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Growth, Yield, and Disease Resistance of 7- to 12-Year-Old Poplar Clones in the North Central United States

D.A. Netzer, D.N. Tolsted, M.E. Ostry, J.G. Isebrands,
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Abstract

Poplar plantations were established across a four-state area in the North Central United States from 1987 to 1992 to determine growth potential and acceptability of clones selected from the available cultivars for large-scale plantations. Mid-rotation (5 years old) production of the 1987-88 plantings and clonal ranking based on growth and disease resistance for all plantations were reported previously. The 1987-88 plantings were remeasured in 1998 at rotation age. Mean annual increment across all plantings peaked by year 10 with an average production of 7 metric tons per hectare per year (MTH). The two best sites, Granite Falls, MN and Mondovi, WI averaged 9.2 MTH. Measurements of 7- to 12-year-old clonal trials indicated seven clones that should be tested further: DN164, DN177, DN154, NM2, NE264, DN170, and DN21.

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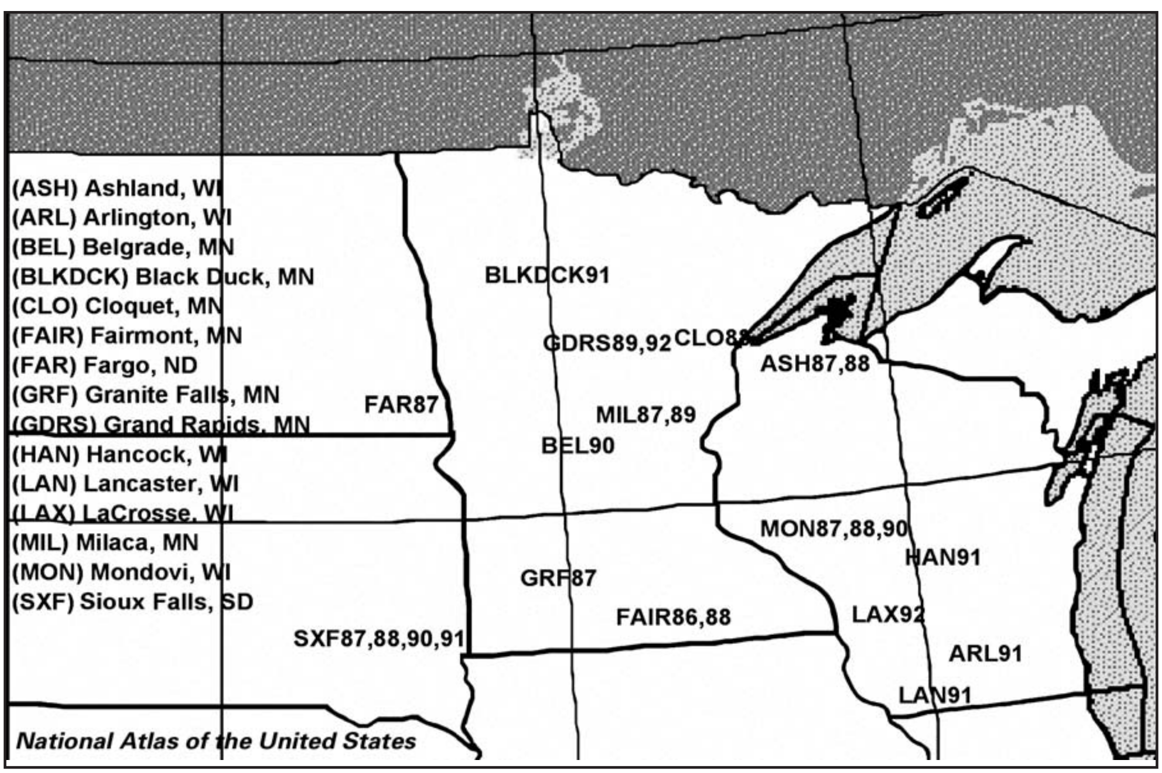
Introduction

A network of poplar plantations was established in Wisconsin, Minnesota, and North and South Dakota from 1987 to 1992 to determine growth potential and acceptability of clones from available cultivars for large-scale plantings in the North Central Region (figure 1). Mid-rotation (5 years old) production of the 1987-88 plantings and clonal ranking based on growth and disease resistance for all plantations were reported in Hansen *et al.* (1994). In the study reported here, we measured replicated yield blocks of common clones (older widely planted varieties including DN34, DN17, DN182) through age 11 years in plantations established in 1987-88 to develop equations to predict yield. We also measured growth of up to 95 clones per site of smaller (16 tree) non-replicated plots at 20 plantings in the region that ranged from 7 to 12 years old, and we compared their ranking with that in the previously published report.

Many hybrid poplar clones planted in the North Central U.S. have been extensively damaged by diseases, primarily Septoria canker caused by *Septoria musiva*, Melampsora leaf rust caused by *Melampsora* spp., and Marssonina leaf spot caused by *Marssonina brunnea* (Tuskan 1998). Selection of new and existing clones with high levels of resistance to the pathogens is the best disease control strategy. However, selection of resistant clones may decrease potential biomass yields because high yielding clones in the section Tacamahaca are often more susceptible than clones in the *Aigeiros* section (Ostry and Berguson 1993). Ninety-five different poplar clones in 16 research plantations at 12 locations were assessed annually for resistance to foliar and stem diseases. Twelve clones were common to all 16 plantations.

Figure 1.—Locations of poplar plantations established during 1986-1992 in the North Central United States.



Materials and Methods

The plant materials we tested were predominantly hybrid poplars from breeding programs in the Northeastern United States (NE clones) and clones originally bred in Europe and further tested in Ontario, Canada (DN clones) (Dickmann and Stuart 1983). In this study, we included four clones that have been planted extensively in windbreaks in the North Central United States for a number of years: DN34 (Eugenei or Imperial Carolina), DN182 (Raverdeau), DN17 (Robusta), and Siouxland. New promising clones were also included from several tree breeders in the North Central Region. The parentages of all the poplar material evaluated in this study are listed in table 1.

The plantations were established on former agricultural land that had been in row crops, small grain, or hay the year before the trees were planted (appendix 1). Almost all of the trees were grown from dormant unrooted 25-cm-long hardwood cuttings. The exceptions were *P. deltoides* and hybrid poplar clone NC5339, which were difficult to root and were planted as 1-year-old rooted cuttings. Hybrid aspen was planted as 1- or 2-year-old top pruned seedlings.

Site preparation included glyphosate herbicide application in the fall prior to planting to kill perennial grasses and weeds. This was followed by deep fall plowing and disking. The sites were disked again in the spring just prior to tree planting. Trees were planted at 2.4 x 2.4 m with weeds controlled through a combination of cultivation and herbicides for 3 years (Hansen *et al.* 1993). All sites were sprayed with the pre-emergent herbicide linuron immediately after dormant, soaked poplar cuttings were hand planted. Broadleaf weeds and grasses reinvaded most sites by mid-growing season. Shallow cultivation and hand weeding around each tree were moderately successful in controlling these weeds. In subsequent years tillage was continued as needed on these sites. Overall weed control varied substantially but was less than perfect on most sites. Competing weeds reduced growth, especially in years 1 to 3 on most sites (Buhler *et al.* 1998, Netzer and Hansen 1994).

In 1987-88, 0.405-ha blocks of selected clones were planted at 12 sites to provide for replicated 25-tree plots for biomass yield estimates. The same trees were measured throughout the study. Tree survival and diameter at breast height (DBH) were collected each fall on the better clones at all sites. Selected non-measurement trees were periodically harvested, weighed green, sub-sampled, and ovendried to determine total tree dry weight (appendix 2).

DBH and biomass dry weights of selected harvested trees were used to develop equations to predict biomass production in metric tons per hectare per year (MTH) for these 1987-88 large block plantations through culmination of mean annual increment. Using these ovendry tree weight data, we developed biomass regression equations of the form “Tree weight = a + b * DBH + c * DBH^2” to predict biomass yield in the plantations. We also developed equations for each site with sufficient trees (n>20), which included Ashland, Mondovi, Granite Falls, and

Table 1.—Poplar clones tested 1987-1992. Some clones not planted each year

Clone	Parentage	Section[1]		Blocks planted	Blocks with live trees (%)	Canker[2] mean
NC-5260	*P. tristis* x *P. balsamifera* 'Tristis'	Tx	T	16	88	1
NC-5339	*P. alba* x *P. grandidentata* 'Crandon'	Px	P	8	38	0
NC-5377	*P. deltoides* x *P. nigra* 'Wisconsin 5'	Ax	A	7	57	1
NE-6	*P. nigra* x *P. laurifolia*	Ax	A	15	20	2.3
NE-10	*P. nigra* x *P. trichocarpa*	Ax	T	15	27	3.4
NE-16	*P. nigra* var. *charkowiensis* x *P. deltoides*	Ax	A	15	40	2.7
NE-17	*P. nigra* var. *charkowiensis* x *P. nigra* var. *caudina*	Ax	A	15	67	3.2
NE-19	*P. nigra* var. *charkowiensis* x *P. nigra* var. *caudina*	Ax	A	15	93	2.8
NE-20	*P. nigra* var. *charkowiensis* x *P. nigra* var. *caudina*	Ax	A	16	94	2.8
NE-21	*P. nigra* var. *charkowiensis* x *P. nigra* var. *caudina*	Ax	A	15	80	2.7
NE-22	*P. nigra* var. *charkowiensis* x *P. nigra* var. *incrassata*	Ax	A	15	13	3
NE-27	*P. nigra* var. *charkowiensis* x (*P. laurifolia* x *P. nigra*)	Ax	TxA	15	27	3.5
NE-28	*P. nigra* var. *charkowiensis* x *P. trichocarpa*	Ax	T	16	44	2.4
NE-33	*P. deltoides* var. *angulata* x *P. laurifolia* x *P. nigra*	Ax	TxA	15	60	1.5
NE-35	*P. deltoides* var. *angulata* x *P. nigra* var. *plantierensis*	Ax	A	15	80	1.6
NE-37	*P. deltoides* var. *sargentii* x *P. laurifolia* x *P. nigra*	Ax	TxA	15	27	3.2
NE-41	*P. maximowiczii* x *P. trichocarpa* 'Androscoggin'	Tx	T	15	47	2.5
NE-42	*P. maximowiczii* x *P. trichocarpa*	Tx	T	15	27	3.1
NE-44	*P. maximowiczii* x *P. laurifolia* x *P. nigra*	Tx	TxA	15	27	2.6
NE-47	*P. maximowiczii* x *P. laurifolia* x *P. nigra* 'Oxford'	Tx	TxA	15	20	3.6
NE-48	*P. maximowiczii* x *P. laurifolia* x *P. nigra*	Tx	TxA	15	33	2.7
NE-49	*P. maximowiczii* x *P. laurifolia* x *P. nigra*	Tx	TxA	15	53	0.8
NE-50	*P. maximowiczii* x *P. laurifolia* x *P. nigra*	Tx	TxA	1	100	3
NE-51	*P. maximowiczii* x *P. nigra* var. *plantierensis*	Tx	A	15	53	3.1
NE-52	*P. maximowiczii* x P. plantierensis	Tx	A	1	100	3
NE-54	*P. balsamifera* var. *candicans* x (*P. laurifolia* x *P. nigra*)	Tx	TxA	15	33	3.3
NE-56	(*P. laurifolia* x *P. nigra*) x *P. nigra* var. *caudina*	TxA	A	15	33	2.8
NE-202	*P. deltoides* x *P. trichocarpa*	Ax	T	15	47	2.8
NE-222	*P. deltoides* x *P. nigra* var. *caudina*	Ax	A	16	100	1
NE-224	*P. deltoides* x *P. nigra* var. *caudina*	Ax	A	8	88	3
NE-225	*P. deltoides* x *P. nigra* var. *caudina*	Ax	A	1	100	3
NE-237	*P. deltoides* x *P. nigra* cv. Volga	Ax	A	1	100	0
NE-242	*P. deltoides* x *P. nigra* var. *plantierensis*	Ax	A	16	63	2.5
NE-252	*P. deltoides* var. *angulata* x *P. trichocarpa*	Ax	T	15	60	2.3
NE-256	*P. deltoides* var. *angulata* x *P. trichocarpa*	Ax	T	4	25	3
NE-257	*P. deltoides* var. *angulata* x *P. trichocarpa*	Ax	T	7	71	1.7
NE-258 (5534)	*P. deltoides* var. *angulata* x *P. trichocarpa*	Ax	T	10	60	2.9
NE-259	*P. deltoides* var. *angulata* x *P. nigra* cv. Incrassata	Ax	A	15	33	2.9
NE-264	*P. deltoides* var. *angulata* x *P. nigra* cv. Volga	Ax	A	13	69	0.4
NE-265	*P. deltoides* var. *angulata* x *P. nigra* cv. Volga	Ax	A	14	57	1.9
NE-283	*P. nigra* x *P. laurifolia*	Ax	T	15	27	3
NE-285	*P. nigra* x *P. trichocarpa*	Ax	T	1	100	3
NE-293	*P. nigra* var. *betulifolia* x *P. nigra* cv. Volga	Ax	A	5	20	3.3
NE-295	*P. nigra* var. betulifolia x *P. nigra* cv. Volga	Ax	A	15	53	1.5
NE-299 (5331)	*P. nigra* var. *betulifolia* x *P. trichocarpa*	Ax	T	15	47	2.6
NE-300	*P. nigra* var. *betulifolia* x *P. trichocarpa*	Ax	T	8	63	1.7
NE-308	*P. nigra* var. *charkowiensis* x *P. nigra* cv. Incrassata	Ax	A	15	87	2.8
NE-351	*P. deltoides* x *P. nigra* var. *caudina*	Ax	A	7	71	2.8
NE-366	*P. deltoides* x *P. nigra* var. *caudina*	Ax	A	14	14	3.6
NE-386 (5263)	*P. balsamifera* var. *candicans* x (*P. laurifolia* x *P. nigra*)	Tx	TxA	8	38	3.3
NE-387 (5262)	*P. balsamifera* var. *candicans* x (*P. laurifolia* x *P. nigra*)	Tx	TxA	16	44	2.3
NE-389	*P. deltoides* x *P. nigra* var. *caudina*	Ax	A	3	100	1
DN-1	*P. deltoides* x *P. nigra* 'Allenstein'	Ax	A	8	88	1.4
DN-2	*P. deltoides* x *P. nigra* 'Baden'	Ax	A	16	94	1.6
DN-5	*P. deltoides* x *P. nigra* 'Gelrica'	Ax	A	8	100	0.5
DN-9	*P. deltoides* x *P. nigra* 'Lons'	Ax	A	14	93	1.6
DN-16	*P. deltoides* x *P. nigra* 'Regenere Batard d'Hauterive'	Ax	A	15	87	1.3
DN-17	*P. deltoides* x *P. nigra* 'Robusta'	Ax	A	16	100	1.1
DN-18	*P. deltoides* x *P. nigra* 'Tardif de Champagne'	Ax	A	15	93	1.7
DN-21	*P. deltoides* x *P. nigra* 'Jacometti'	Ax	A	15	73	1.6
DN-22	*P. deltoides* x *P. nigra* 'I-262'	Ax	A	15	73	1.2
DN-28	*P. deltoides* x *P. nigra* 'Ostia'	Ax	A	8	63	2.3
DN-34	*P. deltoides* x *P. nigra* (Eugenei)	Ax	A	16	88	0.3
DN-38	*P. deltoides* x *P. nigra*	Ax	A	8	88	2.1
DN-55	*P. deltoides* x *P. nigra*	Ax	A	15	87	1.8

Table 1.—Continued

Clone	Parentage	Section[1]		Blocks planted	Blocks with live trees (%)	Canker[2] mean
DN-70	*P. deltoides* x *P. nigra*	Ax	A	8	100	0.4
DN-74	*P. deltoides* x *P. nigra*	Ax	A	8	100	0.3
DN-93	*P. deltoides* x *P. nigra*	Ax	A	5	0	*
DN-106	*P. deltoides* x *P. nigra*	Ax	A	8	88	2.9
DN-114	*P. deltoides* x *P. nigra*	Ax	A	8	75	1.9
DN-128	*P. deltoides* x *P. nigra*	Ax	A	8	100	3
DN-131	*P. deltoides* x *P. nigra*	Ax	A	15	100	1.4
DN-132	*P. deltoides* x *P. nigra*	Ax	A	NR[3]	NR	NR
DN-154	*P. deltoides* x *P. nigra*	Ax	A	NR	NR	NR
DN-160	*P. deltoides* x P. nigra	Ax	A	8	100	2.5
DN-164	*P. deltoides* x *P. nigra*	Ax	A	NR	NR	NR
DN-170	*P. deltoides* x *P. nigra*	Ax	A	7	100	0.7
DN-173	*P. deltoides* x *P. nigra*	Ax	A	7	86	2
DN-174	*P. deltoides* x *P. nigra*	Ax	A	8	100	1.9
DN-177	*P. deltoides* x *P. nigra*	Ax	A	8	100	1.4
DN-179	*P. deltoides* x *P. nigra*	Ax	A	8	100	1.3
DN-181	*P. deltoides* x *P. nigra*	Ax	A	8	88	1.6
DN-182	*P. deltoides* x *P. nigra* (Raverdeau)	Ax	A	16	81	1.4
I-45/51	*P. deltoides* x *P. nigra*	Ax	A	15	100	0.6
I-476 (4878)	*P. deltoides* x *P. nigra*	Ax	A	8	88	0.4
SIOUXLAND	*P. deltoides* x *P. nigra*	Ax	A	16	94	1.5
14271	*P. deltoides* x *P. nigra*	Ax	A	NR	NR	NR
IS-31	*P. deltoides* x *P. nigra*	Ax	A	NR	NR	NR
107.14	*P. deltoides* x *P. nigra*	Ax	A	NR	NR	NR
117.53	*P. deltoides* x *P. nigra*	Ax	A	NR	NR	NR
D-101	*P. deltoides*	A		NR	NR	NR
D-102	*P. deltoides*	A		NR	NR	NR
D-103	*P. deltoides*	A		NR	NR	NR
D-104	*P. deltoides*	A		NR	NR	NR
D-105	*P. deltoides*	A		NR	NR	NR
D-108	*P. deltoides*	A		NR	NR	NR
D-109	*P. deltoides*	A		NR	NR	NR
D-110	*P. deltoides*	A		NR	NR	NR
D-111	*P. deltoides*	A		NR	NR	NR
D-112	*P. deltoides*	A		NR	NR	NR
D-113	*P. deltoides*	A		NR	NR	NR
D-114	*P. deltoides*	A		NR	NR	NR
D-118	*P. deltoides*	A		NR	NR	NR
D-122	*P. deltoides*	A		NR	NR	NR
D-124	*P. deltoides*	A		NR	NR	NR
D-125	*P. deltoides*	A		NR	NR	NR
D-115	*P. deltoides*	A		NR	NR	NR
D-117	*P. deltoides*	A		NR	NR	NR
D-119	*P. deltoides*	A		NR	NR	NR
D-121	*P. deltoides*	A		NR	NR	NR
45-1	*P. deltoides*	A		15	100	0
178-4	*P. deltoides*	A		NR	NR	NR
193-5	*P. deltoides*	A		NR	NR	NR
FARGO	*P. deltoides*	A		NR	NR	NR
42.7	*P. deltoides*	A		NR	NR	NR
9252.46	*P. deltoides*	A		NR	NR	NR
7300501	*P. deltoides*	A		NR	NR	NR
8000113	*P. deltoides*	A		NR	NR	NR
Jackii4	*P. balsamifera* x *P. deltoides*	Tx	A	16	100	3
NW	*P. deltoides* x *P. nigra* cv. *Volga* 'Northwest'	Ax	A	8	75	0.8
DTAC-7	*P. deltoides* x *P. trichocarpa*	Ax	T	6	67	2.5
DTAC-16	*P. deltoides* x *P. trichocarpa*	Ax	T	7	57	2.6
DTAC-26	*P. deltoides* x *P. trichocarpa*	Ax	T	7	57	0.5
HY-5	*P. trichocarpa* x *P. deltoides*	Tx	A	7	0	*
HY-11	*P. trichocarpa* x *P. deltoides*	Tx	A	7	0	*

Table 1.—Continued

Clone	Parentage	Section[1]		Blocks planted	Blocks with live trees (%)	Canker[2] Mean
NM-2	*P. nigra* x *P. maximowiczii*	Ax	T	8	100	2
NM-6	*P. nigra* x *P. maximowiczii*	Ax	T	8	100	0.3
TRIP	*P. tremuloides* x *P. tremula*	Px	P	1	100	0
DIPL	*P. tremuloides* x *P. tremula*	Px	P	1	100	0
19-89	*P. tremuloides* x *P. tremula*	Px	P	NR	NR	NR
21-89	*P. tremuloides* x *P. tremula*	Px	P	NR	NR	NR
T50-197	*P. trichocarpa* x *P. deltoides*			NR	NR	NR
14044	*P.* x *petrowskyana*			NR	NR	NR
14165	*P.* x 'Melville'			NR	NR	NR
14174	*P. balsamifera* x *P. simonii* (38P38)			NR	NR	NR
14271	*P. deltoides* x *P. nigra* 'Italica' #78102			NR	NR	NR
14390	*P.* xp., PX71-W131 OP progeny of 'Walker'			NR	NR	NR
13277	*P. trichocarpa*			NR	NR	NR
13279	*P. trichocarpa*			NR	NR	NR
13280	*P. trichocarpa*			NR	NR	NR
13281	*P. trichocarpa*			NR	NR	NR

[1] A = Aigeiros
P = Populus (formerly Leuce)
T = Tacamahaca

[2] Canker Rating:
1 = branch canker(s) only.
2 = stem canker(s).
3 = dieback and breakage associated with canker.
4 = death associated with canker
* = death not associated with canker

[3] NR = not rated.

Milaca. For the remaining sites, we used a generalized regression equation developed from all the tree dry weight data from all sites (n=152) to calculate biomass production (table 2, appendix 3).

Each location may have had more than one planting in different years so "site" refers to a particular plantation in any one year (table 3). Single 16-tree plots of promising clones were located in all plantings from 1987 through 1992. The number of clones varied by year and site and included as many as 76 clones in some instances. These single clone plots are not replicated on any site for any one year and were not always planted in consecutive years: tree DBH, tree survival, stem canker incidence, and tree form (1 = stems deformed from sunscald damage and major stem defects; 2 = crooked stems, heavy branching, minor defects; 3 = slight stem sweep, medium branching, no defects; 4 = straight clean stems with few branches) were recorded and were used to develop index scores to rank clones in the clonal trial plots (appendix 4). These rankings were compared to the mid-rotation rankings previously reported by Hansen *et al.* 1994. Clones with extremely poor growth and survival were not measured. All clones tested are listed in table 1.

Clones were assessed annually from 1991 through 1998 for incidence and severity of foliar and stem diseases, winter injury, and survival at Cloquet, Fairmont, Granite Falls, Milaca in MN; Ashland, Rhinelander, and Mondovi in WI; Sioux Falls, SD; and Fargo, ND. Clones were replicated across sites and over time at some sites. A total of 95 clones (46 to 76 per plantation) were assessed using the following rating classes for rating foliage diseases: 0 = none; 1 = slight; 2 = moderate, infection throughout crown; 3 = premature defoliation. The following classes were used for rating stem disease: 0 = none; 1 = branch canker(s) only; 2 = stem canker(s); 3 = stem dieback and breakage associated with canker; 4 = death associated with canker.

Table 2.—Regression equation coefficients for North Central U.S. poplar plantations and clones

(Tree weight = a + bDBH + $cDBH^2$)

Equation	a	b	c	r^2	n
General equation	6.16	-2.23	0.353	98.3	152
By site					
Ashland, WI	1.86	-0.54	0.245	98.6	35
Mondovi, WI	8.75	-2.97	0.405	99.2	32
Granite Falls, MN	3.05	-1.49	0.327	99.4	28
Milaca, MN	10.20	-2.78	0.357	98.0	44
By clone					
DN34	4.73	-1.99	0.349	99.0	41
DN17	4.62	-1.78	0.332	97.7	40
DN182	8.51	-2.86	0.375	98.5	32

Table 3.—*Populus* clonal trial plantings established in the North Central United States from 1987 through 1992. Each planting originally had 16 trees per clone in unreplicated blocks.

Location	Year planted	Age measured (years)	# Clones measured
Arlington, WI	1991	8	19
Belgrade, MN	1990	9	13
Blackduck, MN	1991	8	12
Cloquet, MN	1988	12	16
Fargo, ND	1987	12	3
Grand Rapids, MN	1989	10	12
Grand Rapids, MN	1992	7	12
Granite Falls, MN	1987	11	11
Hancock, WI	1991	8	17
LaCrosse, WI	1992	7	19
Lancaster, WI	1991	8	28
Milaca, MN	1987	12	15
Milaca, MN	1989	10	11
Mondovi, WI	1987	12	14
Mondovi, WI	1988	11	11
Mondovi, WI	1990	9	15
Sioux Falls, SD	1987	12	10
Sioux Falls, SD	1988	11	11
Sioux Falls, SD	1990	9	2
Sioux Falls, SD	1991	8	2

RESULTS

The 1998 index scores for all clones at all sites along with average DBH by clone by site and score adjusted for survival are listed in appendix 4. Three clones—NE222, I45-51, and DN34—are listed in the top 12 in all 6 years (table 4). Additionally, DN5, DN70, DN2, NM6, and DN182 are ranked in the top 12 in 4 of the 6 years. Clones DN177, DN17, and DN164 are listed in 3 of the 6 years. Several clones, NM2, NE264, 45-1, DN154, DN131, DN170, DN74, and DN21 are listed in 2 of the 6 years. If we compare the top 25 poplars ranked by Hansen *et al.* in 1994 with the top 25 in 1998, we see a dramatic change of ranking in the position of the top clones although 18 clones were in the top 25 in both years (table 5).

Table 4.—Top 12 clones ranked in descending order by growth, form, and stem canker resistance by year for hybrid poplar trials planted 1987-1992. Only trees grown from unrooted hardwood cuttings are ranked. Not all clones were planted in all years.

Rank	12 years old	11 years old	10 years old	9 years old	8 years old	7 years old
1	DN177	NM6	DN5	DN164[1]	DN164	DN5
2	NE222	DN70	NM6	DN132[1]	NE222	NM6
3	I45-51	NE252	DN2	DN170	DN177	DN164
4	45-1	NE222	DN70	I45-51	NM2	DN17
5	DN5	DN21	NM2	DN34	DN154	DN182
6	NE264	I45-51	DN182	NE222	NM6	DN70
7	DN170	DN131	DN131	DN2	T50-197	DN34
8	I476	DN34	DN34	DN17	DN34	I45-51
9	DN34	45-1	DN17	DN182	DN70	NE222
10	DN2	DN181	I45-51	DN132[1]	DN2	DN55
11	DN174	NE264	NE222	DN21	DN5	DN154
12	DN74	DN182	DN74	DN70	I45-51	DN177

[1] The first year these clones were planted.

Table 5.—The top 25 clones ranked by growth and disease resistance indices in 1998 compared to ranking in 1994

Clone98	Rank98	Rank94	#Sites98
DN164	1	NR[1]	8
NM6	2	2	13
DN170	3	11	6
DN5	4	1	14
DN177	5	10	12
NE222	6	8	17
DN70	7	3	12
DN154	8	NR	8
I45-51	9	6	17
45-1	10	20	9
I476	11	12	4
DN34	12	5	17
DN2	13	4	17
NM2	14	17	14
DN182	15	26	17
DN17	16	7	17
NE264	17	14	7
NE252	18	NR	2
DN74	19	16	12
T50-197	20	NR	6
DN132	21	NR	8
DN21	22	NR	16
DN131	23	22	17
DN181	24	29	12
DN55	25	25	16

[1] Not ranked in the top 25

Table 6.—Growth index scores of hybrid poplar clones planted from 1987 through 1992 in plantations located in Wisconsin, Minnesota, and South Dakota

Index scores = DBH (mm) x survival x (disease + form)																	
Site*	**GRF**	**MIL**	**SXF**	**MON**	**CLO**	**MON**	**SXF**	**GRD**	**MIL**	**BEL**	**MON**	**ARL**	**LAN**	**BLD**	**HAN**	**LAX**	**GRD**
	87	87	87	87	88	88	88	89	89	90	90	91	91	91	91	92	92
Age (yrs)	12	12	12	12	11	11	11	10	10	9	9	8	8	8	8	7	7
Clone	**GRF**	**MIL**	**SXF**	**MON**	**CLO**	**MON**	**SXF**	**GRD**	**MIL**	**BEL**	**MON**	**ARL**	**LAN**	**BLD**	**HAN**	**LAX**	**GRD**
DN2	35	90	0	84	0	65	0	**104**	72	36	95	14	84	65	49	31	24
DN5	**159**	99	0	58	NP	NP	NP	**138**	**102**	56	20	31	76	39	56	47	**122**
DN17	24	59	50	46	0	59	0	56	37	52	57	21	69	46	20	79	67
DN21	0	0	0	0	**114**	65	0	0	0	0	94	0	92	0	0	NP	0
DN34	28	70	70	53	0	42	75	58	36	72	85	23	**104**	50	37	62	50
DN55	0	0	0	0	0	0	0	0	0	0	0	0	0	NP	0	0	75
DN70	NP	NP	NP	NP	77	**106**	83	77	73	56	24	71	87	16	37	NP	59
DN74	0	**121**	26	26	NP	NP	NP	0	49	NP	NP	79	62	0	41	0	0
DN131	0	0	0	0	**123**	0	0	**110**	0	0	0	0	**110**	0	0	0	0
DN132	NP	NP	NP	NP	NP	NP	NP	NP	NP	96	0	NP	NP	NP	50	0	NP
DN154	NP	NP	NP	NP	NP	NP	NP	NP	NP	88	90	88	92	0	54	74	0
DN164	NP	NP	NP	NP	NP	NP	NP	NP	NP	**107**	92	**137**	69	76	56	70	86
DN170	52	34	95	92	NP	NP	NP	NP	NP	62	**108**	NP	NP	NP	0	NP	NP
DN174	**121**	0	0	60	NP	NP	NP	0	0	0	0	0	77	0	0	49	0
DN177	**165**	**152**	**146**	**127**	NP	NP	NP	NP	NP	0	70	**139**	83	0	55	65	0
DN181	NP	NP	NP	NP	**102**	0	0	0	0	0	0	0	0	0	0	NP	0
DN182	0	52	0	0	58	36	0	84	43	38	65	36	63	32	48	56	76
NE222	60	89	90	**103**	42	98	41	0	85	50	88	**120**	**127**	30	56	43	63
NE252	0	0	0	0	**123**	NP	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
NE264	0	**137**	87	87	0	NP	61	NP	NP	NP	NP	NP	NP	NP	NP	NP	40
NM2	43	61	0	68	NP	NP	NP	97	46	0	61	29	**121**	69	38	55	0
NM6	NP	NP	NP	NP	**106**	90	96	**129**	**107**	20	41	33	**116**	55	20	41	**121**
I476	48	**126**	49	0	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP
I45-51	**106**	98	52	65	51	94	0	17	72	66	**102**	57	91	40	16	73	34
T50-197	NP	NP	NP	NP	NP	NP	NP	NP	NP	0	0	41	70	57	NP	NP	0
45-1	0	92	88	**142**	0	**105**	0	NP	NP	NP	NP	NP	NP	NP	NP	0	0

NP = not planted
0 = Poor survival or severely diseased

*GRF=Granite Falls, MN 1987, MIL=Milaca, MN 1987, SXF=Sioux Falls, SD 1987, MON=Mondovi, WI 1987, CLO=Cloquet, MN 1988, MON=Mondovi, WI 1988, SFX=Sioux Falls, SD 1988, GRD=Grand Rapids, MN 1989, LAN=Lancaster, WI 1991, MIL=Milaca, MN 1989, BEL=Belgrade, MN 1990, MON=Mondovi, WI 1990, ARL=Arlington, WI 1991, HAN=Hancock, WI 1991, LAX=LaCrosse, WI 1992, GRD=Grand Rapids, MN 1992, BLD=Black Duck, MN 1991

Index scores for clones with a score greater than 100 by site are listed in bold print in table 6. Clone DN177 and NM6 had scores greater than 100 on five sites followed by DN5 on four sites. Other clones ranked high on two and three sites include DN 131, DN164, NE222, 45-1, and I45-51. It should be noted that only clones grown from unrooted cuttings are ranked here. Sites are compared by DBH and soil texture in table 7. The most productive soil textures for agricultural crops based on crop equivalency ratios generally produce more diameter growth; however, there are exceptions indicating that multiple factors including clone and cultural practices are influencing growth.

Septoria canker was the most damaging disease at all locations throughout the study, resulting in stem breakage of many susceptible clones at nearly all the sites (tables 1, 8). Canker incidence and severity has increased over time, beginning after the second or

Table 7.—Soil texture of 17 midwest U.S. *Populus* plantations ranked by mean annual diameter growth of all clones planted on each site

Sites and year planted	Mean annual diameter growth (cm)	Soil texture
Arlington, WI 1991	2.39	Silt Loam
Granite Falls, MN 1987	2.16	Loam
Mondovi, WI 1988	2.09	Silt Loam
Lancaster, WI 1991	1.94	Silt Loam
Milaca, MN 1987	1.94	Silt Loam
Mondovi, WI 1987	1.94	Silt Loam
Milaca, MN 1989	1.81	Silt Loam
Grand Rapids, MN 1989	1.81	Sandy Loam
Mondovi, WI 1990	1.80	Silt Loam
Hancock, WI 1991	1.69	Loamy Sand
Sioux Falls, SD 1988	1.66	Silty Clay Loam
Belgrade, MN 1990	1.61	Sandy Loam
Sioux Falls, SD 1987	1.58	Silty Clay Loam
Grand Rapids, MN 1992	1.57	Sandy Loam
LaCrosse, WI 1992	1.45	Silt Loam
Cloquet, MN 1988	1.45	Loam
Blackduck, MN 1991	1.34	Unknown

Table 8.—Mean Septoria canker ratings[1] and block survival of a) 95 hybrid poplar clones, b) 12 clones common to 16 plantings, and c) 51 clones common to nine locations.

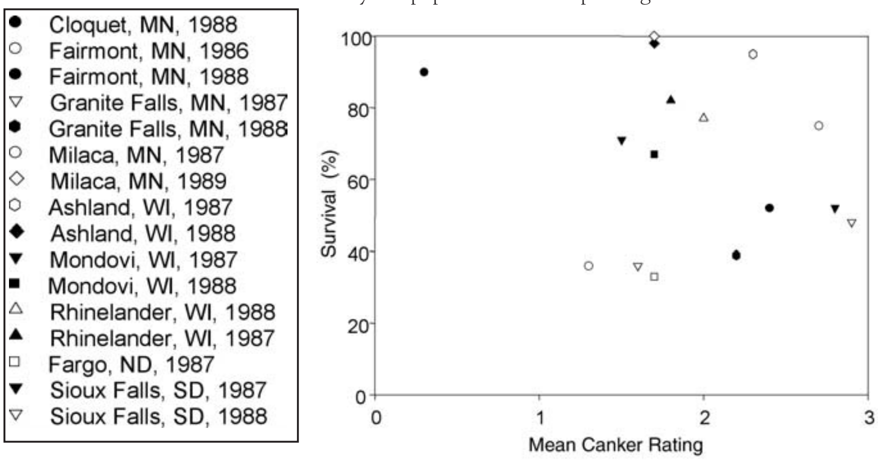
		a		b			c	
Location	Year	Canker rating	Survival (%)	Canker rating	Survival (%)	Location	Canker rating	Survival (%)
Ashland	1987	2.3	95	1.9	100	Ashland	2.1	100
Ashland	1988	1.7	98	1.2	100	Cloquet	0.3	92
Cloquet	1988	0.3	90	0.4	100	Fairmont	2.4	76
Fairmont	1986	1.3	36	0.7	75	Fargo	2	24
Fairmont	1988	2.4	52	1.7	92	Granite Falls	2.1	59
Fargo	1987	1.7	33	2.8	42	Milaca	2.8	96
Granite Falls	1987	1.6	36	1.4	58	Mondovi	1.8	88
Granite Falls	1988	2.2	39	1.9	67	Rhinelander	2	94
Milaca	1987	2.7	75	2.7	92	Sioux Falls	3	82
Milaca	1989	1.7	100	2.2	100			
Mondovi	1987	1.5	71	1.1	92			
Mondovi	1988	1.7	67	1.6	92			
Rhinelander	1987	1.8	82	1.6	100			
Rhinelander	1988	2	77	1.8	100			
Sioux Falls	1987	2.8	52	2.5	92			
Sioux Falls	1988	2.9	48	2.1	75			

[1]0 = none, 1 = branch canker(s) only, 2 = stem canker(s), 3 = dieback and breakage associated with canker, 4 = death associated with canker.

Data collected 1995-1998.

third year after planting. In 1998, the mean canker rating of the 12 clones common to all plantings was greater in the 1989 plantings (2.2) than in the 1987 (2.0), 1988 (1.5), or 1986 (0.7) plantings (fig. 2).

Figure 2.—Mean Septoria canker ratings[1] and block survival of 95 hybrid poplar clones in 16 plantings established 1986-1989.

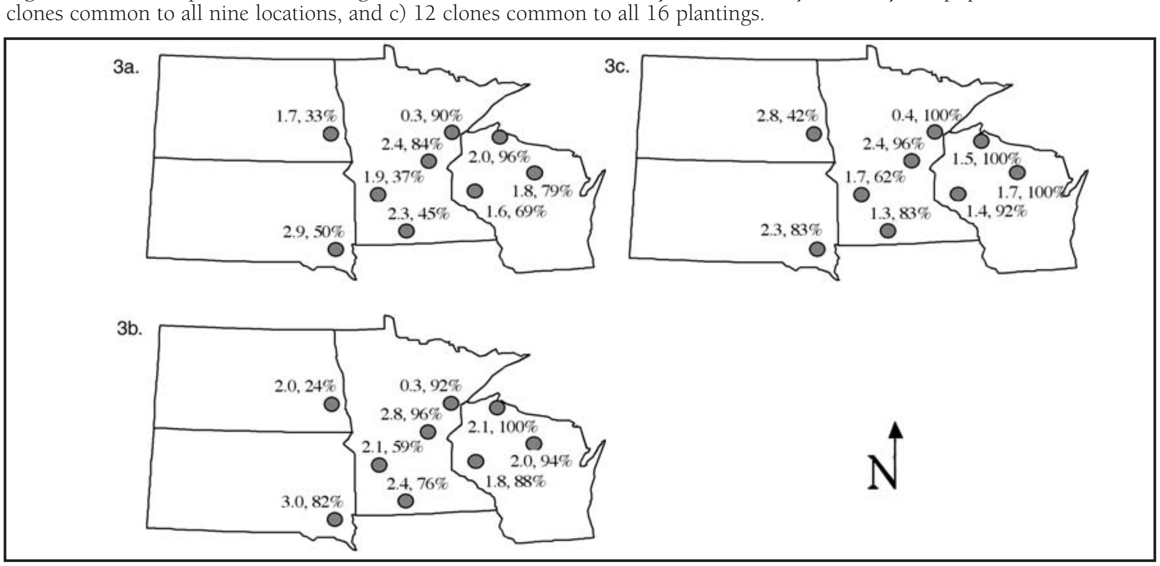


[1]0 = none, 1 = branch canker(s) only, 2 = stem canker(s), 3 = dieback and breakage associated with canker, 4 = death associated with canker. Data collected 1995-1998.

Canker incidence and severity varied across locations. Canker damage on the 12 common clones was lowest at the Cloquet-88 and Fairmont-86 plantings, and it was greatest at the Fargo-87 and Milaca-87 plantings (table 8, fig. 3). Clone survival (blocks with live trees) was greatest at the Milaca-89, Ashland-87 and -88, and Cloquet-88 plantings (table 8). The poorest survival was at the Fargo-87 and Granite Falls-87 and -88 plantings.

There were differences among clones of the various *Populus* sections in resistance to Septoria canker. *Populus* (=*Leuce*) section hybrids, *P. deltoides* clones, and certain *P. deltoides* x *P. nigra* and *P. nigra* x *P. maximowiczii* hybrids were the most canker resistant (table 1). Clones with little or no Septoria canker and with above average survival included 45-1, diploid and triploid aspen, DN74, NE237, NM6, I476, DN34, and DN70. Hybrids most susceptible to Septoria canker were those in the section Tacamahaca, and clones with *P. nigra* parentage. Clones most severely damaged by Septoria canker were NE366, NE386, NE51, DTAC16, NE17, NE224, NE52, NE50, NE389, NE285, NE225, Jackii 4, and DN128. Some of the highest yielding clones were also susceptible to canker (fig. 4). While some clones were either highly resistant or highly susceptible across sites, others were highly variable in canker susceptibility depending on site (table 9).

Figure 3.—Mean Septoria canker ratings[1] and block survival of a) ninety-five 8- to 10-year-old hybrid poplar clones, b) 51 clones common to all nine locations, and c) 12 clones common to all 16 plantings.

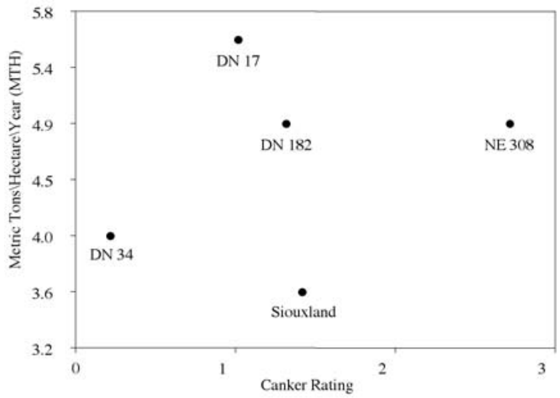


[1]0 = none, 1 = branch canker(s) only, 2 = stem canker(s), 3 = dieback and breakage associated with canker, 4 = death associated with canker. Data collected 1995-1998.

Leaf diseases were generally not a serious problem in hybrid poplar plantations although the major foliar pathogens *M. medusae*, *M. brunnea*, and *S. musiva* were present at all of the sites. Leaf disease severity was variable during this study and highly dependent on climatic conditions. One exception was the yearly premature defoliation of clone 'Northwest' that was caused by *M. medusae*. Various other clones were partially defoliated by leaf rust. Depending on seasonal weather patterns, several other clones were partially defoliated by *M. brunnea* and *S. musiva*.

Trees at the Cloquet, MN, site had the lowest disease severity of all sites. Although the incidence of Septoria canker began to increase 6 years after planting, for reasons unknown, susceptible clones at this site continued to have levels of disease significantly less than at all of the other sites. Comparisons of edaphic factors among the planting sites and the canker severity and tree survival revealed that precipitation and soil acidity may have had more influence than other soil characteristics (fig. 5).

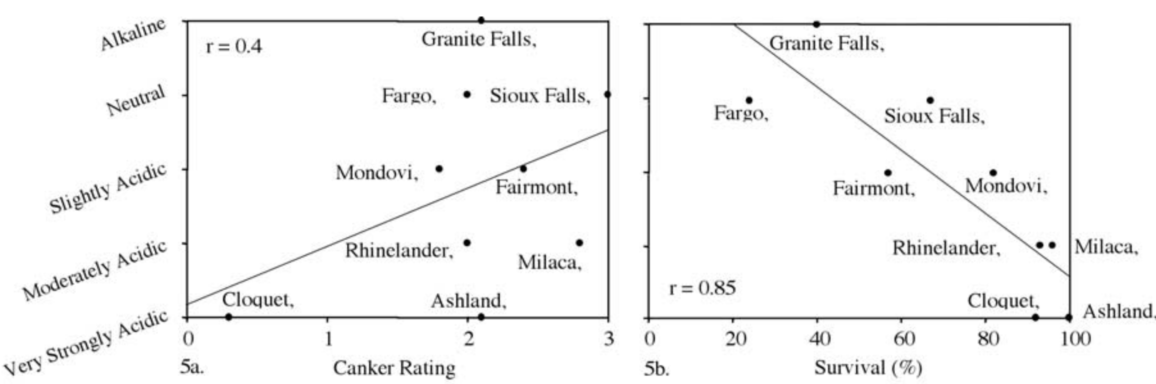
Figure 4.—Mean Septoria canker ratings[1] and biomass production of five hybrid poplar clones in eight locations.



[1]0 = none, 1 = branch canker(s) only, 2 = stem canker(s), 3 = dieback and breakage associated with canker, 4 = death associated with canker. Canker data collected on 8- to 10-year-old clones in 1995-1998 and biomass data collected in 1991 on 6-year-old clones.

Biomass yields of poplar plantations established in WI, MN, ND, and SD during 1987-88 through years 10 and 11 are reported here as well as estimated yields of the best performers in the small clonal trials. Hansen *et al.* 1994 reported mid-rotation (4- and 5-year-old) yields of the 1987-88 plantings in 1992. They reported that the mean annual increment had not peaked (trees were still growing each year at a greater rate than the year before) in the plantations. Therefore, we continued measurements until all plantations began to decline. We selected three

Figure 5.—a) Mean Septoria canker ratings[1] and b) block survival, of fifty-one 8- to 10-year-old hybrid poplars common to nine locations, and soil acidity.



[1]0 = none, 1 = branch canker(s) only, 2 = stem canker(s), 3 = dieback and breakage associated with canker, 4 = death associated with canker. Data collected 1995-98.

Table 9.—Variance in mean Septoria canker ratings of 8- to 10-year-old hybrid poplar clones in 16 plantings

Clone	Parentage			Blocks planted	Surviving blocks (%)	Canker variance	Canker rating[1]
Clones highly resistant across sites							
45-1	*P. deltoides*			15	100	0	0.0
NC5339	*P. alba*	x	*P. grandidentata*	8	38	0	0.0
DN4	*P. deltoides*	x	*P. nigra*	8	100	0.50	0.3
NM6	*P. nigra*	x	*P. maximowiczii*	8	100	0.50	0.3
DN34	*P. deltoides*	x	*P. nigra*	16	88	0.53	0.3
DN70	*P. deltoides*	x	*P. nigra*	8	100	0.55	0.4
NE264	*P. deltoides* var. *angulata*	x	*P. nigra* cv. *Volga*	13	69	1.03	0.4
I476	*P. deltoides*	x	*P. nigra*	8	88	1.29	0.4
Clones highly susceptible across sites							
NE224	*P. deltoides*	x	*P. nigra* var. *caudina*	8	88	0	3.0
DN128	*P. deltoides*	x	*P. nigra*	8	100	0	3.0
JACKII4	*P. balsamifera*	x	*P. deltoides*	16	100	0	3.0
DN106	*P. deltoides*	x	*P. nigra*	8	88	0.14	2.9
NE386	*P. balsamifera* var. *candicans*	x	*P. laurifolia* x *P. nigra*	8	38	0.25	3.3
NE366	*P. deltoides*	x	*P. nigra* var. *caudina*	14	14	0.30	3.6
NE17	*P. nigra* var. *charkowiensis*	x	*P. nigra* var. *caudina*	15	67	0.31	3.2
NE51	*P. maximowiczii*	x	*P. nigra* var. *plantierensis*	15	53	0.32	3.1
NE27	*P. nigra* var. *charkowiensis*	x	*P. laurifolia* x *P. nigra*	15	27	0.50	3.5
NE47	*P. maximowiczii*	x	*P. laurifolia* x *P. nigra*	15	20	0.53	3.6
NE10	*P. nigra*	x	*P. maximowiczii*	15	27	0.53	3.4
NE22	*P. nigra* var. *charkowiensis*	x	*P. nigra* cv. *Incrassata*	15	13	1.00	3.0
Clones exhibiting variable canker ratings across sites[2]							
NE44	*P. maximowiczii*	x	*P. laurifolia* x *P. nigra*	15	27	3.78	2.6
NE300	*P. nigra* var. *betulifolia*	x	*P. trichocarpa*	8	63	3.47	1.7
NE257	*P. deltoides* var. *angulata*	x	*P. trichocarpa*	7	71	3.47	1.7
DN114	*P. deltoides*	x	*P. nigra*	8	75	3.14	1.9
NE265	*P. deltoides* var. *angulata*	x	*P. nigra* cv. *Volga*	14	57	2.99	1.9
NE295	*P. nigra* var. *betulifolia*	x	*P. nigra* cv. *Volga*	15	53	2.94	1.5
NE252	*P. deltoides* var. *angulata*	x	*P. trichocarpa*	15	60	2.93	2.3
NE6	*P. nigra*	x	*P. laurifolia*	15	20	2.92	2.3
DN28	*P. deltoides*	x	*P. nigra*	8	63	2.90	2.3
DN22	*P. deltoides*	x	*P. nigra*	15	73	2.86	1.2

[1]0 = none, 1 = branch canker(s) only, 2 = stem canker(s), 3 = dieback and breakage associated with canker, and 4 = death associated with canker.
[2]Generally, lower canker ratings in Ashland 1988 and Cloquet 1988 plantings, and higher canker ratings in Fairmont 1988, and in Sioux Falls 1987 and 1988.

Data collected 1995-1998.

Figure 6.—Combined average production of hybrid poplar clones DN17, DN34, and DN182 planted in 1987 at six locations in the North Central U.S.

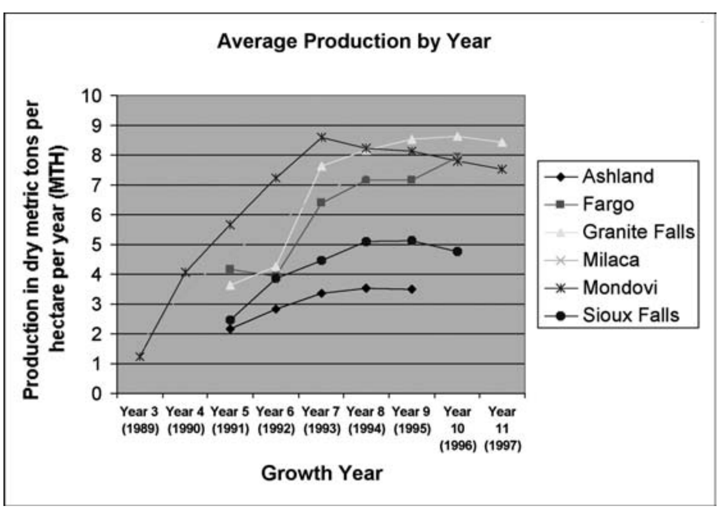
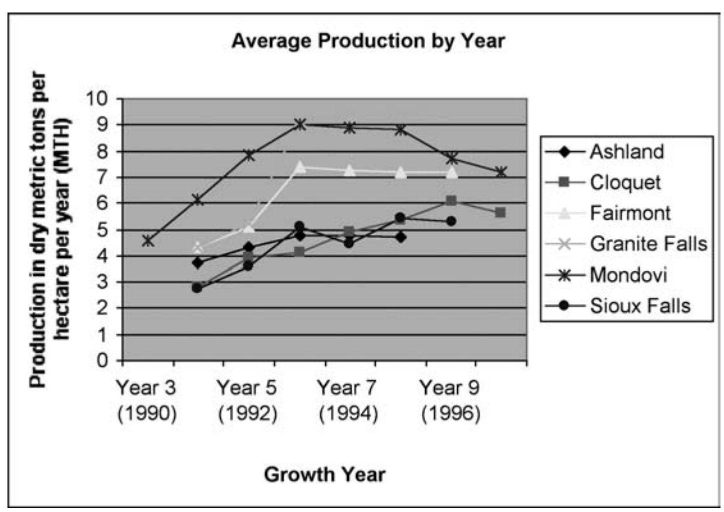
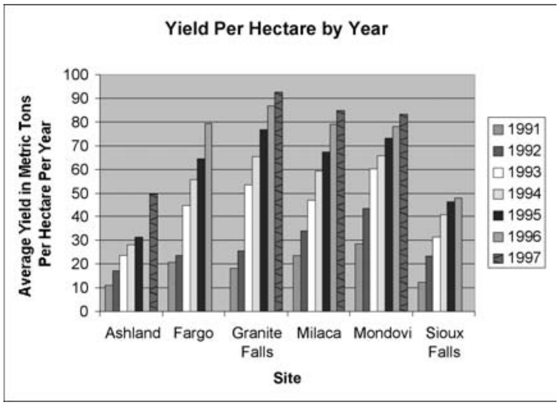


Figure 7.—Combined average production of hybrid poplar clones DN17, DN34, and DN182 planted in 1988 at six locations in the North Central U.S.



replications of plots of 25 trees (including older widely planted varieties DN34, DN17, DN182) immediately after planting for each clone on each site tested.

Figure 8.—Combined average yield per hectare for hybrid poplar clones DN17, DN34, and DN182 in six midwest plantations established in 1987.



Biomass production in the 10- and 11- year-old plantations in 1997 ranged up to 9.4 MTH (table 10). Peak production for all sites was nearly identical for the 1987 and 1988 plantings at 7 MTH (figs. 6 and 7). The best three sites (Granite Falls, Milaca, Mondovi) in the 1987 plantings had an average production of 8.3 MTH while the two best sites in 1988 (Granite Falls, Mondovi) had an average production of 9.2 MTH. Production peaked earlier in the 1988 plantings with all but Cloquet peaking in year 6 or 7. The 1987 plantings peaked later in the rotation with Granite Falls and Milaca peaking at year 10 while the other three sites peaked at year 8 or 9. After MTH peaked, the standing biomass on a site (fig. 8) continued to climb. This allowed plantation managers the option of harvesting for a few years beyond the peak production with a plantation still increasing in MTH, although at a reduced rate.

Figure 9.—Production of two hybrid poplar clones at 12 years at Granite Falls, MN (GRF); Milaca, MN (MIL); Sioux Falls, SD (SXF); and Mondovi, WI (MON), and at 8 years at Arlington, WI (ARL).

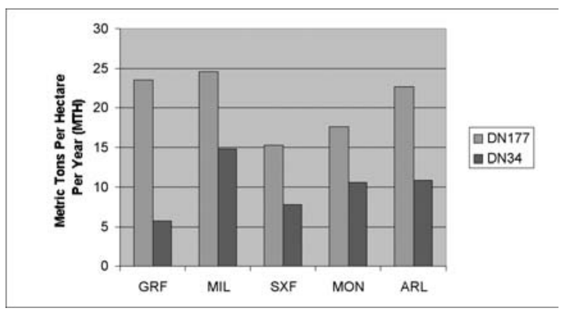


Table 10.—Biomass production in dry metric tons per hectare per year and (dry tons per acre per year) for hybrid poplar plantations planted in 1987 and 1988 at several North Central U.S. locations. Based on the mean of 25-tree replicated blocks of DN34, DN17, and DN182.

Plantation established in 1987	Ashland	Fargo	Granite Falls	Milaca	Mondovi	Sioux Falls
Year 3 (1989)	NM[1]	NM	NM	1.68 (0.75)	1.23 (0.55)	NM
Year 4 (1990)	NM	NM	NM	3.47 (1.55)	4.08 (1.82)	NM
Year 5 (1991)	2.17 (0.97)	4.15 (1.85)	3.65 (1.63)	4.71 (2.10)	5.67 (2.53)	2.46 (1.10)
Year 6 (1992)	2.85 (1.27)	3.93 (1.75)	4.26 (1.90)	5.67 (2.53)	7.24 (3.23)	3.88 (1.73)
Year 7 (1993)	3.36 (1.50)	6.39 (2.85)	7.62 (3.40)	6.73 (3.00)	8.59 (3.83)	4.48 (2.00)
Year 8 (1994)	3.52 (1.57)	7.17 (3.20)	8.18 (3.65)	7.40 (3.30)	8.23 (3.67)	5.09 (2.27)
Year 9 (1995)	3.50 (1.56)	7.17 (3.20)	8.52 (3.80)	7.49 (3.34)	8.11 (3.62)	5.13 (2.29)
Year 10 (1996)	NM	7.94 (3.54)	8.65 (3.86)	7.89 (3.52)	7.80 (3.48)	4.77 (2.13)
Year 11 (1997)	4.04 (1.80)	NM	8.43 (3.76)	7.71 (3.44)	7.55 (3.37)	NM

Plantations established in 1988	Ashland	Cloquet	Fairmont	Granite Falls	Mondovi	Sioux Falls
Year 3 (1990)					4.60 (2.05)	NM
Year 4 (1991)	3.74 (1.67)	2.80 (1.25)	4.33 (1.93)	4.33 (1.93)	6.12 (2.73)	2.76 (1.23)
Year 5 (1992)	4.33 (1.93)	3.92 (1.75)	5.09 (2.27)	5.22 (2.33)	7.85 (3.50)	3.59 (1.60)
Year 6 (1993)	4.77 (2.13)	4.15 (1.85)	7.02 (3.13)	9.12 (4.07)	8.97 (4.00)	5.09 (2.27)
Year 7 (1994)	4.77 (2.13)	4.93 (2.20)	7.24 (3.23)	9.48 (4.23)	8.90 (3.97)	5.45 (2.43)
Year 8 (1995)	4.69 (2.09)	5.38 (2.40)	7.17 (3.20)	9.46 (4.22)	8.83 (3.94)	5.42 (2.42)
Year 9 (1996)	NM	6.05 (2.70)	7.17 (3.20)	9.26 (4.13)	7.71 (3.44)	5.27 (2.35)
Year 10 (1997)	NM	5.6 (2.50)	NM	NM	7.20 (3.21)	NM

[1]NM = no measurements made to calculate yields.

DISCUSSION

This study confirms that successful production of hybrid poplars on 5- to 10-year rotations in the North Central United States will require disease resistant clones for establishing plantations. Results of these clonal trials support previous recommendations that clones be tested under local conditions before large areas are planted. Many clones exhibited good early growth but failed mid-way in the rotation because of their susceptibility to disease. Some clones that did not rank as top clones at mid-rotation were the top producers at the end of the rotation.

From 1989 to 1992, rooted stock of hard to root clones was included in the clonal trials. They are included in the ranking of all clones at all sites in appendix 3 and include pure *P. deltoides* and the *P. alba*-hybrid NC5399. Many of these rank very high and may warrant further testing. Comparison between rooted and unrooted stock is difficult due to differences in growth and survival in the establishment year. Evaluation of production costs may determine whether rooted stock of selected materials may be planted in certain situations.

Establishment and growth of all poplar clones is influenced by environmental and cultural stresses. Competing weeds are the most important stress factor in decreasing poplar plantation success (Hansen and Netzer 1985). Plantation growth has improved where land managers' efforts in the establishment year to control weeds continued as late as August. Hybrid poplar growth in August often makes up a large portion of the growth for the year in the Midwest U.S. Poplar growth is reduced throughout the life of the plantation by competing weeds until they are controlled chemically, mechanically, or by shading of the plantation canopy.

Good site preparation is the next critical factor for success and makes controlling weeds much easier. For good poplar growth, sites should have deep, fertile sandy-loam to clay-loam soils with a pH between 5 and 7.5, and should be well drained, but not droughty (Hansen *et al.* 1993). Local testing to determine clone-site matching is critical. Selection of good sites can be difficult and not necessarily tied to one factor. For example, table 7 lists the best and worst sites that occur on a generally accepted productive soil, a silt loam.

Other site factors including climate, drainage, and location must be considered. Soils with high pH (>7.8) will likely be difficult to establish poplar plantations on. Plantations that we established in 1987-88 were planted during a historic (100 year) drought that may have initially reduced growth. We also recorded years with record rainfall on several sites. Despite these weather events of historic proportions, we were able to successfully establish poplar plantations. Appropriate cultural methods used on good sites apparently can overcome severe weather in plantation establishment.

Previous mid-rotation clonal recommendations (Hansen *et al.* 1994) included nine clones (DN34, DN17, DN182, DN2, DN5, DN70, NM6, NE222, and I45-51). Our ranking in table 6 lists seven of these with index scores of 100 or more on at least one site. Clone DN17 and DN182 did not have an index score of 100 or greater at any site. In table 4 we find all previously recommended clones in the top 12 at least 3 of the 6 years measured. It should be noted, however, that in years 10 and 11 only 12 clones had index scores high enough to be included in the rankings. New clones not previously recommended have ranked consistently high and in some cases higher than previously recommended clones. These include DN177, DN154, DN164, DN21, DN170, NM2, and NE264.

Biomass production in North Central hybrid poplar plantations tested was greater than 6.7 MTH. Yields on better sites average near or slightly above 9 MTH. Generally, peak production at 2.4 by 2.4 m spacing will be between years 7 and 10 in the Midwest U.S. with adequate weed control, limited fertilization, and non-selected clones. The potential for greater production through clonal selection can be seen if we calculate the yield of DN177 and compare the MTH to the standard clone DN34 on the same site at the same age (fig. 9). DN177 has a production of 22.6 MTH at Arlington, WI, compared to 7.2 MTH for DN34 at 8 years. At Granite Falls, MN, the 12-year-old planting would have a yield of 23.5 MTH for DN177 compared with 5.7 MTH for DN34. Although these data are calculated from unreplicated small plots, they do illustrate the potential. Clonal breeding and selection, mid-rotation fertilization, and improved weed control all have the potential to greatly increase the yields reported here. Landowners must test clones on their particular sites to determine suitability. Local testing of promising poplar clones and use of the best cultural practices available will ensure successful poplar plantations.

Literature Cited

Buhler, D.D.; Netzer, D.A.; Riemenschneider, D.E.; Hartzler, R.G. 1998. Weed management in short rotation poplar and herbaceous perennial crops grown for biofuel production. Biomass and Bioenergy. 14: 385-394.

Dickmann, D.I.; Stuart, K.W. 1983. The culture of poplars in Eastern North America. East Lansing, MI: Michigan State University Department of Forestry. 168 p.

Dickmann, D.I.; Isebrands, J.G.; Eckenwalder, J.E.; Richardson, J., eds. 2001. Poplar culture in North America. Ottawa, ON, Canada: NRC Research Press. 397 p.

Hansen, E.A.; Netzer, D.A. 1985. Weed control using herbicides in short-rotation intensively cultured poplar plantations. Res. Pap. NC-260. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Hansen, E.A.; Netzer, D.A.; Tolsted, D.N. 1993. Guidelines for establishing poplar plantations in the north-central U.S. Res. Note NC-363. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

Hansen, E.A.; Ostry, M.E.; Johnson, W.D.; Tolsted, D.N.; Netzer, D.A.; Berguson, W.E.; Hall, R.B. 1994. Field performance of *Populus* in short-rotation intensive culture plantations in the north-central U.S. Res. Pap. NC-320. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 13 p.

Netzer, D.A.; Hansen, E.A. 1994. Establishment and tending of poplar plantations in north-central U.S. In: Stokes, B.J.; McDonald, T.P., eds. IEA/BA task 9 activity 1 short rotation intensive culture forestry; 1994 March 1-3; Mobile, AL. Mobile, AL: IEA/BA SRIC Mechanization: 79-87.

Ostry, M.E.; Berguson, W.E. 1993. Selecting hybrid poplars to reduce disease risk may also reduce biomass yield. Tree Planters' Notes. 44(3): 128-131.

Tuskan, G.A. 1998. Short-rotation woody crops: What we know and what we need to know. Biomass and Bioenergy. 14: 307-315.

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Conversion Factors for Commonly Used English and Metric Units

Multiply by X to convert metric to U.S. X	Multiply by Y to convert English to metric Y
.3937 inch	2.5400 centimeter (cm)
3.2808 foot (ft)	.3048 meter (m)
1.1023 ton (t)	.9072 metric ton (mt)
.4461 ton per acre (t/a)	2.2417 metric ton per hectare (mth)
2.4710 acre (a)	.4047 hectare (h)

Poor weed control will reduce growth and survival and will lead to plantation failure.

◀ Good weed control is essential for optimum growth and survival in poplar plantations. ▼

Biomass production equations were developed from periodic tree harvest.

Choose poplar plantation sites that have deep, fertile sandy-loam to clay-loam soil with a pH between 5 and 7.5 for best results. Test soil fertility, and fertilize according to corn recommendations. Nitrogen is the element most often deficient.

Selection of disease resistant poplars is critical to plantation success.

Appendix 1—

Description of *Populus* plantations established from 1987 to 1992 in Minnesota, Wisconsin, and North and South Dakota

Milaca, MN 1987

Located on private land in east central Minnesota. The 1987 hybrid trial is planted in a rocky, low-lying field that was formerly in hay and pasture. The water table is close to the ground surface often flooding with spring snowmelt and heavy precipitation. Early weed control was adequate mainly through cultivation and hand weeding. Septoria canker and sunscald are both present. The planting is protected from wind by woodlots on two sides. Good growth of poplars may be related to the high water table.

Milaca, MN 1989

Located on higher ground just west of the 1987 planting and does not benefit from a high water table. The soil is somewhat rocky, and was used for hay production prior to planting poplars. Control of weeds was adequate. Sunscald is present on some clones causing severe scarring of the trunks. Cankering is severe on stems of many clones. The planting is protected on two sides with native woodlots.

Granite Falls, MN 1987

Located in south central Minnesota just east of the Northern States Power plant on company land. The plantation is in a low-lying area on the Minnesota River flood plain. It is considered good agricultural soil and was used mostly for alfalfa production. The planting is protected on one side with natural woodlot and on another by high road banks. Several clones were removed early in the rotation due to relocation of an adjacent road. Outbreaks of cottonwood leaf beetles damaged new tree growth throughout the plantation rotation.

Mondovi, WI 1987

Located in west central Wisconsin on private land at the northern edge of the driftless (unglaciated) coulee region. The planting is on a southwest-facing slope protected by natural woodlots and steep terrain. This site is considered a productive agricultural site. It was in corn production until 1986. Heavy weed cover was removed in 1987 prior to planting. Weed control was adequate in the first 3 years followed by an invasion of taller weeds including giant ragweed. First-year tree growth was poor due to drought conditions but subsequent growth was considered good.

Mondovi, WI 1988

The 1988 hybrid trial is located adjacent to the 1987 planting on a southeast-facing slope. This planting has an agricultural history similar to the 1987 planting. Growth early in the rotation was exceptional. A dramatic reduction in growth and increases in stem disease occurred in the second half of the rotation from unknown causes, possibly from contaminated runoff from a nearby gravel pit.

Mondovi, WI 1990

This plantation is located near the 1987 and 1988 plantings and has similar history and growth. This site was first planted in 1989 and failed due to poor weed control. There is concern that coppicing from the 1989 planting may be confused with trees in the 1990 planting.

Lancaster, WI 1991

Located at the University of Wisconsin-Lancaster Experimental Farm in the southwest corner of Wisconsin's driftless area. The site is highly productive agricultural landscape that is farmed for corn in contour strips alternated with grass strips to prevent erosion. The plots are located in several of these 20-foot-wide strips with the last contour next to a natural woodlot. Growth was reduced in the trees nearest the woods from shading and continued deer browse. This was one of the more productive sites relative to overall growth and survival of many clones. A red clay layer between the topsoil and limestone bedrock transfers water downslope, creating a good moisture supply for the tree roots. Grass, mainly foxtail, caused tree growth reduction in the establishment years.

Hancock, WI 1991

Located at the University of Wisconsin-Hancock Experimental Farm in central Wisconsin. The hybrid trial is planted on a light sandy soil that is subject to drought. The site was in hay before trees were planted. Potatoes grown under irrigation are the typical crop for this area. The plantation is in the open and not protected from wind. Early weed control was adequate with severe sunscald and stem canker present on many clones. Poplar plantings on this site would do best with irrigation and fertilization.

LaCrosse, WI 1992

Located on the Coulee Experimental Forest managed by the Wisconsin Department of Natural Resources. The site is on a southwest-facing slope on a ridgetop in the driftless area of west central Wisconsin. The field was in continual hay production until it was site prepped for tree planting. The soil is a somewhat eroded silt loam over limestone bedrock. The tree plots are planted in 20-foot-wide contour strips separated by grass. Early weed control was difficult because the slope allowed for tillage in only one direction. Intense deer browse significantly reduced first-year growth. An electric fence installed at the end of the first season reduced but did not eliminate damage. The planting is exposed to south and southwest winds. Growth varies across the site with the best growth on the upslope grading to poorer growth on the downslope. Disease incidence is minimal.

Grand Rapids, MN 1989

Located in north central Minnesota at the University of Minnesota's North Central Research Station Nursery. The planting is on a sandy loam soil that has been in experimental field plots for many years. Several hybrid clones are growing well here that are not growing well at most field sites. Tree pruning has produced severe stem scarring on lower stems. Weed control was adequate. Sunscald affects some clones. Disease incidence appears to be low in this planting.

Grand Rapids, MN 1992

Located near the 1989 plantation. Poplars are smaller in this site than would be expected for their age. Continued deep disking may have caused some root damage to the trees. Sunscald is less than in the 1989 planting, and similar stem scars appear from pruning. Incidence of stem canker appears slightly higher here than in the 1989 planting.

Sioux Falls, SD 1987

Located on a private farm 1 hour west of Sioux Falls in southeast South Dakota. The 1987 plantation is located on fertile farmland that had been in corn and soybean production. Weed control was excellent in the establishment years. Stem cankering has caused stem breakage of many clones. Additional damage occurred to treetops and some stems from a severe ice storm in 1996. The plantation is exposed to winds except on the south side, which is protected by a woodlot.

Sioux Falls, SD 1988

The 1988 plantation is located one-fourth mile west of the 1987 plantation. Soils are poor with limited grazing occurring prior to plantation establishment. The site faces east grading into lowland to the north. The soils are rocky and eroded resulting in poor tree growth. There is heavy stem cankering here. Only 5 out of 65 clones planted were deemed good enough for measurement.

Sioux Falls, SD 1990

The plantation is located in a failed part of the 1987 plantation. Early weed control was poor resulting in failure of most of the planted stock except the rooted deltoides. In 1991 a small area was again replanted with hybrid poplar clones DN164 and DN154 surviving and showing potential for this site.

Arlington, WI 1991

Located on the University of Wisconsin Experimental Farm-Arlington in south central Wisconsin. The site consists of deep silt loam soils and was in alfalfa production prior to plantation establishment. It is protected on the south by a windbreak. Tree growth potential is very high although many trees suffer from stem canker, sunscald, and wind damage.

Cloquet, MN 1988

Located on private land in northeast Minnesota. The 1988 plantation is on a nutrient poor silt loam soil intermixed with gravel and small rock deposits. Agricultural production is considered marginal on this site with much of the history in hay production. This plantation has had the lowest disease incidence through most of the rotation of any planting site in our trials. A number of NE clones that are susceptible to stem cankers perform better here than the same clones at other sites. This site is exposed to winds from the north.

Belgrade, MN 1990

Located on private land in central Minnesota east and south of Westport. The site was formerly in corn and small grains. The west side of the plantation is a low poorly drained area that produced very poor tree growth. Vigor and tree size are better grading to the higher ground on the east side of the plot. Early weed control was limited especially on the wet east edge. Stem canker is present but little tree breakage has been observed. No sunscald has been observed. Ranking of the clones on this site can be related to location in the plot in addition to disease factors. The plantation is unprotected and subject to prairie winds.

Blackduck, MN 1991

Located on private land in north central Minnesota. This site is low lying with infertile sandy loam soils. Trees are smaller than on other sites planted in 1991. Early weed control was poor contributing to the reduced tree growth. Trees are damaged in the upper crown due to a hail storm. Disease and sunscald are minimal on this site. The planting is protected from wind by native aspen stands.

Fargo, ND 1987

Located on private land near the intersection of Interstates 94 and 29 on the southwest edge of Fargo. The soils are poorly drained clay with an area on the west side mixed with rubble deposits left from road construction. The site is productive for small grains and melons but frequent spring flooding combined with poor drainage has reduced tree growth. The site is not protected from prairie winds and is a marginal planting site at best. Only three clones were measured at 12 years. Of note is that DN2 had a growth index of greater than 100 (104). Subsequent attempts to establish plantings in 1988, 1989, and 1992 failed. Severe winter damage along with cankering occurs on the surviving trees.

Appendix 2—

Trees harvested from central U.S. plantations by age. Tree diameters and total tree dry weights used to establish yield tables.

Site	Clone	DBH (cm)	HGT (m)	Dry wgt (Kg)	Tree age (yrs)
Ashland	DN34	13.8	10.3	40.7	7
Ashland	DN34	11.5	9.8	27.62	7
Ashland	DN34	10.3	9.3	21.88	7
Ashland	DN34	9.5	9.1	15.46	7
Ashland	DN34	8.3	7.5	15.34	5
Ashland	DN34	3.1	3.6	3.51	3
Ashland	DN34	2.7	3.4	2.09	3
Ashland	DN34	2.6	3.3	2.19	3
Ashland	DN34	1.8	2.6	1.16	3
Ashland	DN34	1.2	2.2	0.47	3
Ashland	NE308	10.1	9.2	17.66	5
Ashland	NE308	5.3	5.1	5.17	3
Ashland	NE308	4.2	4.4	4.31	3
Ashland	NE308	3.5	3.9	2.84	3
Ashland	NE308	2.8	3.3	2.48	3
Ashland	NE308	2	2.9	0.97	3
Ashland	DN182	8.9	8	19.38	5
Ashland	DN182	3.5	4.3	4.79	3
Ashland	DN182	3.3	4.2	4.29	3
Ashland	DN182	2.2	3.2	2.17	3
Ashland	DN182	2	2.7	1.49	3
Ashland	DN182	1.6	2.2	0.99	3
Ashland	DN17	13.7	11	42.8	7
Ashland	DN17	11.7	11.3	29.84	7
Ashland	DN17	10.6	10.7	22.37	7
Ashland	DN17	9.4	10.1	18.49	7
Ashland	DN17	7.8	8.1	14.73	5
Ashland	DN17	5	6.3	6.12	5
Ashland	DN17	4.2	4.1	3.96	3
Ashland	DN17	3.6	4.2	3.72	3
Ashland	DN17	3.2	3.9	2.85	3
Ashland	DN17	2.5	3.4	2.07	3
Ashland	DN17	2.2	3.1	1.67	3
Ashland	DN17	1.9	2.8	0.72	3
Ashland	Siouxland	7.5	6.7	9.6	5
Granite Falls	DN34	22.9 *		132.7	10
Granite Falls	DN34	22.2	17.5	128.2	10
Granite Falls	DN34	19.3	15.6	93.16	8
Granite Falls	DN34	18.5	16.3	83.5	8
Granite Falls	DN34	17.5	15.3	72.4	8
Granite Falls	DN34	16	15.1	61.39	8
Granite Falls	DN34	2	3.1	0.9	3
Granite Falls	DN34	3.2	4.6	2.01	3
Granite Falls	DN34	4.3	5.1	2.82	3
Granite Falls	DN34	5.2	5.6	4.23	3
Granite Falls	DN34	6.4	6.4	7.03	3
Granite Falls	NE308	3.2	4.6	1.34	3
Granite Falls	NE308	4.1	5.8	2.36	3
Granite Falls	NE308	5	6.3	3.9	3
Granite Falls	NE308	6.8	8.2	7.68	3
Granite Falls	NE308	7.6	7.4	9.7	3
Granite Falls	DN182	3.2	3.9	1.89	3
Granite Falls	DN182	4.1	5.5	3.38	3
Granite Falls	DN182	5.2	5.1	3.96	3
Granite Falls	DN182	6.7	6.9	6.94	3
Granite Falls	DN182	7.5	7.1	8.93	3
Granite Falls	DN17	2.2	3.5	1.02	3
Granite Falls	DN17	3.9	4.5	2.62	3
Granite Falls	DN17	4.7	5.6	3.22	3
Granite Falls	DN17	5	5.8	4.72	3
Granite Falls	DN17	6.3	6.4	7.32	3
Granite Falls	DN17	19.8	18.5	112.3	10
Granite Falls	DN17	20.7	18.5	124.4	10
Milaca	NE387	11.4	8.5	25.19	5
Milaca	NE387	10.6	8	22.66	4
Milaca	NE387	9.1	7.8	15.57	4
Milaca	NE387	7.4	7.2	10.05	4

Appendix 2—Continued

Site	Clone	DBH (cm)	HGT (m)	Dry wgt (Kg)	Tree age (yrs)
Milaca	NE387	6.6	6.8	7.51	4
Milaca	NE387	5.3	5.6	6.15	4
Milaca	NE54	10.3	8.6	20.43	5
Milaca	NE54	6.2	7.3	7.56	5
Milaca	NE54	10.5	8.8	23.4	4
Milaca	NE54	9.5	8.6	23.11	4
Milaca	NE54	8.4	8	17.2	4
Milaca	NE54	6.5	7.5	8.02	4
Milaca	NE54	5.7	7.3	6.84	4
Milaca	DN182	21.5	19.4	118.9	10
Milaca	DN182	19.5	18.5	84.6	10
Milaca	DN182	18.6	15.5	83.77	8
Milaca	DN182	16.5	15.8	60.74	8
Milaca	DN182	12.2	11.1	28.58	5
Milaca	DN182	12	10	25.61	4
Milaca	DN182	10	9.4	20.37	4
Milaca	DN182	5.8	7.6	6.09	4
Milaca	DN182	4.5	5.8	4.77	4
Milaca	NE308	12.9	12	28.49	5
Milaca	NE308	12.1	9.4	23.55	4
Milaca	NE308	10.2	9	15.13	4
Milaca	NE308	7.8	8	9.6	4
Milaca	NE308	5.1	6.5	3.45	4
Milaca	DN17	19.7	19.3	106.3	10
Milaca	DN17	21	18.8	98.5	10
Milaca	DN17	19.9	16	84.33	8
Milaca	DN17	14.9	15.4	55.32	8
Milaca	DN17	13.5	11.1	33.6	5
Milaca	DN17	11.1	8.9	21.28	4
Milaca	DN17	8.8	8.5	16.11	4
Milaca	DN17	5.6	7.4	5.81	4
Milaca	DN17	3.6	5	2.25	4
Milaca	DN34	20.8	18.1	115.4	10
Milaca	DN34	19.2	18.7	98	10
Milaca	DN34	13.4	9.7	35.23	5
Milaca	DN34	9.5	7.6	15.89	4
Milaca	DN34	7.2	7.4	10.97	4
Milaca	DN34	6.1	7.2	6.41	4
Milaca	DN34	3.1	5	1.7	4
Milaca	Siouxland	13.4	11.4	29.07	5
Sioux Falls	Siouxland	7	5.4	9.87	5
Sioux Falls	NE308	9	7.2	15.03	5
Sioux Falls	DN182	9	7.4	16.28	5
Sioux Falls	DN34	12.2	10.3	27.35	7
Sioux Falls	DN34	11	10.1	21.05	7
Sioux Falls	DN34	9.9	7.4	21.33	5
Sioux Falls	DN17	13.6	11.1	39.04	7
Sioux Falls	DN17	11.5	10.6	24.05	7
Sioux Falls	DN17	9.1	7.5	16.8	5
Mondovi	DN182	20.1	20.6	118.7	10
Mondovi	DN182	22	20.2	133.7	10
Mondovi	DN182	12.7	13.1	34.13	5
Mondovi	DN182	11.1	10.3	25.61	4
Mondovi	DN182	9.4	9.9	15.27	4
Mondovi	DN182	5.7	7.3	5.23	4
Mondovi	DN182	3.8	5.6	2.52	4
Mondovi	NE308	12	12.4	36.74	5
Mondovi	NE308	10.2	10.2	23.3	4
Mondovi	NE308	8.6	10.6	11.79	4
Mondovi	NE308	6.8	8.9	7.82	4
Mondovi	NE308	4.6	7	3.04	4
Mondovi	DN17	17.8	17.1	78.22	7
Mondovi	DN17	16.3	16.7	64.04	7
Mondovi	DN17	15.5	15.4	59.58	7
Mondovi	DN17	14.3	16.2	47.87	7
Mondovi	DN17	13.1	12.8	41.63	4
Mondovi	DN17	10.2	9.8	20.62	4

Appendix 2—Continued

Site	Clone	DBH (cm)	HGT (m)	Dry Wgt (Kg)	Tree age (yrs)
Mondovi	DN17	8.8	9	12.91	4
Mondovi	DN17	5.2	8	4.6	4
Mondovi	DN17	3.7	5.7	2.02	4
Mondovi	DN34	20.1	21	122.8	10
Mondovi	DN34	21	20	127.3	10
Mondovi	DN34	16.8	14.5	68.56	7
Mondovi	DN34	15.7	15.3	56.08	7
Mondovi	DN34	14.6	15.7	55.96	7
Mondovi	DN34	11.2	11.3	28.65	5
Mondovi	DN34	9.2	9.4	18.08	4
Mondovi	DN34	8.1	8.8	12.02	4
Mondovi	DN34	6.1	7.4	6.1	4
Mondovi	DN34	4.3	5.5	3.59	4
Mondovi	Siouxland	12.3	11.9	33.01	5
Fargo	DN182	14.6	11.1	46.65	8
Fargo	DN182	15.2	10.8	44.68	8
Cloquet	DN182	17.6	15	65	9
Cloquet	DN182	16.4	15.1	60.4	9

Appendix 3—

Biomass production in dry metric tons per hectare per year for hybrid poplar clones DN17, DN34, and DN182 established in 1987 and 1988 at several Midwest U.S. locations. To convert to tons per acre, multiply by 0.4461.

Plantations established in 1987		Ashland	Fargo	Granite Falls	Milaca	Mondovi	Sioux Falls
Year 9 (1995)	DN17	4.9	7.2	8.5	8.5	8.5	5.6
	DN34	2.5	NM[1]	8.5	6.1	7.4	4.3
	DN182	NM	7.0	NM	7.9	8.5	5.6
Year 10 (1996)	DN17	NM	8.3	8.3	8.5	7.6	4.3
	DN34	NM	NM	9.0	6.7	7.6	4.5
	DN182	NM	7.4	NM	8.3	8.1	5.4
Year 11 (1997)	DN17	4.7	NM	7.6	8.5	7.6	NM
	DN34	4.0	NM	9.2	6.7	7.4	NM
	DN182	NM	NM	NM	8.1	7.6	NM

Plantations established in 1988		Ashland	Cloquet	Fairmont	Granite Falls	Mondovi	Sioux Falls
Year 8 (1995)	DN17	3.8	NM	6.5	10.1	7.2	4.7
	DN34	5.2	5.2	7.4	9.2	10.1	6.7
	DN182	4.9	5.6	7.6	9.0	9.4	4.7
Year 9 (1996)	DN17	NM	NM	6.5	9.4	7.0	4.5
	DN34	NM	5.8	7.6	9.2	8.3	6.1
	DN182	NM	6.3	7.6	9.0	8.1	NM
Year 10 (1997)	DN17	NM	NM	NM	NM	6.5	NM
	DN34	5.2	5.4	NM	NM	7.4	NM
	DN182	4.9	5.6	NM	NM	7.6	NM

[1]NM = not measured.

Appendix 4—

Rank ([1]) of hybrid poplar clones based on DBH, DBH adjusted for survival, and DBH adjusted for survival x (form + canker). Sites are listed by age measured. Most trees were planted as unrooted hardwood cuttings. Hard to root clones were included in 1989 through 1992 as rooted stock and are marked with an (*). Criteria for scoring rank, form, and disease are located on the bottom of the final page of this appendix.

Site	Clone	Number measured	Standard deviation of mean	Rank by DBH (cm)	Clone	Rank adjusted for survival	Clone	Rank/ surv/form + disease	Age (yrs)
Grand Rapids, MN 1992 ([2])	DN5	16	4.25	15.23	DN5	15.24	DN5	121.92	7
	NM6	16	2.12	15.09	NM6	15.09	NM6	120.72	7
	DN182	16	3.32	12.61	DN182	12.61	DN164	85.92	7
	DN55	16	2.84	12.44	DN55	12.44	DN182	75.66	7
	DN17	16	1.53	11.1	DN17	11.1	DN55	74.64	7
	DN2	7	2.61	10.79	DN164	10.74	DN17	66.6	7
	DN164	16	1.27	10.74	NE222	10.51	NE222	63.06	7
	NE222	16	2.75	10.51	DN70	8.49	DN70	59.43	7
	NE264	11	1.9	9.65	DN34	8.3	DN34	49.8	7
	DN70	15	2.08	9.06	NE264	6.63	NE264	39.78	7
	DN34	15	2.75	8.85	I45-51	5.71	I45-51	34.26	7
	I45-51	15	2.44	6.09	DN2	4.72	DN2	23.6	7
LaCrosse, WI 1992	NC5339*	16	1.8	14.13	NC5339*	14.13	NC5339*	98.91	7
	DN154	14	2.55	12.13	DN154	10.61	DN17	78.56	7
	DN1	14	4.87	11.79	DN1	10.31	DN154	74.27	7
	NM6	8	2.57	11.78	DN174	9.82	I45-51	73.04	7
	IS42.7*	10	3.87	10.97	DN17	9.82	IS31*	70.88	7
	DN177	12	3.68	10.8	DN182	9.37	DN164	69.84	7
	DN164	13	1.95	10.75	I45-51	9.13	DN177	64.8	7
	DN182	14	1.81	10.71	IS31*	8.86	DN34	62.24	7
	DN174	15	3.34	10.47	DN164	8.73	DN1	61.86	7
	NM2	12	5.89	10.41	DN132	8.33	ISU107*	57.4	7
	DN17	16	2.46	9.83	ISU107*	8.2	DN182	56.22	7
	DN132	14	2.88	9.52	DN177	8.1	NM2	54.67	7
	ISU107*	14	2.71	9.37	NM2	7.81	DN132	49.98	7
	DN2	9	2.05	9.2	DN34	7.78	DN174	49.1	7
	I45-51	16	2.48	9.13	IS42.7*	6.86	IS42.7*	48.02	7
	IS31*	16	2.62	8.86	DN5	6.69	DN5	46.83	7
	DN5	13	1.92	8.23	NE222	6.14	NE222	42.98	7
	DN34	16	1.93	7.78	NM6	5.89	NM6	41.23	7
	NE222	15	5.57	6.55	DN2	5.18	DN2	31.08	7
Arlington, WI 1991	DN177	12	3.34	23.13	D109*	22.75	D109*	159.25	8
	D109*	4	1.76	22.75	D107*	20.575	D107*	144.02	8
	DN154	8	3.15	21.94	NC5339*	17.5	DN177	138.72	8
	T50 197	6	3.59	21.92	DN177	17.34	DN164	136.56	8
	I45-51	6	0.98	21.82	NE222	17.11	NC5339*	122.5	8
	NM2	11	5.22	20.855	DN164	17.07	NE222	119.77	8
	D107*	4	2.4	20.58	D110*	16.95	D110*	118.65	8
	NE222	14	2.77	19.55	NM6	16.62	DN154	87.76	8
	DN182	10	3.23	19.31	NM2	14.33	DN74	78.9	8
	NC5339*	15	3.06	18.67	DN74	13.15	DN70	71.4	8
	DN5	9	2.17	18.59	DN182	12.07	I45-51	57.26	8
	DN2	6	6.96	18.25	DN70	11.9	T50 197	41.05	8
	DN164	15	2.43	18.21	DN154	10.97	DN182	36.21	8
	DN34	7	2.22	17.8	DN5	10.46	NM6	33.24	8
	NM6	15	3.98	17.73	T50 197	8.21	DN5	31.38	8
	D110*	4	1.05	16.95	I45-51	8.18	NM2	28.66	8
	DN70	12	3.02	15.87	DN34	7.79	DN34	23.37	8
	DN74	14	2.11	15.03	DN2	6.84	DN17	20.84	8
	DN17	6	4.3	13.88	DN17	5.21	DN2	13.68	8

Appendix 4—Continued

Site	Clone	Number measured	Standard deviation of mean	Rank by DBH (cm)	Clone	Rank adjusted for survival	Clone	Rank/ surv/form + disease	Age (yrs)
Hancock, WI 1991	NM2	10	3.52	20.51	DN74	13.81	NC5339*	91.77	8
	T50 197	10	1.81	18.14	DN154	13.44	T50 197	56.7	8
	NC5339*	14	3.06	14.99	NC5339*	13.11	DN164	56.28	8
	NM6	11	1.74	14.86	NM2	12.82	DN5	56.1	8
	DN2	14	2.08	13.95	DN70	12.37	NE222	55.5	8
	DN74	16	1.5	13.81	DN2	12.2	DN177	55.2	8
	NE222	11	2.3	13.46	DN182	11.94	DN154	53.76	8
	DN154	16	2.39	13.44	T50 197	11.34	DN2	48.8	8
	DN70	15	3.38	13.19	DN177	11.04	DN182	47.76	8
	DN182	15	3.21	12.73	NM6	10.22	DN74	41.43	8
	DN177	11	3.4	12.62	DN17	10.02	NM2	38.46	8
	I45-51	7	3.29	12.2	DN164	9.38	DN70	37.11	8
	D121*	4	2.59	12.18	DN5	9.35	DN34	37	8
	DN164	13	2.6	11.55	NE222	9.25	D121*	21.258	8
	DN17	14	1.51	11.46	DN34	9.25	NM6	20.44	8
	DN5	14	1.73	10.69	I45-51	5.34	DN17	20.04	8
	DN34	14	1.62	10.57	D121*	3.04	I45-51	16.02	8
Lancaster, WI 1991	DN154	11	2.44	18.95	NM2	17.37	NE222	127.2	8
	NM2	15	2.67	18.53	DN173	17.23	NM2	121.38	8
	DN173	15	3.23	18.38	NM6	16.62	NM6	116.34	8
	NM6	15	3.46	17.73	NC5339*	16.46	D109*	111.16	8
	NE222	15	1.28	16.96	NE222	15.9	DN131	109.62	8
	NC5339*	16	4.58	16.46	D109*	15.88	D113*	109.41	8
	DN174	12	2.25	16.23	DN131	15.66	D193.5*	105.91	8
	T50 197	14	3.07	15.94	D113*	15.63	DN34	104.3	8
	D109*	4	1.75	15.88	DN38	15.19	NC5339*	98.76	8
	DN74	9	5.15	15.73	D193.5*	15.13	DN21	92.05	8
	DN131	16	2.17	15.66	DN34	14.9	DN154	91.17	8
	D113*	4	2.58	15.63	DN70	14.49	DN38	91.14	8
	DN16	14	2.24	15.62	D121*	13.98	I45-51	91.07	8
	DN5	13	4.2	15.58	T50 197	13.94	DN70	86.94	8
	DN70	15	3.24	15.45	DN16	13.67	D121*	83.88	8
	D112*	3	2.2	15.37	DN21	13.15	DN2	83.65	8
	DN38	16	1.37	15.19	DN154	13.02	DN177	83.39	8
	D193.5*	4	1.39	15.12	I45-51	13.01	DN16	82.02	8
	DN34	16	2.29	14.9	DN174	12.81	D112*	80.64	8
	I45-51	14	1.83	14.87	DN5	12.66	DN174	76.86	8
	DN177	13	3.64	14.66	DN182	12.57	DN5	75.96	8
	DN1	11	2.43	14.4	DN2	11.95	T50 197	69.7	8
	DN182	14	2.55	14.37	DN177	11.91	DN164	69.04	8
	DN17	13	2.26	14.14	D112*	11.52	DN17	68.94	8
	D121*	4	5.75	13.98	DN17	11.49	DN173	68.92	8
	DN164	10	2.33	13.8	DN1	9.9	DN182	62.85	8
	DN21	16	3.69	13.15	DN74	8.85	DN74	61.95	8
	DN2	15	3.83	12.75	DN164	8.63	DN1	59.4	8

Appendix 4—Continued

Site	Clone	Number measured	Standard deviation of mean	Rank by DBH (cm)	Clone	Rank adjusted for survival	Clone	Rank/ surv/form + disease	Age (yrs)
Blackduck, MN 1991	NM2	14	1.88	11.19	DN2	10.89	D121*	75.6	8
	DN2	9	1.87	10.89	D121*	10.8	DN164	75.52	8
	D121*	4	1.1	10.8	NM2	9.79	NM2	68.5	8
	NM6	14	2.39	10.48	DN164	9.44	DN2	65.33	8
	DN164	15	0.87	10.07	NM6	9.17	NM6	55.02	8
	DN17	13	3.21	9.48	DN34	8.4	DN34	50.4	8
	DN34	15	3.2	9	DN17	7.7	DN17	46.2	8
	DN5	12	3.5	8.67	DN5	6.5	I45-51	40.25	8
	NE222	8	3.45	8.15	I45-51	5.75	DN5	39	8
	DN182	11	2.71	7.76	DN182	5.34	DN182	32.04	8
	I45-51	13	1.51	7.08	NE222	4.23	NE222	29.61	8
	DN70	9	1.98	5.77	DN70	3.24	DN70	16.2	8
Sioux Falls, SD 1991	DN164	11	2.27	11.05	DN164	7.59	DN164	45.54	8
	DN154	4	2.71	9.95	DN154	2.49	DN154	17.43	8
Belgrade, MN 1990	DN132	12	4.79	21.27	DN132	15.95	DN164	106.96	9
	DN5	9	3.51	16.54	DN164	13.37	DN132	95.7	9
	DN170	10	3.74	16.45	DN154	12.57	DN154	87.99	9
	NE222	10	2.55	15.84	DN34	12.08	DN34	72.48	9
	DN154	13	5.08	15.48	DN17	10.4	I45-51	65.52	9
	DN164	14	2.52	15.28	DN170	10.28	DN170	61.68	9
	DN182	10	1.44	15.16	NE222	9.9	DN70	56	9
	I45-51	10	2.59	14.97	DN182	9.475	DN5	55.86	9
	DN17	12	2.89	13.87	I45-51	9.36	DN17	52	9
	DN34	15	2.17	12.89	DN5	9.31	NE222	49.5	9
	DN2	9	3.04	12.67	DN70	8	DN182	37.9	9
	DN70	12	2.38	10.67	DN2	7.125	DN2	35.63	9
	NM6	7	3.6	7.43	NM6	3.25	NM6	19.5	9
Mondovi, WI 1990	DN70	3	3.31	21.47	NM2	15.26	DN170	108.32	9
	NM2	12	4.07	20.35	DN154	14.99	I45-51	101.85	9
	DN154	13	3.3	18.45	I45-51	14.55	DN2	94.99	9
	DN2	12	3.6	18.09	DN2	13.57	DN21	94.22	9
	DN170	12	3.34	18.06	DN170	13.54	DN164	92.24	9
	DN21	12	3.13	17.94	NM6	13.51	DN154	89.94	9
	DN182	12	4.28	17.39	DN21	13.46	NE222	87.81	9
	NM6	13	3.73	16.62	DN182	13.04	DN34	85.4	9
	I45-51	15	2.71	15.52	NE222	12.53	DN177	70.42	9
	DN164	12	3.06	15.38	DN34	12.2	DN182	65.2	9
	DN177	11	2.78	14.64	DN164	11.53	NM2	61.04	9
	NE222	14	3.58	14.32	DN177	10.06	DN17	56.94	9
	DN34	15	3	13.01	DN17	9.49	NM6	40.53	9
	DN17	13	3.26	11.68	DN70	4.02	DN70	24.12	9
	DN5	6	3.63	10.45	DN5	3.92	DN5	19.6	9
Sioux Falls, SD 1990	D110*	6	2.8	18.38	D108*	16.54	D108*	115.78	9
	D108*	8	2.78	16.54	D110*	6.89	D110*	48.23	9

Appendix 4—Continued

Site	Clone	Number measured	Standard deviation of mean	Rank by DBH (cm)	Clone	Rank adjusted for survival	Clone	Rank/ surv/form + disease	Age (yrs)
Grand Rapids, MN 1989	DN131	14	2.17	20.86	DN2	20.8	DN5	138.53	10
	DN2	16	4.01	20.8	DN5	19.79	NM6	128.73	10
	DN5	16	3.87	19.79	DN131	18.25	DN131	109.5	10
	D113*	7	2.62	18.81	NM6	18.39	DN2	104	10
	D125*	6	1.17	18.75	DN182	16.7	NM2	96.96	10
	NM2	14	1.7	18.47	NM2	16.16	DN182	83.5	10
	NM6	16	3.12	18.39	DN34	14.64	DN70	77.28	10
	DN34	13	3.26	18.03	DN17	13.9	DN34	58.56	10
	DN182	15	2.34	17.81	DN70	12.88	D125*	56.24	10
	DN70	12	4.95	17.18	D113*	8.23	DN17	55.6	10
	DN17	14	2.75	15.88	D125*	7.03	D113*	49.38	10
	I45-51	3	0.75	12.93	I45-51	2.42	I45-51	16.94	10
Milaca, MN 1989	I45-51	10	3.71	16.52	NM6	15.25	NM6	106.75	10
	NM6	15	3.95	16.27	DN5	14.58	DN5	102.06	10
	DN34	13	2.73	14.59	DN2	14.49	NE222	84.8	10
	DN5	16	3.89	14.58	DN182	14.41	DN70	72.72	10
	DN2	16	2.24	14.49	DN17	12.23	DN2	72.45	10
	DN182	16	3.31	14.41	DN70	12.12	I45-51	72.31	10
	DN74	11	4.01	14.26	DN34	11.85	DN74	49.05	10
	NM2	13	5.32	14.15	NM2	11.5	NM2	46	10
	NE222	12	2.55	14.13	NE222	10.6	DN182	43.23	10
	DN70	14	4.03	13.86	I45-51	10.33	DN17	36.69	10
	DN17	15	3.21	13.05	DN74	9.81	DN34	35.55	10
Cloquet, MN 1988	NE295	9	3.53	20.9	DN131	15.35	DN131	122.8	11
	NE49	8	3.46	20.53	NE252	15.35	NE252	122.8	11
	NE33	4	2.16	19.88	DN21	14.19	DN21	113.52	11
	NE54	8	4.83	19.64	NM6	13.33	NM6	106.4	11
	DN131	14	2.86	17.54	DN181	12.78	DN181	102.24	11
	NE252	14	2.25	17.54	NE242	12.61	NE295	82.32	11
	NE265	11	2.94	16.92	NE295	11.76	NE265	81.41	11
	NE222	5	7.85	16.86	NE300	11.69	DN70	77.56	11
	NE242	12	2.29	16.81	NE265	11.63	NE242	75.66	11
	NE300	12	3.23	15.58	DN70	11.08	NE300	70.14	11
	DN70	12	5.03	14.78	NE49	10.27	NE49	61.62	11
	I45-51	7	3.44	14.61	NE54	9.82	DN182	58	11
	DN181	14	1.4	14.6	DN182	7.25	I45-51	51.12	11
	DN182	8	2.72	14.5	I45-51	6.39	NE222	42.16	11
	DN21	16	1.75	14.19	NE222	5.27	NE33	39.76	11
	NM6	16	1.89	13.33	NE33	4.97	NE54	39.28	11

Appendix 4—Continued

Site	Clone	Number measured	Standard deviation of mean	Rank by DBH (cm)	Clone	Rank adjusted for survival	Clone	Rank/ surv/form + disease	Age (yrs)
Mondovi, WI 1988	DN2	9	5.33	28.08	DN70	17.59	DN70	105.54	11
	I45-51	7	6.82	26.81	NE35	16.6	45-1	105.42	11
	NE35	11	5.74	24.14	DN2	16.19	NE222	98.49	11
	DN182	6	5.56	24.1	DN21	16.13	I45-51	93.84	11
	NM6	10	5.44	23.88	45-1	15.06	NM6	89.58	11
	NE222	10	5.74	22.51	NM6	14.93	NE35	83	11
	45-1	11	7.71	21.9	DN17	14.81	DN2	64.76	11
	DN17	11	4.38	21.55	NE222	14.07	DN21	64.52	11
	DN34	8	3.92	21.2	I45-51	11.73	DN17	59.24	11
	DN21	13	4.96	19.85	DN34	10.6	DN34	42.4	11
	DN70	15	5.26	18.76	DN182	9.03	DN182	36.12	11
Sioux Falls, SD 1988	NE264	6	2.48	23.38	DN70	16.68	NM6	96.48	11
	DN70	14	3.79	19.06	NM6	16.08	DN70	83.4	11
	DN34	12	2.11	16.58	DN34	12.43	DN34	74.58	11
	NE222	8	4.46	16.25	NE264	8.77	NE264	61.39	11
	NM6	16	2.16	16.08	NE222	8.13	NE222	40.65	11
Fargo, ND 1987	DN2	13	3.79	19.58	DN5	16.01	DN2	111.3	12
	NE222	11	3.64	17.31	DN2	15.9	DN5	96.06	12
	DN5	15	3.53	17.08	NE222	11.9	NE222	71.4	12
Granite Falls, MN 1987	DN174	10	5.21	32.34	DN177	23.57	DN177	164.99	12
	I476	4	6.06	32.1	DN5	22.74	DN5	159.18	12
	I45-51	9	2.88	26.82	DN174	20.21	DN174	121.26	12
	DN2	7	6.51	26.66	I45-51	15.09	I45-51	105.63	12
	DN5	14	4.23	25.99	NM2	14.36	NE222	60.41	12
	DN177	15	4.15	25.14	DN2	11.66	DN170	52.22	12
	DN17	4	1.23	24.05	NE222	8.63	I476	48.18	12
	DN170	5	8.04	23.88	I476	8.03	NM2	43.08	12
	NE222	6	6.34	23.02	DN170	7.46	DN2	34.98	12
	NM2	10	6.14	22.98	DN17	6.01	DN34	28.25	12
	DN34	4	6.36	22.6	DN34	5.65	DN17	24.04	12
Milaca, MN 1987	I476	10	8.14	28.66	DN177	21.65	DN177	151.55	12
	45-1	9	5.35	27.29	NM2	20.41	NE264	136.88	12
	DN170	3	2.27	26.3	DN74	20.12	I476	125.37	12
	DN2	11	5.38	26.25	DN2	18.05	DN74	120.72	12
	NE264	11	3.64	24.89	I476	17.91	DN5	99.42	12
	DN74	13	6.83	24.76	NE264	17.11	I45-51	97.58	12
	DN177	14	5.72	24.74	DN5	16.57	45-1	92.16	12
	DN182	9	6.77	23.34	45-1	15.36	DN2	90.25	12
	DN34	10	4.02	22.47	NE222	14.77	NE222	88.62	12
	NM2	15	5.39	21.77	DN17	14.76	DN1	82.86	12
	DN5	13	6.77	20.39	DN34	14.04	DN34	70.2	12
	I45-51	11	5.61	20.281	I45-51	13.94	NM2	61.23	12
	DN1	11	2.6	20.09	DN1	13.81	DN17	59.04	12
	DN17	12	6.14	19.68	DN182	13.13	DN182	52.52	12
	NE222	13	5.41	18.18	DN170	4.93	DN170	34.51	12

Appendix 4—Continued

Site	Clone	Number measured	Standard deviation of mean	Rank by DBH (cm)	Clone	Rank adjusted for survival	Clone	Rank/ surv/form + disease	Age (yrs)
Mondovi, WI 1987	DN182	4	1.53	27.2	NM2	22.58	45-1	141.61	12
	45-1	12	5.71	26.33	DN2	21.1	DN177	127.12	12
	DN2	13	4.12	25.97	45-1	20.23	NE222	103.32	12
	NE264	7	2.68	24.89	DN174	20	DN170	92.33	12
	I45-51	6	3.03	24.72	DN177	18.16	NE264	87.12	12
	DN174	13	5.92	24.61	DN17	15.58	DN2	84.4	12
	NM2	15	5.21	24.09	NE222	14.76	NM2	67.74	12
	DN170	9	6.79	23.46	DN5	14.47	I45-51	64.89	12
	DN177	13	5.76	22.47	DN170	13.19	DN174	60	12
	NE222	11	3.64	21.47	DN34	13.18	DN5	57.88	12
	DN74	10	4.68	20.91	DN74	13.07	DN34	52.72	12
	DN17	12	4.39	20.77	NE264	10.89	DN17	46.74	12
	DN5	12	3.5	19.29	I45-51	9.27	DN74	26.14	12
	DN34	11	5.67	19.17	DN182	6.8	DN182	13.6	12
Sioux Falls, SD 1987	DN177	13	3.26	22.38	DN177	18.19	DN177	145.52	12
	I476	6	4.28	21.78	45-1	14.7	DN170	95.06	12
	45-1	11	4.85	21.38	DN170	13.58	NE222	90.02	12
	DN170	11	4.41	19.76	I45-51	12.96	45-1	88.2	12
	NE222	11	2.53	18.7	NE222	12.86	NE264	86.66	12
	NE264	11	3.23	18	DN17	12.52	DN34	70.38	12
	DN74	4	5.1	17.43	NE264	12.38	I45-51	51.84	12
	DN34	11	2.97	17.06	DN34	11.73	DN17	50.08	12
	DN17	12	3.03	16.7	I476	8.17	I476	49.02	12
	I45-51	13	3.75	15.95	DN74	4.36	DN74	26.14	12

([1]) Criteria used for scoring rank, form, and disease:

Stem Canker Rating
4- Clean, no cankers evident
3- Light to medium cankers, no defects
2- Medium to heavy cankers, scarring
1- Dieback and breakage from cankering

Rank
1,2,3-not acceptable
4,5,6-marginal
7,8,9-higher quality, promote use

Form Rating
4- Straight clean stems with few branches
3- Slight stem sweep, medium branching, no defects
2- Crooked stems, heavy branching, minor defects
1- Stems deformed from sunscald damage and major stem defects

([2]) Indicates the year planted.

Netzer, D.A.; Tolsted, D.N.; Ostry, M.E.; Isebrands, J.G.; Riemenschneider, D.E.; Ward, K.T. 2002. **Growth, yield, and disease resistance of 7- to 12-year-old poplar clones in the north central United States.** Gen. Tech. Rep. NC-229. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 31 p.

Summarizes growth, yield, and disease resistance of 95 poplar clones at or near rotation age (culmination of mean annual increment). Plantations were established from 1986 to 1992 in Wisconsin, Minnesota, North and South Dakota. Clones DN164, DN177, DN154, NM2, NE264, DN170, and DN21 are recommended for further testing.

KEY WORDS: Hybrid poplar, intensive culture, biomass yields, disease resistance, hybrid trials.

Mission Statement

We believe the good life has its roots in clean air, sparkling water, rich soil, healthy economies and a diverse living landscape. Maintaining the good life for generations to come begins with everyday choices about natural resources. The North Central Research Station provides the knowledge and the tools to help people make informed choices. That's how the science we do enhances the quality of people's lives.

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Pesticide Precautionary Statement:

Pesticides used improperly can be injurious to humans, animals, and plants. Follow label directions and heed all precautions on the labels. Store all pesticides in original containers, out of reach of children and foodstuffs. Apply pesticides selectively and carefully. Do not apply a pesticide when there is danger of drift to other areas. After handling a pesticide, do not eat, drink, or smoke until you have washed. Dispose of empty pesticide containers properly. It is difficult to remove all traces of a herbicide (weed killer) from equipment. Therefore, to prevent injury to desirable plants do not use the same equipment for insecticides that you use for herbicides.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Federal Environmental Protection Agency, consult your county agricultural agent or State extension specialist to be sure the intended use is still registered.

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