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Importance of Cutting Diameter and Method of Production on Early Growth of Hybrid Poplar

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Rapid early growth of hybrid poplars— Populus spp.– established from hardwood cuttings is critical to the success of plantations. Without rapid growth, weed competition and drought can significantly affect tree survival and productivity. Producing vigorous cuttings, quickly developing roots, and initiating shoot growth are therefore important. Hardwood cutting diameter was not an indicator of tree vigor for 8 of 15 hybrid poplar clones tested and only a weak indicator for 7 clones. The angle at Vehicle cuttings are excised from stems significantly influenced early growth of 1 poplar clone. The assumption that cutting diameter is an important index of subsequent growth is challenged, and the lack of criteria for excising cuttings is addressed. Tree Planters' Notes 47(2):76-80; 1996.

Vegetative propagation from dormant-season hardwood cuttings is an efficient and increasingly used practice for a number of deciduous tree species. The initial success of plantation establishment using cuttings depends upon site quality, the intensity of competing vegetation, and weather. The physiological rooting capability of various hybrid poplar-Populus spp.— clones, the vigor and health of the parent tree, cutting storage environment, care of handling, and treatment during processing and planting are also important to tree establishment and early growth (Hansen and Phipps 1983; Hansen and others 1983; Morin and Demeritt 1984; Stuhlinger and Toliver 1985).

Cutting diameter is often used as an index of potential cutting vigor. Larger diameters are generally considered to be positively correlated with the success of plant establishment and early growth, and nursery practices generally exclude cuttings smaller than 0.6 cm diameter (Dickmann and others 1980; Hansen and others 1983; Morin and Demeritt 1984). In the current study, we report 2 experiments testing the hypothesis that cutting diameter influences tree establishment and growth.

In a third experiment, we assess the impact of the method of cutting production on tree growth. The manner in which cuttings are physically excised from harvested "whips" (stems growing off the poplar stools) can be variable. Root development and productivity may be affected by the angle at excised relative to the stem. The "angle of excision" has not previously been studied, and there are no standard recommendations for nursery practice. Lesser angles increase the bottom surface area and circumference of exposed cambial tissue from which roots might emerge. By better defining the characteristics of vigorous cuttings, more productive cuttings can be produced and wasteful practices curtailed.

Materials and Methods

Relationship of cutting diameter to survival and growth in the field. The soil on the site (University of Wisconsin—Madison's Arlington Experiment Station in Columbia County) was a Plano silt loam, 0 to 2% slope (fine-silty; mixed, mesic Typic Argiudolls). All site preparation was conducted during early fall 1987. The existing alfalfa, *Medicago sativa,* was killed with 1.1 kg (active ingredient)/ha 2,4-D (dimethylamine salt of 2,4dichlorophenoxy acetic acid) and 0.6 kg ai/ha Banvel™ (diethylamine salt of 3,6-dichloro-o-anisic acid), followed by tillage and site treatment with 3.6 kg ai/ha simazine (2-chloro-4,6-bis(ethylamino)-s-triazine) to prevent weed reestablishment.

Dormant hardwood cuttings (25 cm long) with viable buds, cut perpendicular to the original stem, were made from 15 hybrid poplar clones during the winter of 1987-88 (table 1). Cuttings were kept frozen and sealed in plastic bags until planting (about 6 months). Frozen cuttings were soaked in water for 12 hours immediately before planting in saturated soil on 23-24 April 1988. Cuttings were planted so that their tops were flush with the soil surface at 1.22 x 1.22-m spacing. Cuttings were carefully inserted into dibble holes to prevent the surface soil containing the herbicide simazine from falling into the rooting zone. Trees were established in 4 tree blocks, in a randomized block design, from which 6 of 12 replicates were used in this study. Long-term results from this plantation are described in Robison and Raffa (1997).

Because of the dry conditions during the summer of 1988 (Trenberth and others 1988), supplementary spot irrigation was applied as 4 to 8 liters of water/tree 8 times between 2 June and 7 July 1988 (40 to 75 days after planting), respectively (Robison and Raffa 1997).

Table 1— *Hybrid poplar clonal designations and parentages*

Designation(s)*	Parentage	Taxonomic sections†
NC5339, Crandon	*alba* × *grandidentata*	100% L
NC5271, NE19	*nigra* 'Charkowiensis' × *nigra* 'Caudina'	100% A
NC5377, Wisconsin #5	*deltoides* × *nigra*	100% A
NC11004, Siouxland	*deltoides*	100% A
NC5260, Tristis #1	*tristis* × *balsamifera*	100% T
NC11505, NE388, NE88	*maximowiczii* × *trichocarpa*	100% T
NC5262, NE387	*balsamifera* 'subcordata–Candicans' × *berolinensis*‡	75% T × A
NC11396, NE49	*maximowiczii* × *berolinensis*‡	75% T × A
NE332	*simonii* × *berolinensis*‡	75% T × A
NC5331, NE299	*nigra* 'Betulifolia' × *trichocarpa*	50% T × A
NC11432, NE252	*deltoides* 'Angulata' × *trichocarpa*	50% T × A
NC11445, NE280, NE157	*nigra* × *laurifolia*	50% T × A
NM6, 'Max 5'	*nigra* × *maximowiczii*	50% T × A
NC11382, NE27	*nigra* 'Charkowiensis' × *berolinensis*‡	25% T × A
DTAC2	*deltoides* 'Angulata' × *berolinensis*‡	25% T × A

* Designations beginning with NC refer to clones (re)named by the USDA North Central Forest Experiment Station and with NE by the USDA Northeastern Forest Experiment Station; NM and DTAC were clones developed by the Ontario Ministry of Natural Resources, Canada.
† Percentage of *Populus* spp. taxonomic section represented in each hybrid: L = Leuce, T = Tacamahaca, A = Aigerios.
‡ *berolinensis* = *nigra* × *laurifolia*.

The top diameter of each cutting was measured (±0. 1 mm) after planting, and tree heights (from soil surface to top of apical bud) were measured at 56 and 79 days after planting (± 1 cm). The difference between cutting diameter of surviving and dead trees was examined by Student's t-test for each clone. Homogeneity of variance was verified graphically. The relationship between cutting diameter and tree height was examined by correlation analysis.

Relationship of cutting diameter to growth in the glasshouse. Fifteen hybrid poplar clones (table 1) were established as 12-cm-long dormant hardwood cuttings in a glasshouse, following the same initial procedures described previously. However, they were planted flush with the soil surface in 20-cm-diameter plastic pots in saturated Redi-Earth Peat-Lite® potting soil, and each fertilized with 15 g of Osmocote® slow-release fertilizer (17:6:12 plus micronutrients). The environmental conditions were 16 hours light and 8 hours dark cycle, 20 to 27 °C, and 30 to 55% RH. The top diameter of each cutting was measured after planting. Height growth at 43 days post planting was measured and related by correlation analysis to cutting diameter.

Effect of cutting angle on growth. Clone NM6 was planted as 10-cm-long dormant hardwood cuttings in saturated potting soil in plastic pots in a glasshouse, as described previously. These cuttings were planted frozen, without a period of soaking. In addition, both ends of each cutting were freshly clipped immediately before planting so that half were cut perpendicular (90°) to the length of the stem at the top and bottom, and half were cut at a 45° angle to the length of the stem at the top and bottom. One 90° and one 45° cutting were made from each original (frozen) 25-cm-long cutting. All freshly cut end-surfaces exposed green, healthy cambium.

The surface area of the bottom of each cutting was measured before planting; 2 diameter measurements perpendicular to each other (± 0.1 mm) were taken and the area was calculated). Seventy-nine days after planting, the height of each stem was recorded I cm and the basal diameter (± 0.1 mm) of each primary stem per plant measured at 5 cm above the soil. Intact plants were removed from the potting soil by submerging the pots in water and gently washing the soil away from the roots. The number of primary roots originating along the length of the cuttings and those around the circumference of the cut surface were recorded. The basal diameters (± 0.1 mm) of the 3 largest roots/plant and the length of the single longest root (±1 cm) were recorded. Harvested plants were separated into roots, stems, leaves including petioles, and residual cutting, and oven-dried at 65 °C to constant weight (± 10 mg). Differences between these measures of plant productivity and cutting angle were evaluated by analysis of variance (Abacus Concepts 1989). Homogeneity of variance was verified graphically for each parameter.

Results and Discussion

Only clones NC5260 and NC5262 showed significant variation in survival related to cutting diameter at P# 0.10 and P# 0.05, respectively (table 2). For all clones, except NC11505, mean cutting diamteter was larger for surviving trees than for those which had died, although not statistically larger (table 2). Height growth of clones NC5331, NC11396, NC11445, and DTAC2 at 79 days was significantly correlated with cutting diameter in the field, but not in the glasshouse at 43 days (P #0.1) (table 3). Only clone NE332 had height growth significantly correlated with cutting diameter in both environments (P # 0.1).

Standard nursery practice recommendations are for cuttings of at least 0.6 to 1 cm diameter (Hansen and others 1983, Morin and Demeritt 1984). Given the range of cutting diameters in the current study, our results corroborate this criterion, but indicate that sensitivity to cutting diameter is generally weak among the clones tested. Cutting diameter was related to survival of 2 clones (table 2), and height growth of 5 other clones (table 3), but the results for these 7 clones were not consistent across all experiments. Four of the 5 clones for which cutting diameter was related to height growth were also among those with high field survival (NC11396, NC11445, NE332, DTAC2) (tables 2 and 3). Clones with high field survival are likely to have a high physiological rooting capability. These clones appear to be the most sensitive to cutting diameter.

Although clonal differences in survival and growth were observed, the relationships among cutting diameter, physiological rooting capability, survival and growth are unclear. Cutting mass might be a more useful index of potential survival and/or growth than diameter. This possibility requires testing. If it were found true, larger diameter cuttings would require shorter lengths to satisfy survival and growth expectations.

The potential for high survival and growth of cuttings smaller than 0.6 cm diameter is unknown. Therefore it may be appropriate to test each clone to determine a minimum diameter requirement. Field observations suggest that, for many *Populus* spp. and *Salix* spp. clones, cutting diameters less than 0.6 cm are adequate, even in dry years. Expectations that larger diameter cuttings will be more productive, and that cuttings below the established minimum diameter will be relatively unproductive, may be false. For the large-scale production of cuttings, clone-specific minimum diameter recommendations may be appropriate to minimize stool-bed waste.

Cuttings produced at a 45/ angle had significantly greater cut surface areas than those cut at 90/, as expected (2.54 versus 1.54 cm^2; F=80.62, P= 0.0001, df=1.8) (table 4). Both types of cuttings had equivalent residual dry mass (5.09 versus 5.05 mg). The ovendry weight of leaves (F=3.4055, P=0.0756, df=1,28) and roots (F=5.4575, P=0.0269, df=1.8) were significantly greater on plants grown from 90/ cuttings. All other parameters were equivalent between the cutting types at P# 0.10.

Table 2—*Mean cutting top diameters and hybrid poplar clonal survival at 56 and 79 days after planting at the Arlington Experiment Station, Wisconsin*

	Mean cutting diameter (mm)											
	56 days post planting					79 days post planting						
Clone	Surviving trees	(n)		Dead trees	(n)	Surviving trees	(n)		Dead trees	(n)	Cutting diam. range (mm)	Height at 56/79 days (cm)
NC5339	11.4	(11)	ns	11.2	(12)	—	(0)	—	11.3	(23)	8.0–15.0	4 / —
NC5260	10.5	(21)	**	7.7	(3)	11.4	(13)	**	8.7	(11)	7.5–15.5	10 / 37
NC11505	8.0	(15)	ns	8.8	(8)	8.0	(13)	ns	8.6	(10)	6.0–13.5	5 / 23
NC5271	15.5	(22)	—	13.0	(1)	15.5	(22)	—	13.0	(1)	5.5–20.5	32 / 64
NC5377	9.6	(22)	ns	7.5	(2)	9.8	(13)	ns	9.0	(11)	5.5–15.5	6 / 26
NC11004	12.4	(20)	ns	12.3	(3)	12.5	(18)	ns	11.8	(5)	7.5–18.5	22 / 53
NC5262	5.7	(18)	ns	5.5	(6)	5.8	(15)	*	5.3	(9)	4.5– 7.0	12 / 42
NC5331	7.8	(8)	ns	6.8	(16)	7.4	(7)	ns	6.8	(17)	6.0– 9.5	10 / 30
NC11382	9.6	(20)	ns	8.1	(4)	9.5	(17)	ns	8.9	(7)	7.0–16.0	13 / 37
NC11396	10.5	(21)	ns	8.9	(2)	10.6	(18)	ns	9.6	(5)	7.5–14.5	25 / 70
NC11432	10.0	(12)	ns	9.0	(12)	9.8	(7)	ns	9.4	(17)	6.0–12.5	12 / 50
NC11445	11.1	(22)	—	7.5	(1)	11.2	(21)	ns	9.0	(2)	7.0–16.5	22 / 54
NE332	9.2	(22)	—	7.5	(1)	9.2	(22)	—	7.5	(1)	6.0–12.5	26 / 54
NM6	14.5	(24)	—	—	(0)	14.5	(24)	—	—	(0)	12.0–19.0	44 / 83
DTAC2	15.1	(20)	ns	11.8	(2)	14.7	(19)	ns	10.0	(3)	9.5– 1.0	14 / 36

**, * refer to significant differences in cutting diameter between surviving and dead trees at 56 and 79 days, at $P \leq .05$ and .10, respectively.
Note: for some clones, total n is less than 24 due to unrecovered cuttings (that is, dead trees or buried cuttings) at the time of diameter measurement.

Table 3— *Correlation coefficients between cutting diameter (CD) and tree height (Ht) at 56 and 79 days after planting hybrid poplar clones in the field at the Arlington Experiment Station, Wisconsin, and 43 days after planting indoors in a glasshouse*

	Correlation coefficients for CD vs. Ht				
Clone	56 days—field	79 days—field	43 days—indoors	CD range (mm) indoors	n indoors
NC5339	.48	—	.57	7.6– 8.9	4
NC5260	.30	.22	−.12	4.6– 6.5	8
NC11505	.04	.00	.62	8.4– 9.9	6
NC5271	−.04	−.04	−.04	8.9–11.6	8
NC5377	.17	.16	.37	6.7– 8.4	8
NC11004	.29	.18	−.27	7.1–11.0	8
NC5262	.39	.06	−.12	4.0– 9.0	8
NC5331	.01	.69*	.30	6.5– 9.5	8
NC11382	−.22	−.21	.27	6.6– 9.4	8
NC11396	.39*	.42*	.44	7.2– 9.4	8
NC11432	.32	.54	−.10	7.5– 9.0	8
NC11445	.47**	.46**	−.05	7.8–10.8	8
NE332	.49**	.38*	.85*	5.2– 8.4	5
NM6	.11	−.03	.17	11.0–13.5	8
DTAC2	.34	.51**	.21	8.1–10.7	6

**, * refer to significant correlations at P<0.05 and 0.10, respectively; field study cutting diameter and n are in table 2.

The smaller size of the plants from cuttings prepared with 45/ cuts (table 4) may be due to the greater number of cambial cells damaged in a 45/ cut, and the relative distance to healthy cells from the cut surface. Because cambial cells are parallel to the length of the stem, a 90/ cut results in approximately 1 cell damaged for each nearest healthy cell. However, at 45/, the ratio of damaged to near-healthy cells could approach 2:1. Thus, roots from the 45/ cut-end would have to arise from and bridge a greater area of necrotic tissue than those from a 90/ cut. Nearly one-third more roots arose from the cut surface of the 90/ cuttings (table 4).

The greater aboveground surface area of the top of the 45/ cuttings, relative to the 90/ cuttings, may have hastened drying and also contributed to retarded growth. The current data suggest that 45/ cutting is not a beneficial practice. Although other clones need to be tested, these results suggest that cuttings should be made at a strictly 90/ angle.

Management Implications

Cutting diameters above 0.6 cm were not well related to improved survival or growth. Thus there appears to be little reason for favoring larger cuttings. Cutting diameters less than 0.6 cm may be suitable for some clones but would need to be tested explicitly. Such testing may be justified for clones to be mass-produced. Increasing the length of exposed cambium from which roots emerge, by reducing the cutting angle from 90/ to 45/, reduced rooting and growth of clone NM6.

Table 4— *Mean characteristics (± SD) of hybrid poplar clone NM6 79 days after establishment with 2 types of cuttings*

Characteristic	90° Angle cutting (n=14)	*P*	45° Angle cutting (n=16)
Area of the bottom surface of the cutting (cm2)	1.5±0.2	.0001	2.5±0.4
Height of primary stem (cm)	70.1±17.7	.7498	68.5±9.5
Cumulative height of all stems (cm)	85.5±30.2	.3488	77.4±15.0
Main stem diameter at 5 cm (mm)	5.2±1.1	.2822	4.9±0.6
Total number of primary roots	14.4±6.4	.5085	13.2±3.5
Total number of primary roots arising at the cut end	7.7±5.0	.1860	5.8±2.3
Total number of primary roots arising along cutting length	6.7±3.0	.5177	7.4±2.6
Primary roots basal diameter (mm)	1.7±0.5	.8087	1.6±0.3
Length of longest root (cm)	31.3±6.7	.2335	34.4±7.4
Oven-dry weight of stem(s) (mg)	2.9±1.3	.1564	2.3±0.8
Oven-dry weight of leaves (mg)	5.6±2.3	.0756	4.3±1.3
Oven-dry weight of roots (mg)	1.1±0.4	.0269	0.8±0.3
Oven-dry weight of residual cutting (mg)	5.1±0.6	.9031	5.1±0.8

Therefore, as a general practice, a 90/ cutting angle is recommended and with an automated production system is easier to make.

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