation. Because black alder sprouts readily, multiple stems frequently developed from sprouts after dieback due to climatic stress or injury. Thus, the tendency to develop multiple

TABLE 2.--Performance of 48 *Alnus glutinosa* provenances after 5 years in a southern Illinois plantation.

Provenance No.	Provenance Origin	Survival (%)	Height (m)	DBH (mm)	Flowering trees (%)
118	IRE	41	5.00	44.6	92
127	IRE	25	4.41	34.8	100
131	SCO	38	2.45	17.6	0
151	SCO	34	4.06	27.1	9
172	WAL	53	4.63	40.6	41
211	NOR	17	2.52	12.7	0
213	NOR	47	2.54	18.8	7
216	NOR	3	2.00	12.0	0
221	DEN	41	4.13	31.1	85
222	DEN	22	3.82	28.4	29
261	FIN	21	2.58	15.5	0
281	EST	22	4.46	36.0	14
291	LAT	16	4.24	34.1	0
431	GER	44	4.82	38.9	71
451	GER	53	5.20	45.0	35
472	GER	50	5.91	54.1	44
481	GER	50	5.01	44.5	83
511	POL	25	4.87	42.4	88
541	POL	12	3.62	31.2	0
542	POL	28	4.06	35.8	0
561	POL	34	4.64	41.5	27
562	POL	32	4.53	40.8	36
571	CZE	66	5.12	44.9	67
582	CZE	58	4.24	42.8	44
591	HUN	41	5.04	39.2	100
592	HUN	59	5.06	39.1	90
614	NET	75	5.64	48.6	97
633	SWI	53	4.64	40.9	59
638	SWI	44	3.90	35.4	21
653	FRA	38	4.28	33.7	25
682	FRA	66	5.35	46.8	57
704	BUL	66	4.16	34.8	10
722	YUG	52	5.37	51.3	38
724	YUG	42	4.95	47.0	10
792	BUL	45	4.17	39.4	22
795	BUL	72	4.96	46.0	9
801	IRA	50	2.87	21.9	0
803	IRA	31	2.41	13.6	0
841	USS	59	4.12	39.6	5
843	USS	54	5.33	48.4	62
901	GRE	53	4.27	37.4	18
911	SPA	31	1.93	12.3	0
912	SPA	38	2.91	20.5	0
962	ITA	75	5.36	48.6	100
973	ITA	50	4.05	32.9	62
975	ITA	66	3.89	31.5	43
981	ITA	53	3.27	26.3	0
985	ITA	56	3.76	28.8	11
Mean		44.2	4.28	36.0	40.6

stems may actually represent lack of hardiness or resistance to insects or disease attack instead of an undesirable genetic stem trait.

Flowering

Early flowering is desirable in a breeding program but may lead to growth reduction in black alder (Verweij 1977). Therefore, we have monitored onset and abundance of flowering in the southern Illinois plantation. Flowers in black alder are preformed and both male and female catkins are visible the fall before flowering takes place. At the end of the third growing season 3.7 percent of the trees had flowers (table 3). In the seven provenances that had flowering trees, between 6 and 50 percent of the trees flowered and flowering was light or moderate in most trees (table 3). After the fourth year, 20.4 percent of the trees flowered and 24 provenances had from 4 to 85 percent flowering trees. By this time flowering was light in 29 percent, moderate in 29 percent, and heavy in 42 percent of the trees with flowers (table 3). Two-thirds of the provenances had flowers at the end of the fifth growing season when 40.6 percent of the trees flowered. Within the 36 flowering provenances, the percentage of flowering trees varied significantly from 5 to 100 (table 2). The amount of flowers was light in 42 percent, moderate in 27 percent, and heavy in 31 percent of the flowering trees.

TABLE 3.--Incidence and abundance of flowering in plantation after 3, 4, and 5 years in the field.

Year	Flowering class				All flowering
	None	Light	Moderate	Heavy	
	- - - - - - - Percent of trees - - - - - - -				
1982	96.3	1.5	1.5	0.7	3.7
1983	79.6	6.0	5.8	8.6	20.4
1984	59.4	16.9	11.0	12.7	40.6

The onset of flowering seemed little related to geographic origin of the trees. The provenances that flowered after 3 years in the field came from Denmark, Wales, Germany, Hungary, and Italy; these provenances flowered again in each of the following years. The Hungarian provenances (591 and 592) also were the first to flower in the Iowa plantation (Hall et al. 1984). By the fourth year the origin of flowering trees extended from Norway to Italy and from Ireland to the Black Sea (provenance 841). Once flowering began in a provenance, the number of flowering trees usually increased in the following years.

In general, most flowering trees were larger than non-flowering trees in all 3 years. For example, in 12 provenances that had about equal proportions of the two types, the average 5-year height of 5.21 m for 106 flowering trees was significantly greater than the mean of 4.48 m recorded for 111 non-flowering trees. On the other hand, the two groups had about the same fifth-year height growth, 1.51 m and 1.55, respectively. Hall et al. (1984) reported a similar relationship for 4-year-old trees in the Iowa plantation. Apparently, black alder saplings must reach a certain size before flowering begins, as is also true for yellow birch (Betula alleghaniensis (Britt.) (Clausen 1979). But so far, the presence of flowers does not appear to have affected tree height negatively. Although the annual height increments varied from year to year, these fluctuations seem to be responses to climatic conditions in the respective growing seasons.

Regression Analyses

The linear regressions of 5-year height against provenance latitude, longitude, or both were not significant, indicating that tree height is not directly related to seed origin. However, the stepwise multiple regressions showed that a polynomial model employing the variables latitude, longitude, and latitude^2 accounted for 43 percent of the variation in height. Adding longitude^2 to the model improved the fit slightly and the further addition of latitude x longitude gave the best fit (r^2 = 0.447). On the other hand, including latitude^3, longitude^3, or both in the regression did not improve the fit. The 5-year height data were, therefore, fitted into the following regression model:

$$z = a + bX + cX^2 + dY + eY^2 + fXY$$

where z = the predicted performance
X = latitude of seed origin
Y = longitude of seed origin
a = intercept of the model
b = linear effect of seed origin latitude
c = quadratic effect of seed origin latitude
d = linear effect of seed origin longitude
e = quadratic effect of seed origin longitude, and
f = combined effect of seed origin latitude and longitude

Using this equation, I generated a contour plot that shows variation in tree height as a function of latitude and longitude (fig. 2). The contour plot shows that the optimum range for height growth is expected from provenances originating between 44.0 and 54.0 degrees of latitude and between longitudes 3.2 degrees West and 45.5 degrees East. The steeper latitudinal slope indicates that origin latitude is more important than longitude for height growth. The contour plot also predicts that the tallest trees should come from the central part of the range. As shown, nine of the 10 tallest provenances did originate within the optimum area and provenance 682 from southwestern France performed much better than predicted (fig. 2). For comparison, among the slowest-growing provenances four northern provenances all performed below expectations (another one had only one surviving tree), four southern provenances performed as predicted, and one (911 from Spain) performed much below the prediction.

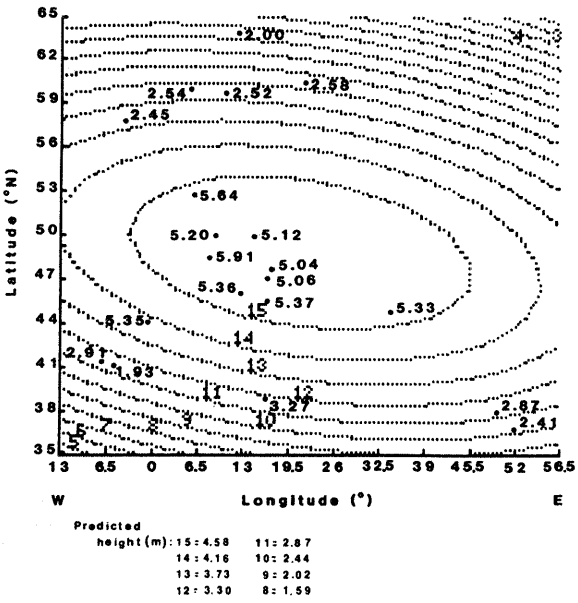


FIGURE 2.--Contour plot predicting 5-year height of European black alder provenances in a southern Illinois plantation. Large numbers identify individual contours. Observed 5-year mean heights (m) are shown for 10 tallest and 10 shortest plantations. (Height = -37.595 + 1.691 lat + 0.017 lat^2 + 0.129 long - 7.768 $long^2$ - 0.002 lat x long)

CONCLUSION

As could be expected, these provenances performed somewhat differently in southern Illinois than in other test locations. Thus, Hall et al. (1984) reported that provenances from Poland and the Baltic States had the best growth in the northern Wisconsin planting, but central European sources were best in the Iowa planting. The results of our study show that provenances from central Europe also grew well in southern Illinois, but the top performers were not necessarily the same in both locations. For example, only five provenances ranked among the 10 tallest in both plantations. Of these, the Dutch provenance (614) grew well in both Iowa and Illinois; German source 472 and Italian source 962 were better choices in Illinois than the Hungarian sources (591 and 592), which were better in Iowa.

Thus, the use of central European provenances seems to offer the best opportunity of introducing fast-growing black alders to southern Illinois and probably other areas of the Central States. However, these provenances may not be as well suited for interplanting with black walnut or similar species that, due to their slow juvenile growth, may be overtopped by the fast-growing alders. Instead, growers might want to select some of the provenances that had slower growth rates in this test. This means choosing provenances originating outside the region of optimum growth identified in the contour plot. Examples are Bulgarian provenances 704 and 792, which had average or better growth and average or better survival. Provenances from south of the optimum region appear preferable to those north of the region due to their better survival. Provenances with even slower growth can also be selected if desired.

Although central European provenances have had the best growth so far in southern Illinois, the trees are still young and rankings may change with time as Funk (1979) reported in his earlier provenance test. Furthermore, if the heavy flowering and fruiting of the fast-growing provenances continue, their growth rate may also be reduced in coming years as Verweij (1977) reported happening in Dutch trials between ages 7 and 10. Therefore, it seems prudent to postpone final recommendations for choice of provenances until the trees are older and further provenance differentiation has taken place.

LITERATURE CITED

CLAUSEN, K. E. 1979. The relation between tree size and flowering in yellow birch saplings. p. 77-82. IN IUFRO Symp.: Flowering and seed development in trees, Starkville, MS.

CLAUSEN, K. E. 1984. Nonlinear regressions and contour plots: techniques for selection and transfer of white ash provenances. For. Sci. 30:441-453.

DeWALD, L. E., R. C. STEINER, and K. K. CARTER. 1983. Juvenile performance in three alder provenance plantations in the Northeast. p. 37-49. IN Proc. 28th Northeast. For. Tree Improv. Conf., Durham, NH.

FUNK, D. T. 1979. Alnus glutinosa provenance trials on Ohio strip mines: sixteen-year results. p. 28-32. IN Proc. First Northcent. Tree Improv. Conf., Madison, WI.

HALL, R. B., G. A. MILLER, J. L. ROBISON, and O. U. ONOKPISE. 1984. Developing Alnus for use in intensive culture. p. 35-45. IN USDA For. Serv. Tech. Rep. NC-91.

KELLISON, R. C. and G. WHITE. 1979. Black alder performance in the southwest. p. 345-355. IN Proc. Symbiotic nitrogen fixation in the management of temperate forests. Workshop, Corvallis, OR.

MAYNARD, C. A. and R. D. HALL. 1981. Early results of a range-wide provenance trial of Alnus glutinosa (L.) Gaertn. p. 184-201. IN Proc. 27th Northeast. For. Tree Improv. Conf., Burlington, VT.

PHARES, R. E., R. C. SCHLESINGER, and G. A. COOPER. 1975. Growth, yield, and utilization of European black alder interplanted with black walnut. p. 102-111. IN Proc. Third Ann. Hardwood Symp. of the Hardwood Res. Council, Statesville, NC.

PLASS, W. T. 1977. Growth and survival of hardwoods and pine interplanted with European alder. USDA For. Serv. Res. Pap. NE-376, 10 p.

VERWEIJ, J. A. 1977. [Research on provenances and progenies of alder (Alnus glutinosa, Alnus incana, and Alnus cordata)]. Rijksinstituut voor onderzoek in de bos-en landschapsbouw "De Dorschkamp", Wageningen. Uitvoerig verslag 15(1):1-23.