DESIGN, ESTABLISHMENT, AND MANAGEMENT OF A BLACK ALDER (ALNUS GLUTINOSA L. GAERTN.) SEED ORCHARD

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Abstract.--Improved selections are being developed for use in the intensive culture of biomass for energy, nitrogen-fixing nurse crop plantings, and for soil reclamation plantings. As a complement to this selection work, we have been studying seed-orchard alternatives for the species by establishing and managing an experimental orchard. Five-year-old selected trees were moved by tree spade to establish the orchard. It has been expanded through the use of rooted cuttings. Our initial design of this orchard takes into account the existence of a self-incompatibility system in Alnus and tries to balance current uncertainties as to whether inter- or intra-provenance crosses should be favored. This design will be modified in place as our knowledge improves. Seed collections made from seven typical seed orchard trees in the fall of 1985 and 1986 gave a total seed yield of 3.6-7.4 million seeds (5630-11,693 g) with germination rates of 23-74%. Because of delayed fertilization in alder, it is likely to be important to be able to irrigate an orchard during early summer droughts to protect seed viability. Pollen dispersion from our plantings indicate that an isolation strip 710 m wide is needed to exclude 91% of the pollen from nonselected trees. Early fall is the best time for seed collection. A systemic insecticide has been used to control a defoliating insect in the orchard. We have begun studies to determine the feasibility of periodic coppicing of the seed orchard trees to facilitate seed collection and maintain smaller trees.

Additional keywords: Breeding, flowering, coppice growth.

Currently, most European alder planting stock is produced for use in mine-spoil reclamation. In 1985, 484,000 A. glutinosa seedlings were shipped from state nurseries in the northeastern United States, ranking alder as eighth in hardwood popularity behind such species as walnut, red oak, yellow poplar, and the ashes (Scholtes 1985).

Several projects conducted under the U.S. Department of Energy's Short Rotation Woody Crops Program (SRWCP) have identified Alnus as a promising genus for the intensive culture of biomass because of its rapid growth and

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symbiotic nitrogen-fixation capabilities (Ranney et al. 1985). Black alder is being considered for biomass energy production in the Midwest, Lake States, and South/Southeastern Regions where it is classified in the SRWCP's "group 2" of species, with maximum measured yields of 4 to 10 Mg/ha/yr of dry-weight biomass. In addition, alders can fix 150+ kg/ha/yr of nitrogen and this has created interest in finding selections compatible for use in mixture with Populus or other SRWC species. Black alder is also better than most species in its ability to coppice. The genus Alnus is very diverse with considerable alternatives and potential for improvement (Hall and Maynard 1979, Hall et al. 1983). However, no improved alders are currently available. The State of Kentucky did attempt to establish an alder seed orchard, but it failed because no selection for Phomopsis resistance had been practiced (Oak and Dorset 1983).

We began genetic improvement work with Alnus in 1976. We organized a range-wide collection of germplasm for Alnus glutinosa and have grown selected populations of a few other Alnus species. In 1979 and 1980, we established provenance tests of these materials in northern Wisconsin, central Iowa, and southern Illinois, and through cooperators, we provided material for 25 additional provenance tests in many of the eastern United States, Oregon and Washington, and Canada (Robinson and Hall 1981). We have published several articles summarizing our test results and developing a strategy for genetic improvement in the genus (Hall and Maynard 1979, Maynard and Hall 1980, Robison and Hall 1981, Hall et al. 1983, Hall and Miller 1983). We have begun the selection and breeding work with these populations. In this paper, we report our observations on seed orchard design, establishment, and management.

METHODS

Four separate plantings of black alder were used. Observations on age-to-flowering and early seed production for seedlings and coppice growth were made in a range-wide provenance test planted in 1979 and described elsewhere (Hall et al. 1983). Seventeen selected 5-year-old trees from this provenance test were lifted with a large Vermeer tree spade and were replanted as a seed orchard at a 5x5 m spacing in July 1984. This seed orchard was established at a distance of 635 m (2080 ft) from our other alder plantings at the University's Rhodes Farm in central Iowa. In the spring of 1986, the seed orchard was enlarged to a total size of 46 trees by using rooted cuttings of our selections. The additions were put in using the permutated neighborhood design to promote panmixia (Faulkner 1975). In 1981, we also established a small clonal plantation at our Rhodes Farm by using 10 replications each of 26 clones planted as single tree (rooted cuttings) plots on a 1.5x1.5 m spacing (Hall et al. 1983). All these Rhodes Farm plantings are on a gently undulating bottomland area with predominantly a Colo silty clay loam soil type.

Because our experimental seed orchard had not yet come into full production, we used a set of black alder trees at the Iowa State Nursery in Ames to estimate potential seed-orchard production and thereby calculate the acreage of seed orchards needed to support future planting needs. The trees the state nursery were transplanted in 1976 and coppiced in 1978 or 1980 in a fashion and at a spacing very similar to the way our seed orchard has been treated. The trees recovered from the transplant shock, coppiced well, are flowering heavily, and were at a size we consider optimum for seed collection (ca. 8 m tall). The total seed crop from each of seven trees was harvested in the fall of 1985 and again in 1986.

To determine maturation rates in black alder strobili, we made weekly collections from different trees in each of three clones in our clonal plantation. In 1985, these collections were made from Sept. 4 to Oct. 9. In 1986, a longer period, from July 31 to Oct. 15, was sampled. Harvested strobili were air-dried for one week in a greenhouse bay, and seed were extracted by hand-dissection or by shaking opened strobili in a paper bag. Germination tests were run on four replications of 100 seeds all seedlots at the Iowa State Seed Testing Lab using a 30 C day and 20 C night schedule in lighted, high-humidity (>90%) chambers. To study pollen dispersal, three transects of pollen traps were established at our provenance, clonal, and seed orchard sites in March 1987. The pollen trap method of Hoektra (1965) was used, and 10 systematically located fields of view, 0.049 mm each in area, were studied under 400X magnification to determine an average pollen count.

RESULTS AND DISCUSSION

Design

Our recent experience confirms our earlier suggestion (Robison and Hall 1981) that either seedling or clonal seed orchards can be used for black alder. In our provenance test, most of the best phenotypes began flowering in their third growing season. We collected an estimated 390,000 seeds from 83 trees at the end of their fourth growing season. When trees are coppiced, they return to seed production at the end of their second or third growing season, and, as shown later, they are capable of producing commercial quantities of seed by at least 6 years of age. Likewise, trees propagated by rooting cuttings begin flowering in their third year in the field, and from that time on, they flower at least as abundantly as seed-origin trees do. We also have done grafting of flowering scions to greenhouse stock plants since 1983 with varying success. Most of these plants have been kept under greenhouse conditions for only 1 year. Approximately 75 grafted trees have been carried through winter conditions in shade frames or transplanted to the field. Graft survival has been poor; of those surviving, less than 10% have flowered in their second year and maintenance of scion/understock identity is a continual problem. Therefore, it seems that the use of rooted cuttings is the better approach to cloning this species for seed orchard purposes.

The best advantages of both seedling and clonal seed orchards can be combined into one operation. Seedlings can be grown in provenance or progeny tests to their proper age for evaluation. Selected trees can then be lifted and moved by tree spade to a seed orchard. Thus, a well-designed, properly spaced, but small, seedling seed orchard can be created. When we did this with our provenance test selections, the trees did produce seed the year that they were moved and the year following. This offers the opportunity to begin producing controlled- or open-pollinated seed right away for establishing advanced generations and progeny tests of the orchard's potential. At the same time, the selected trees can be propagated by cuttings. When those ramets are ready to go to the field, they can be used to expand the operation into a clonal seed orchard that should produce sufficient quantities of seed for commercial use within 3 to 6 years.

Alders are self-incompatible, evidently with an S-allele system (Hagman 1975), so selfing is not a concern in the design of seed orchards. However, the level of incompatability between relatives is not well known and our breeding studies have not progressed to the stage at which we know whether to emphasize crossing between geographic populations or to select and breed within them. In our experimental seed orchard, we initially established small groupings of trees selected from each provenance. When the orchard was expanded with rooted ramets, we emphasized crossing between individuals of different provenances. When progeny test results are available to indicate the preferred crossing pattern, we can reorganize our existing orchard by moving trees with a tree spade or by starting new rooted cuttings.

Seed production in young alder trees can be very abundant (table 1). The seven trees sampled produced almost 1.5 million viable seeds in 1985 and more than 3.4 million in 1986. Amounts of seed produced and germination rates of the seed do vary by individual tree and by year. However, all trees in this study, and others that we have observed, produce sufficient seed that fecundity need not be a consideration in choosing trees for seed orchards. We anticipate harvesting the seed from stems that are 5 to 10 years of age. Hence, the seed collections reported in table 1 for trees at ages 6 to 9 should be fairly typical. With orchard trees spaced at 5x5 m (16.4 ft) and an average annual production of 1.2+ kg (2.7 lb) of seeds/tree, we should be able to produce 496 kg/ha (432 lb/A) of seed.

Table 1.--Measurements of potential seed orchard production based on trees at the Iowa State Tree Nursery.

Tree No.	1985 Stem Age	1985 Ht. (m)	1985 DBH (cm)	Strobili Produced 1985 Bushels	Strobili Produced Air Dry Weight (g) 1985	Strobili Produced Air Dry Weight (g) 1986	Seed Produced Fresh Weight (g) 1985	Seed Produced Fresh Weight (g) 1986	Seed Produced Germination Percent 1985	Seed Produced Germination Percent 1986
5	6	5.8	10.3	2.00	6651	6061	1963	2475	23.5	23.0
9	6	4.4	4.0	0.21	631	1026	53	486	33.8	23.7
24	8	9.1	13.7	1.82	6886	9437	1373	3117	58.5	62.0
39	6	5.0	6.9	0.29	851	1840	25	736	57.8	59.7
42	6	6.2	7.3	1.00	3036	2748	546	1388	59.5	73.7
46	6	6.6	8.0	0.52	2067	1361	466	420	53.3	50.7
53	6	7.4	11.0	1.33	4788	7035	1204	3071	49.3	55.7
					Total Seed Yield		5630g	11693g		

The future demand for improved black alder seed is hard to predict because it depends on the rise in interest in establishing energy plantations and/or other uses of fast-growing hardwoods. We asked the nurserymen of nine midwestern state forestry organizations to project seedling demand as they saw it developing in their states. Production estimates ranged from 0 to 90,000 seedlings/year. If we compare black alder to species with similar uses that are already established in the commercial trade, 70,000 seedlings/year seems to be an appropriate level of production (Scholtes 1985). Schoepmeyer (1974) estimated that 10,000 nursery seedlings could be produced per pound of seed. Hence, an entire state's planting needs could be supplied by 3 seed orchard trees. More likely, several adjacent states with similar planting environments could share a small orchard, and the minimal number of trees needed to provide genetic diversity would be more than enough trees to supply the need for seed.

Establishment

The best time of year to move selected trees with a tree spade is in late fall. Black alder flowers are receptive in late February to early March (in central Iowa), so trees must be moved in the fall to assure that the first season's seed production is based on the pollen of the orchard trees. Spring is also a period of very poor trafficability on the bottomland soils where alder plantations are typically located. We tried to move our trees in the spring of 1984, but excessively wet conditions prevented the work until July of that year. Then, the trees had only a brief period of good establishment conditions before an August drought caused substantial top dieback and mortality in five of our selections and led to an invasion of wood-boring insects. In 1986, a series of windstorms broke the tops out of all the large stems in the orchard, leaving only coppice growth. All selections should be cloned by the rooting of cuttings before they are moved as insurance against transplant shock mortality.

Rooted cuttings of black alder can be produced by taking the most actively growing new branch growth available on the selections made in the field. The field cuttings are taken early in the morning or during rainy weather when internal moisture stresses are least. The cuttings are transported on ice back to a greenhouse where single internode cuttings are taken from the semilignified portion of the current season's growth The very succulent branch tips are not used. The cuttings are given a 5-sec basal dip in 5,000 ppm IBA and are stuck in a rooting media (equal parts peat, vermiculite, and pearlite) under intermittent mist. After about 3 weeks of rooting time, the cuttings are transferred to pots or other containers to be grown to at least 45 cm in height before they are planted in the field. Rooting of cuttings from the field usually succeeds at no better than a 50% rate, so that must be taken into consideration during scion collection.

A seed orchard spacing of 5x5 m with the trees staggered between rows works well for the size of tree we want to use. Typically, a 500-ft isolation zone is left around seed orchards to minimize contamination from nonselected pollen sources (Wright 1976). However, that design feature is based on pollen dispersal studies with conifers; effective pollen dispersion distances of hardwoods are not well documented. Wright (1976) did report that, for American elm, an isolation distance of 2200 ft would be necessary to exclude 91% of the contaminating pollen. We left 635 m (2080 ft) of isolation zone in establishing our black alder seed orchard. When we quantified pollen dispersion in the spring of 1987 (figure 1), contamination was much greater than we expected. One standard deviation for the dispersal curve extends out to 710 m (2329 ft). Pollen contamination at the seed orchard site was approximately 26% of the source frequency. The terrain in the vicinity of our Rhodes Farm alder plantings consists of a north-south valley surrounded by steep, wooded hillsides that may funnel more pollen from our provenance and clonal tests to our seed orchard than normally would be the case. However, to be safe, the isolation zones for black alder seed orchards should be larger than we had previously recommended. Because tree alders are exotics in most of eastern North America, it should be less of a problem to find a suitably isolated orchard site than is the case for most other important tree species.

Management

The harvesting of black alder strobili has typically been scheduled for late fall (Schoepmeyer 1974) after the scales begin to reflex. We initiated a study of seed maturity dates as an aid to our breeding program. Seed viability reaches its maximum as early as the third week in August (figure 2), when the strobili are still very green. Pizelle (1984) reported a similar finding with black alder grown in France. However, seed extraction is greatly facilitated if strobili have just begun to turn brown (about the third week in September). It definitely is not necessary to wait for the strobili scales to begin opening before the crop is harvested. Brown strobili will open and release their seed easily after a few days of air-drying.

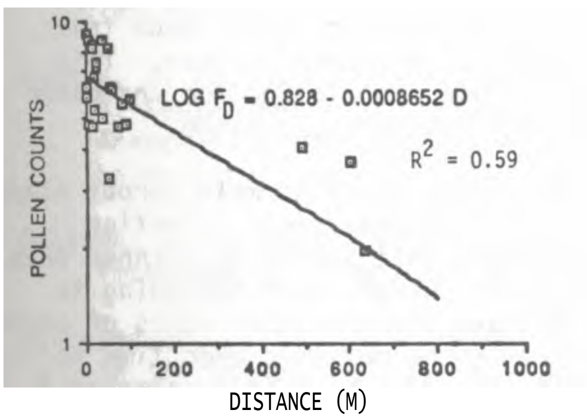

Figure 1. Pollen counts at various distances from black alder stands at the Rhodes Farm. Note that the ordinate axis is logrithmic.
F = pollen frequency at distance = D.

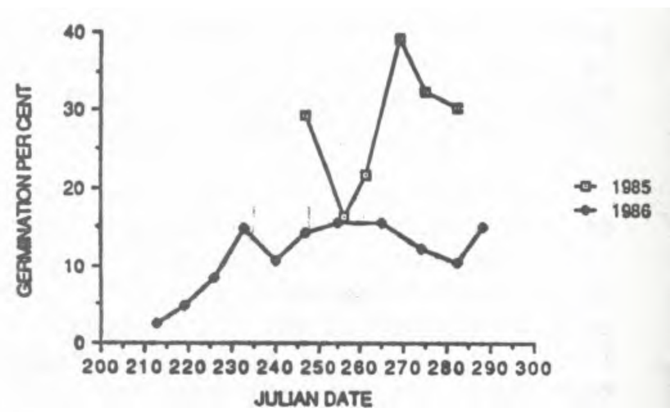

Figure 2. Average germination percent of seeds of three black alder clones from strobili harvested in 1985 and 1986 at the Rhodes Farm.

Although we have not yet run controlled experiments, it does seem that it will be very beneficial to have a means to irrigate the orchard trees during periods of moisture stress. The faster trees can be grown vegetatively, the sooner they reach a flowering condition and the more seed they produce. There does not seem to be a flower-inducing effect of moisture stress as there is in some other tree species. However, the most important concern is likely to be the impact on seed quality. Black alder has delayed fertilization; pollination takes place in early spring. After an initial period of pollen tube growth, there is a hiatus while female meiosis occurs, and then fertilization is completed at the beginning of the summer (McVean 1955). We have observed that our black alder trees have produced strobili and seed every year once they begin flowering, but filled seed percentage can be very low (including 0%) in years when we have a dry May/June period. The availability of irrigation water at that time may be critical to the success of a seed orchard.

No serious strobili or seed pests have been encountered yet. We have had serious infestations of the European alder leafminer, Fenusa dohrnii (Tischbein), in all our plantings. We are in the middle of a multiple-year study of the growth impact of this defoliating insect, but it seems that a range of 15 to 40% dry-weight reduction is occurring, depending on other growing conditions. We have started a program to select and breed for resistance, but in the meantime, we have determined that the application of DiSyston 15 G systemic insecticide will control the problem. We are now annually applying 40 g around the base of each seed orchard tree and covering it with mulch. In a mature seed orchard, we would need 300-600 g of DiSyston per tree. It is likely that this systemic treatment will also help control insects that might attack the strobili.

The early and abundant production of seed, combined with the strong coppicing ability of black alder affords the opportunity for unusual approaches to seed-orchard management. We suggest that orchards be twice as large as necessary to meet seed demands. Then, half of an orchard can be cut every 5 years, any clones that had fallen into disfavor could be replaced, and the stand allowed to regrow for 10 years. After the first or second year, the sprout clumps can be thinned back to one or a few main stems for each tree. By 5 years of coppice age, seed production should be abundant again. This rejuvenated portion of the orchard can then assume the mission for the other half of the orchard where the trees are getting unmanageably large.

Alternatively, it may be possible to carry six to eight main sprout stems on each orchard stump and harvest one each year for easy seed collection. That stem would then give rise to coppice sprouts that should be thinned back to the best replacement stem after 1 or 2 years. We are just beginning to test this alternative. In conclusion, we believe the characteristics of alder allow for the use of small seed orchards that can be modified over time to keep producing the best seed available based on research as it is completed.

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