PROJECTED AND ACTUAL BIOMASS PRODUCTION OF 2- TO 10-YEAR-OLD INTENSIVELY CULTURED POPULUS 'TRISTIS # 1'

by

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Abstract.--Intensively cultured plantations of *Populus* 'Tristis # 1' produce more than 10 mt/ha/year of woody biomass at most spacings as long as they are harvested when mean annual biomass increment (MABI) culminates. In addition, fully stocked plantations produce up to 4.4 mt/ha of leaf litter. Plantations of other poplar clones produce about 30% more woody biomass, but leaf litter production is about the same as in *P.* 'Tristis # 1'. Because projected biomass productions of *P.* 'Tristis # 1' were 42 to 182% higher than the actual productions, caution must be exercised when using projected production values. The discrepancy increased with age. *P.* 'Tristis # 1', although less productive than several other poplar clones in our tests, showed no major deficiencies in 12 years of experimentation. Various *P.* x *euramericana* clones have suffered sun scalding in northern Wisconsin, and other clones, including the highly productive NE-299 (NC-5331), have suffered wind damage. *P.* 'Tristis # 1' should be officially recommended for planting in the Lake States.

Populus 'Tristis # 1', a hybrid between *P.* *tristis* Fisch. and *P.* *balsamifera* L.,[2] was among the first hybrid poplars included in the short-rotation intensive culture (SRIC) studies at the Forestry Sciences Laboratory (FSL) in Rhinelander, Wisconsin (USDA Forest Service 1976). Plantings were established in the FSL nursery in 1970 and again in 1973 at spacings ranging from 0.23 x 0.23 to 2.4 x 2.4 m (9 x 9 in to 8 x 8 ft). In 1974, an additional planting was established at 3.6 x 3.6 m (12 x 12 ft). In 1976/77, large plantings (0.25 ha or 0.6 acre) of Tristis and three other clones were established on the Harshaw Forestry Research Farm near Rhinelander (Hansen *et al.* 1979). Many poplar hybrids have been introduced and tested since 1970, but Tristis is still considered among the most promising clones for this part of the Lake States.

Growth and production data for the 1970 plantings were summarized and published by Dawson and co-workers (Crist and Dawson 1975, Dawson *et al.* 1976, Ek and Dawson 1976a, b, and Zavitkovski *et al.* 1976). Results of the 1973 studies were published by Meldahl (1979). Studies on the utilization potential of 5-year-old Tristis were published by Isebrands *et al.* (1979).

Serious problems often arise when biomass production estimates are based on small plots with unplanted borders (Zavitkovski 1981a). For example, the biomass production of over 20 mt/ha/year predicted by Ek and Dawson (1976a, b) for Tristis may have been far too optimistic. The objectives of this report are to:

(1) summarize the actual growth and biomass production of all available Tristis plantings at Rhinelander during the first rotation phase[3], and

(2) compare the actual growth and aboveground biomass production with the predicted values of Ek and Dawson (1976a, b) and Meldahl (1979).

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[2]Hereafter Tristis

[3]First rotation phase refers to plantations established from cuttings.

METHODS

In each plantation, height and DBH were measured annually in the fall or winter. In the 1973 FSL nursery plantings, a "harvest area," consisting of about one-sixth of the total area, was designated for destructive sampling. In the large plantings on the Harshaw Forestry Research Farm, 16 permanent plots were randomly selected in each planting and DBH's in each plot were measured annually. Destructive sampling for biomass estimation was conducted in other parts of the plantings. After all non-destructive measurements were taken, the trees were divided into five or six DBH classes; one tree was randomly selected and harvested from each DBH class. Trees were cut at ground level and height was measured on the ground with a tape; trees were then separated into components and taken to the laboratory for further processing.

In the laboratory, bark was stripped from a subsample of stems and branches and all materials were dried at 70°C to constant weight. Dry weights were used to develop regression equations suitable for estimating the biomass of all trees in a plot. The biomass of all Tristis plantings was estimated by means of Ek's (1980) equations based on both the DBH and height. Biomasses of other poplar hybrid plantings from age 2 to 6 were estimated by means of allometric equations, based on DBH alone, which were developed separately for each clone and spacing. Biomass of each planting was expressed per unit land area (hectare or acre).

Biomass production of Tristis plantings, expressed as mean annual biomass increment (MABI) in mt/ha/year, is presented separately for the woody parts (stems and branches with bark) and foliage. For comparison, MABI's of several other poplar hybrids planted at the Harshaw Forestry Research Farm in 1976/77 are also presented.

RESULTS AND DISCUSSION

Woody Biomass

For the first few years, the Tristis plantations with close spacing were more productive than those with wider spacing, but with the increasing age, the MABI's of the more open plantings caught up and reached about the same production (Table 1). For example, at age 5 the MABI's of the 0.3 x 0.3 and 0.6 x 0.6 m (1 x 1 and 2 x 2 ft) plantings were 9.9 and 8.9 mt/ha/year, respectively. By comparison, the MABI of the 2.4 x 2.4 m planting was only 3.7 mt/ha/year at age 5, but at age 10 it had reached 10.4 mt/ha/year. We don't know what MABI's would have developed in the two denser plantings by age 10. They were removed at age 6 when they were found unsuitable for further biomass studies mainly because of a pronounced edge effect (Zavitkovski 1981a).

Shape of the growth curves suggests that woody biomasses of the 2.4 x 2.4 and 3.6 and 3.6 m plantings will continue increasing beyond their present levels. Their MABI's may culminate between 12 and 20 years.

Table 1.--Aboveground woody biomass production of 2- to 10-year-old *Populus* 'Tristis #1' at various spacings[1]

AGE	(IN MEAN ANNUAL BIOMASS INCREMENT - MABI)						
	SPACING (m)						
Yrs.	0.3x0.3	0.6x0.6	1.1x1.1[2]	1.2x1.2	2.0x2.0[2]	2.4x2.4	3.6x3.6
	mt/ha/year						
2	3.7	1.9	1.6	1.1	0.2	0.2	0.1
3	7.0	4.9	3.3	2.3	.9	.6	.3
4	9.0	7.9	6.0	5.1	3.8	2.3	1.0
5	9.9	8.9	6.5	6.8	5.5	3.7	1.7
6	-	-	9.6	-	9.1	4.8	3.2
7	-	-		-		6.5	4.8
8	-	-		-		8.4	5.6
9	-	-		-		9.7	6.2
10	-	-		-		10.4	

[1]Data for the 2- to 5-year-old stands at the Forestry Sciences Laboratory Nursery were adapted from Meldahl (1979). Data for the remaining stands were based on our measurements. Biomass of *Populus* 'Tristis # 1' was calculated according to Ek (1980).

[2]Plantings at the Harshaw Forestry Research Farm. All data based on our measurements.

It appears that similar MABI's may be reached in SRIC poplar plantations that were established at various spacings as long as they are harvested when their MABI culminates. Similar principles have been proposed for volume production by Moller (1945), Assmann (1953), and Ek and Brodie (1975), and for biomass production by Hutnik and Hickok (1967).

It is important to note that although they may be similar in terms of sustained annual production, the dense and open poplar plantations will feature very different stand structures -- i.e., many slender sapling-like trees/ha in dense plantations and a few large trees/ha in the open plantations. The manager (or economist) can select the best system.

One biological factor to consider when deciding stand density and rotation length will be the average tree size in the final harvest and its ability to coppice. It is possible that coppicing of large trees will be inhibited, preventing successful regeneration. Our present knowledge on coppicing of hybrid poplars in relation to age and size of the tree is inadequate.

At the Harshaw Forestry Research Farm, the age-6 MABI of clone NE-299 (NC-5331) was about 30% higher than that of Tristis, which was in turn substantially higher than the MABI's of two P. x euramericana clones (DN-34 or NC-5326, and NC-5377 cv. Wisconsin # 5) (Table 2). Moreover, the Tristis plantings were healthiest, had better form, and were less susceptible to wind and sun damage than the other clones.

Leaf Litter Biomass and LAI

Compared with natural stands of various broadleaved species of the temperate zone, the intensively cultured Tristis plantations produce substantially more leaf litter and LAI.

Leaf litter production, like the MABI's of woody parts, was strongly affected by stand density during the early years of plantation development (Table 3). Leaf litter quantities of over 4 mt/ha were collected in dense plantings during the first 5 years and similar quantities several years later in the open plantings. The data suggest that 4.4 mt/ha may be the upper limit of leaf litter production in Tristis regardless of spacing (Zavitkovski 1981b). This level was reached in the 2.4 x 2.4 m planting at age 8 (Table 3). In general, leaf litter production showed little annual variation, a finding consistent with the MABI data discussed in the preceding section (Table 1).

Cumulative leaf area index, LAI, essentially followed the same trend as leaf litter production (Table 3). The highest cumulative LAI's were reached at age 6 in plantings spaced from 0.3 x 0.3 to 1.2 x 1.2 m (1 x 1 to 4 x 4 ft), and 1 year later in the 2.4 x 2.4 m (8 x 8 ft) planting. The uniformity of LAI's over a period of 6 years, except for minor unexplained variations (e.g., LAI 5.7 at age 9), is consistent with that found in the leaf litter production.

Leaf litter production and LAI's from 2- to 6-year-old hybrid poplar plantings on the Harshaw Forestry Research Farm were similar to those reported for Tristis (Table 4). In only one instance, the 0.7 x 0.7 m NE-299 (NC-5331) planting at age 4, did leaf litter production (5.2 mt/ha) exceed the highest (4.4 mt/ha) level for Tristis (Table 3). In general, the LAI's were also similar to those of Tristis.

Comparison of Actual and Predicted MABI's

The MABI's projected by Ek and Dawson (1976 a, b) and Meldahl (1979) for Tristis were considerably higher than the actual measured values. This pattern was also documented for the 1.2 x 1.2 m (4 x 4 ft) 5-year-old Tristis planting that had to be harvested because of wind damage (Isebrands et al. 1982). In that study, the aboveground biomass of the planting, excluding leaves, was 37.92 mt/ha, and the woody MABI was 7.6 mt/ha/year (Isebrands et al. 1979). The projected woody biomass and woody MABI were 53.8 mt/ha and 10.8 mt/ha/year, respectively (Ek and Dawson, 1976a, b), or about 42% higher than the actual.

Table 2.--Aboveground woody biomass production of 2- to 6-year-old hybrid poplars at various spacings at the Harshaw Forestry Research Farm (In mean annual biomass increment - MABI)

AGE	SPACING (m) AND CLONE							
	0.7x0.7	1.1 x 1.1			2.0 x 2.0			
	NE-299 NC-5331	NE-299 NC-5331	NC-5260	NC-5377	NE-299 NC-5331	NC-5260	NC-5377	DN-34 NC-5326
	mt/ha/year							
2	2.2	1.4	1.6	0.7	0.7	0.2	0.2	0.2
3	5.8	4.5	3.3	2.5	2.7	.9	.6	.5
4	8.2	7.0	6.0	4.0	5.7	3.8	1.6	1.3
5	8.7	-	6.5	4.5	7.3	5.5	3.7	1.7
6	12.3	-	9.6	8.4	12.1	9.1	6.2	4.6

Table 3.--Leaf litter biomass and leaf area index (LAI) of 3- to 10-year-old *Populus* 'Tristis #1' at various spacings[1]

AGE	SPACING (m)					
	0.3x0.3	0.6x0.6	1.1x1.1[2]	1.2x1.2[3]	2.0x2.0[2]	2.4x2.4
			LEAF LITTER DRY WEIGHT (mt/ha)			
3	3.3	3.2	2.3	2.6	0.7	1.6
4	4.0	4.1	4.1	3.2	1.8	2.5
5	3.4	3.4	3.5	-	3.0	2.5
6	4.2	4.2	3.7	-	3.6	3.4
7	-	-	-	-	-	3.9
8	-	-	-	-	-	4.4
9	-	-	-	-	-	3.6
10	-	-	-	-	-	4.0
			LEAF AREA INDEX (LAI)			
3	6.0	5.6	3.8	4.9	0.6	1.6
4	6.9	7.1	7.3	5.9	1.6	3.2
5	-	7.3	6.1	-	5.7	-
6	8.6	8.7	7.8	-	8.2	6.8
7	-	-	-	-	-	8.4
8	-	-	-	-	-	7.5
9	-	-	-	-	-	5.7
10	-	-	-	-	-	8.3

[1]Data for 3- to 7-year-old stands, except for stands at the Harshaw Forestry Research Farm, are from Zavitkovski (1981b).

[2]Stands at the Harshaw Forestry Research Farm were established in 1976/77. All other stands were established in 1973 at the Forestry Sciences Laboratory Nursery.

[3]Stand was damaged by wind and harvested in 1977.

Table 4.--Leaf litter biomass and leaf area index (LAI) of 3- to 6-year-old hybrid poplar plantations at various spacings[1]

AGE	SPACING (m) AND CLONE							
	0.7x0.7	1.1x1.1			2.0x2.0			
	NE-299 NC-5331	NE-299 NC-5331	NC-5260	NC-5377	NE-299 NC-5331	NC-5260	NC-5377	DN-34 NC-5326
				LEAF LITTER DRY WEIGHT (mt/ha)				
3	3.0	2.4	2.3	1.5	1.7	0.7	0.6	0.4
4	5.2	4.4	4.1	3.2	4.4	1.8	1.4	1.4
5	4.4	lost[2]	3.5	2.6	2.6	3.0	2.0	1.8
6	4.3	-	3.7	3.1	3.9	3.6	2.7	2.9
				LEAF AREA INDEX (LAI)				
3	5.7	6.2	3.8	1.5	3.5	0.7	0.8	0.7
4	7.3	8.5	7.4	2.6	6.6	1.7	1.4	2.0
5	6.9	lost[2]	6.2	3.4	4.4	5.7	2.6	2.1
6	7.0	-	7.8	5.1	6.1	8.2	3.9	4.1

[1]Plantations at the Harshaw Forestry Research Farm

[2]Stand was damaged by windstorm and harvested.

The actual MABI of the 10-year-old, 2.4 x 2.4m Tristis planting was 10.4 mt/ha/year (Table 1). Ek and Dawson's (1976a, b) projection was 96% higher (20.4 mt/ha/year) and Meldahl's (1979) projection, based in part on data from the 1973 plantations, was 81% higher (18.8 mt/ha/year) (Table 5). The actual MABI of the 9-year-old, 3.6 x 3.6 m Tristis planting was 6.2 mt/ha/year, whereas Ek and Dawson's projection for a slightly more widely spaced planting (3.9 x 3.9 m) was 182% higher (17.5 mt/ha/year).

Table 5.--Comparison of predicted and actual survival, growth, and biomass production of 9- and 10-year-old Populus 'Tristis #1'

DATA	SURVIVAL		DIAMETER		HEIGHT		MABI[1]	SOURCE
	Trees/ha	%	cm	in	m	ft	mt/ha/year	
			10-YEAR-OLD, 2.4 x 2.4 m (8 x 8 ft) PLANTING					
Actual	1,626	97	9.8[2]	3.9	13.5	44	10.4	Present study
Predicted	1,556	93	26.7[2]	10.5	16.2	53	20.4	Ek and Dawson (1976a,b)
Predicted	1,510	90	18.7	7.4	13.7	45	18.8	Meldahl (1979)
			9-YEAR OLD, 3.6 x 3.6 m (12 x 12 ft) PLANTING					
Actual	716	96	10.1[2]	4.0	12.0	39	6.2	Present study
Predicted	625	93	35.8[2]	14.1	15.5	51	17.5	Ek and Dawson (1976a,b)[3]

[1]Mean annual biomass increment, MABI.

[2]Diameter at 2.5 cm (1 in) above-ground.

[3]Projected for a 3.9 x 3.9 m (12.7 x 12.7 ft) planting.

In summary, models used for estimating biomass production of intensively cultured poplar plantations have consistently overestimated actual growth. Although numerous factors may have contributed to these overestimates (see Isebrands et al. 1982), the results of this study suggest that biomass projections based upon limited data from small plots should be used with caution.

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