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YIELDS OF TEN AND ELEVEN YEAR-OLD HYBRID POPLARS IN THE NORTH CENTRAL UNITED STATES

FINAL REPORT

DANIEL NETZER
DAVID TOLSTED (Retired)

NORTH CENTRAL RESEARCH STATION
FORESTRY SCIENCES LABORATORY
Rhinelander, Wisconsin

In cooperation with

U.S. DEPARTMENT OF ENERGY
BIOFUELS FEEDSTOCK DEVELOPMENT PROGRAM
Oak Ridge National Laboratory
Oak Ridge, Tennessee

DOE INTERACENCY AGREEMENT A105-890R21871, MODIFICATION NO. A009

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Abstract

Plantations containing hybrid poplar clones DN34, DN17, DN182 averaged greater than three dry tons per acre per year at year 10 and 11. Better sites averaged greater than four tons per acre per year. These unirrigated plantations were established in 1987 and 1988 during a record drought.

Introduction

This report will present biomass yields of short rotation intensively cultured poplar plantations established in Wisconsin, Minnesota, North and South Dakota during 1987-88. Research in these plantations was, for the most part, completed in 1994 and is published by Oak Ridge National Laboratory (ORNL/M-5058). It was reported at that time that the mean annual increment had not peaked in the plantations. Growth measurements were continued through the 1997 growing season when the plantations had completed their 10^{th} and 11^{th} growing season.

Objectives

The objective of this research is to determine commercially attainable biomass yields given the best site tending possible under the constraints of this extensive network. Biomass yields are reported from the best clones planted in one acre blocks on 8 sites over the four states.

Background

The network of research and demonstration plantations was established in 1987 and 1988 across a 4-state region in the north-central U.S. (Figure 1). The primary criteria in site selection were: 1) the sites are within the region from the eastern edge of the Dakotas into western Wisconsin, 2) each site consisted of agricultural cropland with a single soil type, and 3) soil types are those occurring on large acreage in the region (see Table 1). This energy plantation network was cooperatively supported by the North Central Forest Experiment Station (USDA), the Oak Ridge National Laboratory (DOE), Energy Performance Systems Inc., and the Electric Power Research Institute. Approximately 130 acres out of the original 400 acres remained through year 10 or 11 despite the historic drought in 1988 and 1989 and the loss of substantial acreage resulting from late rent payments with changes in program sponsorship. Biomass production for 1987-1994 has been previously reported in the 1994 final report. Additional measurements for 1995-97 are reported here.

Figure 1.

Table 1. Description of Plantation Sites

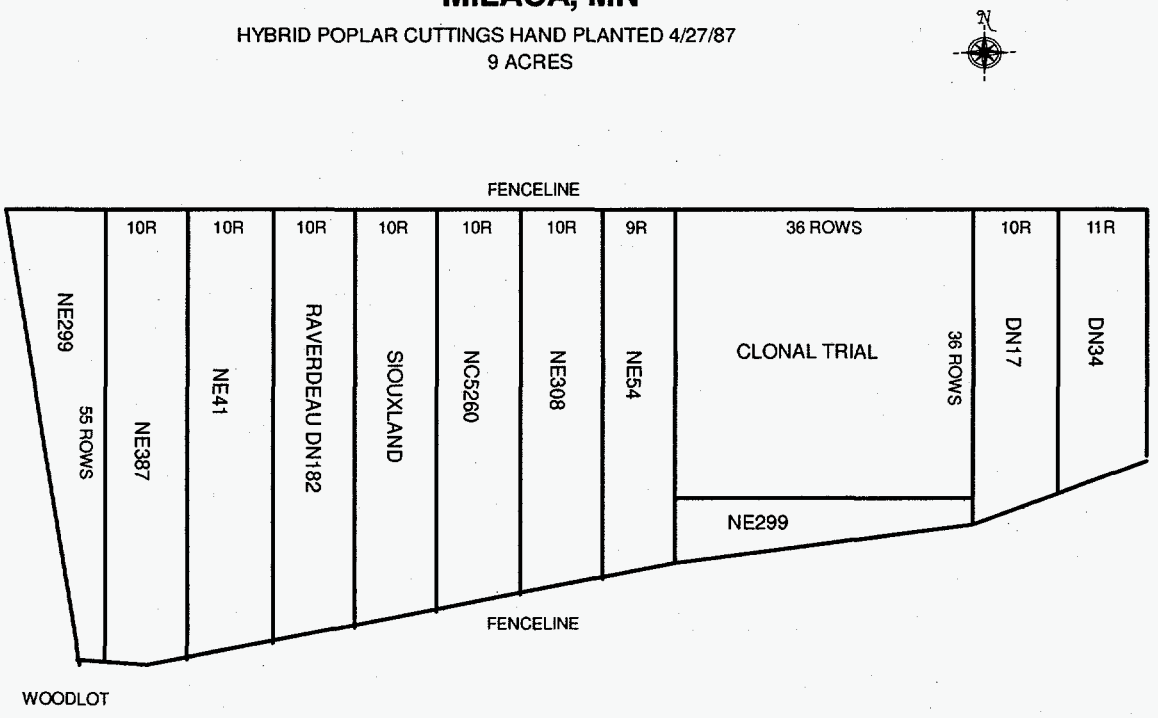
State	County	Town	Soil Series	Texture	CER[1]	Acres
MN	Martin	Fairmont	Coland	Clay loam	62	10
MN	Chippewa	Granite Falls	Dupage	Loam		15
MN	Mille Lacs	Milaca	Milaca	Silt clay	42	14
MN	Carlton	Cloquet	Ahmeek	Loam	42	10
ND	Cass	Fargo	Fargo	Silt clay	67	20
SD	Minnehaha	Sioux Falls	Kranzburg	Silt/clay/loam	70	16
WI	Buffalo	Mondovi	Antigo	Silt loam	50	16
WI	Ashland	Ashland	Ontonagon	Silt clay	35	20

[1] Crop Equivalency Ratio

Plantation Design

The basic planting design for the plantations is shown in Figure 2. Trees in all plantations were hand planted at an 8 x 8 foot spacing. Each 10 acre plantation is subdivided into 10 smaller monoclonal blocks with a different hybrid planted in each block. Each monoclonal block has an area of 0.8 acres with three permanent 25 tree plots located in each block. Trees in these plots were measured annually to determine biomass production and tree mortality.

Figure 2. Planting design for 1987-88 hybrid poplar plantations.



Biomass Results

Tree survival and dbh were collected each fall on better clones at all sites. Selected trees were periodically harvested, weighed green, sub-sampled and oven dried to determine total tree dry weight (Table 2 and Appendix 2).

Table 2. Height, DBH, and dry weight of hybrid poplars harvested at year 9 and 10 in Western Wisconsin and Minnesota.

Site	Clone	DBH (cm)	HGT (m)	Dry Wgt (Kg)	Tree Age
Granite Falls	DN34	22.9	*	132.7	10
Granite Falls	DN34	22.2	17.5	128.2	10
Granite Falls	DN17	19.8	18.5	112.3	10
Granite Falls	DN17	20.7	18.5	124.4	10
Milaca	DN182	21.5	19.4	118.9	10
Milaca	DN182	19.5	18.5	84.6	10
Milaca	DN17	19.7	19.3	106.3	10
Milaca	DN17	21.0	18.8	98.5	10
Milaca	DN34	20.8	18.1	115.4	10
Milaca	DN34	19.2	18.7	98.0	10
Mondovi	DN182	20.1	20.6	118.7	10
Mondovi	DN182	22.0	20.2	133.7	10
Mondovi	DN34	20.1	21.0	122.8	10
Mondovi	DN34	21.0	20.0	127.3	10
Cloquet	DN182	17.6	15.0	65.0	9
Cloquet	DN182	16.4	15.1	60.4	9

• = missing data

Using these oven dry tree weight data, biomass regression equations of the form "Tree weight = $a + b * DBH + c * DBH^2$" were developed to predict biomass production in the plantations. Equations were also developed for each site for which there were sufficient trees to warrant doing so (n>20), which included Ashland, Mondovi, Granite Falls, and Milaca. For the remaining sites, a generalized regression equation developed from all the tree dry weight data from all sites (n=152) was used to calculate biomass production (Table 3).

Table 3. Regression Equation Coefficients for the North Central U.S. Plantation Network

(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**

Biomass production in the 10 and 11 year-old plantations in 1997 ranged up to 4.2 dry tons/acre/year (TAY) (Table 4 and Figure 4). Peak yields for all sites were nearly identical for the 87 and 88 plantings at 3.1 TAY. The best three sites (Granite Falls, Milaca, Mondovi) in the 87 plantings had an average yield of 3.68 TAY while the average yield of the two best sites in 88 (Granite Falls, Mondovi) had an average yield of 4.1 TAY. Yields peaked earlier in the 88 plantings with all but Cloquet peaking in year 6 or 7. The 87 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. Although TAY has peaked, the standing biomass on a site (Figure 5) continues to climb. This allows the plantation manager the option of harvesting for a few years beyond the peak production with a plantation still increasing in TAY, although a reduced rate.

Table 4. Biomass yields in dry tons per acre per year for hybrid poplar plantations Planted in 1987 and 1988 at several mid-west U.S. locations.

Plantation established in 1987

	Ashland	Fargo	Granite Falls	Milaca	Mondovi	Sioux Falls
Year 3 (1989)	NM	NM	NM	0.75	0.55	NM
Year 4 (1990)	NM	NM	NM	1.55	1.82	NM
Year 5 (1991)	0.97	1.85	1.63	2.10	2.53	1.10
Year 6 (1992)	1.27	1.75	1.90	2.53	3.23	1.73
Year 7 (1993)	1.50	2.85	3.40	3.00	3.83	2.00
Year 8 (1994)	1.57	3.20	3.65	3.30	3.67	2.27
Year 9 (1995)	1.56	3.20	3.80	3.34	3.62	2.29
Year 10 (1996)	NM	3.54	3.86	3.52	3.48	2.13
Year 11 (1997)	1.80	NM	3.76	3.44	3.37	NM

Plantations established in 1988

	Ashland	Cloquet	Fairmont	Granite Falls	Mondovi	Sioux Falls
Year 3 (1990)	NM	NM	NM		2.05	NM
Year 4 (1991)	1.67	1.25	1.93	1.93	2.73	1.23
Year 5 (1992)	1.93	1.75	2.27	2.33	3.50	1.60
Year 6 (1993)	2.13	1.85	3.13	4.07	4.00	2.27
Year 7 (1994)	2.13	2.20	3.23	4.23	3.97	2.43
Year 8 (1995)	2.09	2.40	3.20	4.22	3.94	2.42
Year 9 (1996)	NM	2.70	3.20	4.13	3.44	2.35
Year 10 (1997)	NM	2.50	NM	NM	3.21	NM

NM = no measurements made to calculate yields

Figure 3.

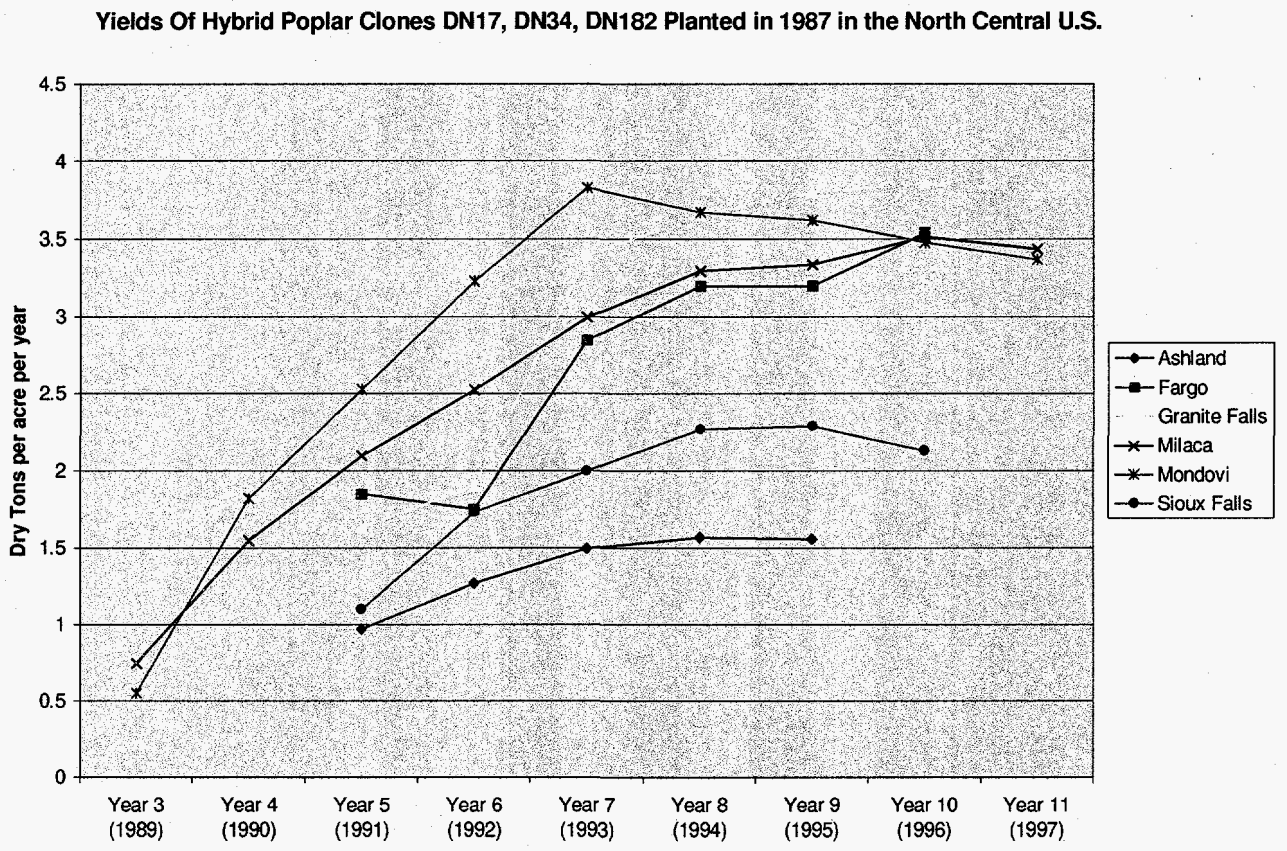

Yields Of Hybrid Poplar Clones DN17, DN34, DN182 Planted in 1987 in the North Central U.S.
Dry Tons per acre per year
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Year 3 (1989)
Year 4 (1990)
Year 5 (1991)
Year 6 (1992)
Year 7 (1993)
Year 8 (1994)
Year 9 (1995)
Year 10 (1996)
Year 11 (1997)
Ashland
Fargo
Granite Falls
Milaca
Mondovi
Sioux Falls

Figure 4.

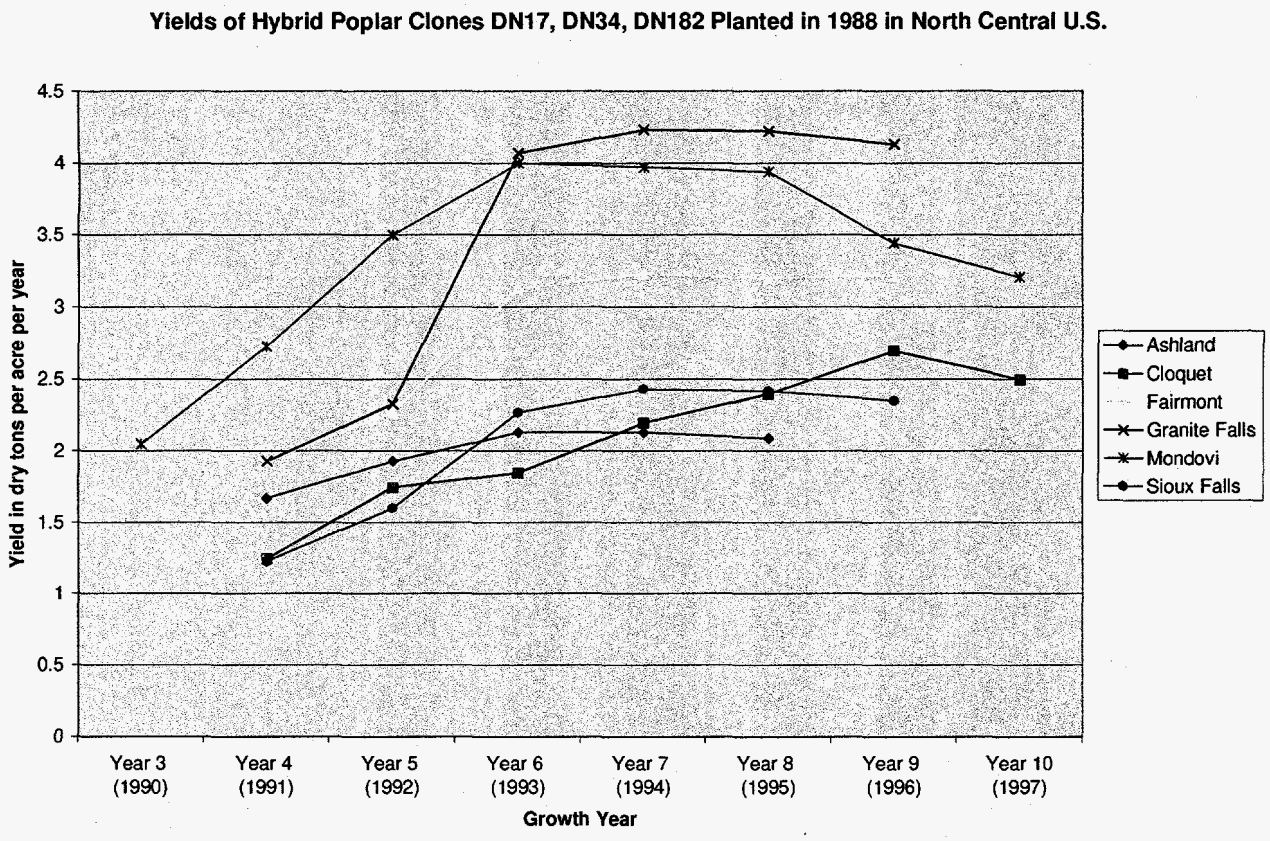
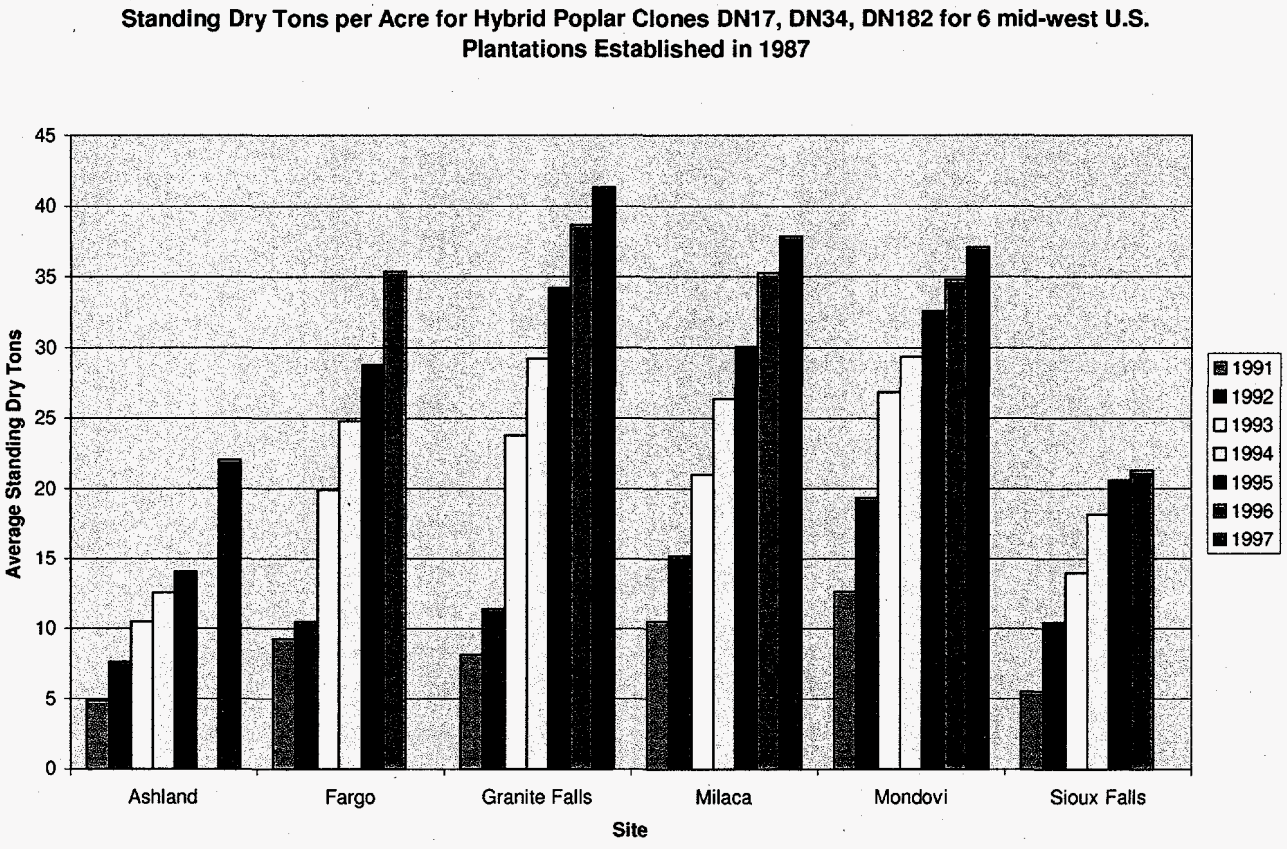

Yields of Hybrid Poplar Clones DN17, DN34, DN182 Planted in 1988 in North Central U.S.
Yield in dry tons per acre per year
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Year 3 (1990)
Year 4 (1991)
Year 5 (1992)
Year 6 (1993)
Year 7 (1994)
Year 8 (1995)
Year 9 (1996)
Year 10 (1997)
Growth Year
Ashland
Cloquet
Fairmont
Granite Falls
Mondovi
Sioux Falls

Figure 5.



Conclusions

Biomass yields in the Midwest hybrid poplar plantations tested have average yields greater than 3 TAY. Yields on better sites average near or slightly above 4 TAY. Favorable establishment year weather and subsequent increases in early growth may shorten the rotation. Generally, peak yields at an 8 foot by 8 foot spacing will be between year 7 to 10 in the mid-west U.S. with adequate weed control, limited fertilization, and non-selected clones. Clonal breeding and selection, mid-rotation fertilization, and improved weed control has the potential of greatly increasing the yield reported here.

Appendix 1

Table a, Biomass yields in dry tons per acre per year for hybrid poplar clones DN17,DN34,DN182 established in 1987 and 1988 at several mid-west U.S. locations.

Plantations established in 1987

		Ashland	Fargo	Granite Falls	Milaca	Mondovi	Sioux Falls
Year 9 (1995)	DN17	2.2	3.2	3.8	3.8	3.8	2.5
	DN34	1.1	NM	3.8	2.7	3.3	1.9
	DN182	NM	3.1	NM	3.5	3.8	2.5
Year 10 (1996)	DN17	NM	3.7	3.7	3.8	3.4	1.9
	DN34	NM	NM	4.0	3.0	3.4	2.0
	DN182	NM	3.3	NM	3.7	3.6	2.4
Year 11 (1997)	DN17	2.1	NM	3.4	3.8	3.4	NM
	DN34	1.8	NM	4.1	3.0	3.3	NM
	DN182	NM	NM	NM	3.6	3.4	NM

Plantations established in 1988

		Ashland	Cloquet	Fairmont	Granite Falls	Mondovi	Sioux Falls
Year 8 (1995)	DN17	1.7	NM	2.9	4.5	3.2	2.1
	DN34	2.3	2.3	3.3	4.1	4.5	3.0
	DN182	2.2	2.5	3.4	4.0	4.2	2.1
Year 9 (1996)	DN17	NM	NM	2.9	4.2	3.1	2.0
	DN34	NM	2.6	3.4	4.1	3.7	2.7
	DN182	NM	2.8	3.4	4.0	3.6	NM
Year 10 (1997)	DN17	NM	NM	NM	NM	2.9	NM
	DN34	2.3	2.4	NM	NM	3.3	NM
	DN182	2.2	2.5	NM	NM	3.4	NM

NM = not measured

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
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

Appendix 2. Continued

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
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

Appendix 2. Continued

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
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
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

Appendix 2. Continued

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
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
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

Appendix 2. Continued

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
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