SURVIVAL AND GROWTH OF TWO INTENSIVELY CULTURED JACK PINE PROVENANCES RAISED IN TUBEPAK AND JIFFY 7 CONTAINERS

J. Zavitkovski and Howard M. Phipps[1]

Abstract.--Container type, provenance, and spacing affect survival, height and d.b.h. growth, and biomass production of intensively cultured jack pine. The Lower Michigan provenance and Tubepak grown plants performed better than the local (Wisconsin) provenance and plants raised in Jiffy 7 pellets. At age 5, biomass of Tubepak plantings was more than 100% higher than that of Jiffy 7 plantings. Plantings of the Michigan provenance had 73% more biomass than those of the local source. The above-ground dry weight yield of the 1.0 x 0.3 m (3.3 x 1 ft) planting at age 5 (60.8 mt/ha (27 tons/acre)), approached yields expected or predicted for hybrid poplar plantations in the Lake States. And jack pine has several advantages over hybrid poplar as a source of biomass for energy: it can be harvested during any season of the year (most hybrid poplars can only be harvested during the dormant season), it can be harvested with stumps and roots (hybrid poplar stumps must be left so new coppice stand can develop), and heat of combustion of jack pine biomass is about 8% higher than that of hybrid poplar biomass.

The present study was designed to show that in suitable containers and under intensive culture, jack pine of a good provenance would grow very rapidly and produce large quantities of biomass. In a previous study (Zavitkovski and Dawson 1978), initial slow growth of jack pine tubelings was traced to the small size and rigid walls of the plastic container that restricted root development and seedling growth. At age 2, the average height of the tubelings was at least 1 year behind that of freely developing seedlings raised under less intensive cultural conditions (Jeffers and Nienstaedt 1973).

In this study we compared survival, and height and d.b.h. growth of two jack pine provenances, a local and a recommended Lower Michigan provenance (Jeffers and Jensen 1980) grown in two containers -- Jiffy 7 pellets and Tubepaks -- at three spacings.

The study was established in 1978 on the Harshaw Forestry Research Farm located about 10 miles west of Rhinelander, WI. The land of the farm is level and was used for about 50 years to grow potatoes. The Farm is operated by researchers at the Forestry Sciences Laboratory, Rhinelander, WI.

MATERIALS AND METHODS

Seed from the Lower Michigan provenance was collected in 1974 from Grand Traverse County, latitude 44.5°N and assigned number NC-7738. Seed from the Wisconsin provenance, number NC-8806, was collected in the winter of 1975/76 from Oneida County, latitude 45.75°N. All seed was kept in cold storage until the beginning of this study.

After a brief stratification, the germinating seed was planted in Jiffy 7 pellets and Tubepak containers[2/3] filled with a 3:1:1

[1]Research Foresters, North Central Forest Experiment Station, Forestry Sciences Laboratory, Rhinelander, WI 54501

[2]The Jiffy 7, manufactured by Jiffy Products of America, is a compressed pellet of peat moss (with fertilizer) that expands upon soaking to form a container about 4 cm (1 3/4 inches) in diameter and 5 cm (2 inches) high (ca. 78 cm^3 or 5 cu in). A plastic net holds the container together. The Tubepak is a semitransparent plastic container that has several cavities each measuring 4 x 5 x 18 cm (1½ x 2 x 7 in) (ca. 266 cm^3 or 17 cu in). It is made up of two parts that can be separated to permit removal of the seedlings for transplanting.

mix of peat, vermiculite, and perlite. They were grown for 5 months (December 1, 1977 to April 30, 1978) in a greenhouse using standard treatment including frequent watering, application of balanced nutrient solution, and daylength extended to 16 hours with incandescent light.

In May 1978, we moved the seedlings into a shadehouse to harden them off and bring them into a dormant stage to ensure thay they would resume growth in the field. The treatment was only partly successful. Many of the seedlings did not set bud, remained succulent and had to be planted carefully to keep them in a vertical position.

At age 6 months, before outplanting, heights of the seedlings averaged:

Container	Grand Traverse, MI	Oneida, WI
	Mean (SD), cm	
Jiffy 7	18.4 (4.2)	17.5 (3.7)
Tubepak	19.4 (3.8)	19.6 (3.2)

Only heights of the Oneida County seedlings (17.5 vs 19.6) were significantly different (at the 5% level).

The seedlings were hand-planted in rows 1 m (3.3 ft) apart. Three spacings were achieved by planting seedlings 0.3 (73 seedlings/row), 0.6 (41 seedlings/row), and 1.0 m (25 seedlings/row) (1, 2, and 3.3 ft) within rows. Seven rows were planted for each of the 6 spacing-container combinations, for a total of 42 rows per provenance. Seedlings from the two sources were planted in blocks separated by a 4 m (13 ft) lane, and one border row was provided around the entire 0.3 ha (0.75 acre) study area. Soil is in the Padus series grading from a silt loam to a sandy loam with sand to gravelly sand subsoil.

The plantings were irrigated when the soil moisture tension reached - 0.5 bar as measured at the 15-30 cm (6-12 in) depth with tensiometers. They were fertilized annually with 112 kg/ha (100 lbs/acre) N applied in several applications through the irrigation system.

All live trees were counted at the end of each growing season. In the middle 3 rows of each spacing-container combination, height was measured every year from age 2. At ages 4 and 5, d.b.h. was measured on 10 systematically selected live trees/row.

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[3]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such does not constitute an official endorsement by the U.S. Department of Agriculture of any product or service to the exclusion of others thay may be suitable.

RESULTS AND DISCUSSION

All three main variables -- provenance, container type, and spacing -- strongly affected survival and height and d.b.h. growth. In most instances, differences between average values were consistent from 1 to 5 years.

Survival

Plants raised in Tubepak containers and the Michigan seed source had a higher survival than plants raised in Jiffy 7 pellets and the Wisconsin (local) seed source (Table 1). Most of the mortality occurred during the first year in the field and, generally, was low during the subsequent 4 years. Density effects on survival were not consistent -- overall survival at age 5 averaged 76, 71, and 77% in plantings spaced at 1.0 x 0.3, 1.0 x 0.6, and 1.0 x 1.0 m, respectively.

At age 5, the Michigan provenance raised in Tubepak containers had the highest survival -- 89% -- and the local provenance raised in the Jiffy 7 pellets had the lowest survival -- 61% (Table 1). In the previous study (Zavitkovski and Dawson 1978), the survival of the jack pine tubelings at age 4 ranged from 84 to 100%. In Minnesota, jack pine tubelings under field conditions had a 77% survival at age 2 and 65% at age 5 (Alm and Schantz-Hansen 1970, 1972). These tubelings were much shorter than our intensively cultured jack pine.

Height and d.b.h. growth

At the end of the greenhouse phase (6 months), seedlings raised in the Tubepak containers were taller than those in the Jiffy 7 pellets, but it was not yet clear which of the two sources might be better. The superiority of the Michigan source became evident at age 2 and significant at age 5 (Table 1).

At age 2, plants of the Michigan provenance were about 23% taller than those of the local provenance, and at age 5 they were about 4% taller. However, the height difference remained about the same -- 10 cm (4 in) -- as at age 2. The mean difference in height between plants raised in Tubepak containers and Jiffy 7 pellets was 29% at age 2 and 16% at age 5. However, the absolute height difference was 12½ cm (5 in) at age 2 and 35 cm (11 in) at age 5 in favor of the Tubepak plants. This shows that the effect of container type on height was greater than the effect of provenance through age 5.

Spacing effect on height growth, like that on survival, was inconsistent. The average maximum height of 280 cm (9.2 ft) was reached at age 5 in the Michigan planting spaced 1.0 x 0.3 m (Table 1). The most uniform average heights -- from 232 to 253 cm (7.6 to 8.3 ft) -- were reached in the 1.0 x 1.0 m plantings of both provenances.

Table 1.--Survival, height, and dbh of 1- to 5-year-old intensively cultured jack pine

AGE	SURVIVAL (%) MICHIGAN JIFFY 7	MICHIGAN TUBEPAK	WISCONSIN JIFFY 7	WISCONSIN TUBEPAK	HEIGHT (cm)[1/] MICHIGAN JIFFY 7	MICHIGAN TUBEPAK	WISCONSIN JIFFY 7	WISCONSIN TUBEPAK	DBH (mm)[1/] MICHIGAN JIFFY 7	MICHIGAN TUBEPAK	WISCONSIN JIFFY 7	WISCONSIN TUBEPAK
SPACING: 1.0 x 0.3 m (Initially 73 seedlings per row.)												
1	79	95	74	85								
2	77	94	67	83	48	65	40	49				
3	76	93	63	82	113	140	89	108				
4	74	93	63	78	182	212	149	172	12	17	7	10
5	71	92	63	76	236^{c} [3/]	280^{a}	210^{d}	256^{b}	22^{b}	26^{a}	17^{c}	20^{bc}
SD[2/]					37	29	36	38	8	8	6	6
SPACING: 1.0 x 0.6 m (Initially 41 seedlings per row.)												
1	70	96	82	91								
2	64	94	68	90	45	66	40	50				
3	64	93	63	89	92	126	87	123				
4	57	91	63	88	141	203	149	190	7	16	7	14
5	54	86	59	86	216^{b}	261^{a}	215^{b}	263^{a}	19^{c}	29^{a}	19^{c}	25^{b}
SD[2/]					46	35	33	28	9	9	7	5
SPACING: 1.0 x 1.0 m (Initially 25 seedlings per row.)												
1	82	95	69	90								
2	81	95	68	87	50	58	40	52				
3	78	95	66	87	108	125	95	120				
4	76	89	60	83	174	191	149	184	12	14	8	14
5	75	89	60	83	242^{ab}	253^{a}	232^{b}	249^{a}	26^{ab}	28^{a}	22^{b}	26^{ab}
SD[2/]					40	45	30	33	10	10	7	8
ALL 3 SPACINGS POOLED												
1	77	95	75	89								
2	74	94	68	87	48	63	40	50				
3	73	94	64	86	104	130	90	117				
4	69	92	62	83	166	202	149	182	10	16	7	13
5	67	89	61	82	231	265	219	256	22	28	19	24

1/ To convert centimeters and milimeters into inches multiply by 0.394 and 0.0394, respectively.

2/ Standard deviation for age 5 of height and d.b.h. is based on 30 measurements, i.e., 10 per row in the middle 3 rows.

3/ At age 5, average heights and d.b.h.'s are not significantly different (at the 5% level) if followed by the same letter.

The effect of spacing on d.b.h. growth was essentially positive. This trend was clearly demonstrated in trees from the Wisconsin source but although it was present, it was not so obvious in trees from the Michigan source.

At age 5, the average height of the trees -- 210 to 280 cm (almost 7 to more than 9 ft) -- was substantially greater than that of the Tubeling jack pine -- 170 to 194 cm (5½ to 6½ ft) -- used in the previous study (Zavitkovski and Dawson 1978). Actually, the heights were within the range of the 6-year-old tubeling trees (247 to 277 cm or 8 to 9 ft).

Our plants grew equally well or better than intensively cultured jack pine in other studies. Three-year-old seedlings of the best Lower Michigan Peninsula provenance averaged 130 cm under nursery culture which included fertilization and irrigation (Canavera and Wright 1973). In our study, 3-year-old seedlings from the Michigan source raised in Tubepaks averaged 130 cm and in the 1.0 x 0.3 m planting averaged 140 cm (Table 1). In a provenance test at Rhinelander, 2-year-old plants of the best Lake States provenances, raised in Jiffy 7 pellets, averaged 50 cm in height (Jeffers and Nienstaedt 1973). Heights of our 2-year-old plants ranged from 40 to 63 cm.

In traditionally cultured plantations, jack pine grows more slowly and height at age 4 averages only about 112 cm in northern Wisconsin (Rudolph 1981); 83 cm in Vermont (Adams 1928); and from 54 to 60 cm in Michigan (Rudolf 1951). At age 5, height of field-planted jack pine tubelings averaged 76 cm in Minnesota (Alm and Schantz-Hansen 1972), bare root planted stock averaged 116 cm in Vermont (Adams 1928) and from 98 to 129 cm in Ontario (Logan 1966, Yeatman 1974).

The d.b.h. of our 5-year-old plants ranged from 18 to 30 mm (0.7 to 1.2 in) (Table 1), and was similar to the d.b.h. reached by 7-year-old trees -- 17 to 30 mm -- in the previous study (Zavitkovski and Dawson 1978). D.b.h. of field-planted jack pine ranged from 19 to 33 mm (0.7 to 1.3 in) in a 10-year-old plantation established with 1-0 stock in Lower Michigan (Rudolf 1951). Not only the d.b.h., but also the average height of these plants was similar to our 5-year-old, intensively cultured jack pine.

Aboveground tree biomass

We estimated total aboveground biomass (including needles) of our 4- and 5-year-old plantings by means of an equation developed for 6- and 7-year-old intensively cultured jack pine spaced at 0.6 x 0.6 m (2 x 2 ft) (Zavitkovski and Dawson 1978):

$$\ln \text{Aboveground biomass} = -6.5642 + 2.1891 \ln \text{d.b.h.}$$

In this equation, biomass is in kg, d.b.h. is in mm, $R^2 = 0.9411$, sy.x = 0.2124, and the correction factor is 1.0228. Stems, branches, and needles accounted for about 45, 29, and 26% of the total biomass, respectively.

Container and provenance effect on dry weight was greater and more variable than their effect on height and d.b.h. In general, biomass decreased as spacing increased (Table 2). Biomass of plantings established from seedlings grown in Tubepaks was from two to several times greater than that of plantings established from seedlings grown in Jiffy 7 containers. The most biomass was in the 1.0 x 0.3 m planting of the Michigan source raised in Tubepaks -- about 60.8 mt/ha at age 5 -- and the least was in the 1.0 x 1.0 m planting of the local source raised in the Jiffy 7 pellets -- about 8.2 mt/ha. Previous studies have demonstrated that total biomass differences between dense and open plantations gradually diminishe (Zavitkovski and Dawson 1978).

The highest total tree aboveground biomass achieved in this study - 60.8 mt/ha -- was about 10% higher than the maximum -- 56.8 mt/ha -- reached in the previous study (Zavitkovski and Dawson 1978) at age 7. This yield approaches mean annual biomass increments expected or predicted for various hybrid poplars. However, jack pine has three advantages over poplar: (1) it can be harvested with roots that may amount to about 20% of the aboveground biomass, i.e. about 12½ mt/ha at age 5; (2) it can be harvested at any time of the year whereas hybrid poplars must be harvested during the dormant season (Strong and Zavitkoski 1982) to ensure the best coppice regeneration; and (3) its heat of combustion is about 8% higher than that of hybrid poplar. Its main disadvantage is that it has to be replanted after each harvest, whereas poplars regenerate by coppicing. These points should be considered when deciding which species to use in energy plantations.

Container effect

The difference in growth between seedlings raised in the Tubepak and Jiffy 7 containers may be partly explained by the difference in container volume. The larger volume of the Tubepak would permit the development of a larger root system. However, some evidence suggests that the plastic net surrounding the Jiffy 7 container may deform or restrict the normal development of the root system of some tree species as they grow older. In the present study, the difference in height, d.b.h. and particularly total dry weight of Tubepak and Jiffy 7 plants appeared to be increasing through age 5 (Tables 1 and 2).

Table 2.--Preliminary estimates of above-ground tree biomass of 4- and 5-year old intensively cultured jack pine[1/] (In metric tons per hectare)[2/]

SPACING m	AGE yrs.	MICHIGAN		WISCONSIN	
		JIFFY 7	TUBEPAK	JIFFY 7	TUBEPAK
1.0 x 0.3	4	11.9	25.3	3.6	7.4
	5	33.3	60.8	16.0	28.1
1.0 x 0.6	4	2.2	10.7	1.8	7.5
	5	10.0	36.2	10.3	25.5
1.0 x 1.0	4	3.3	4.9	1.4	4.3
	5	16.1	23.1	8.2	15.8

1/ Stems, branches, and needles accounted for about 45, 29, and 26%, respectively.
2/ To convert metric tons per hectare into tons per acre multiply by 0.445.

After 2 years in the field, we found that poplar hybrid cuttings rooted in Jiffy 7 pellets were consistently shorter than those rooted in a similar container but without the plastic net coverings.[4/] An examination of the root systems of several poplar hybrid trees propagated in Jiffy 7 containers and grown for 6 months in pots in a greenhouse showed fewer long roots than those grown in pots without the container. Also, roots of the former plants tended to grow horizontally and to have a spiral configuration.

CONCLUSIONS

1. Results of the study indicate that selection of container type, provenance, and spacing is extremely important and may affect survival, height, d.b.h., and biomass of jack pine plantations for at least 5 years.
2. In the field, plants from the Michigan source and Tubepaks had a higher survival -- by 6½% for the source and 21% for the container at age 5 than those from the Wisconsin source and Jiffy 7 pellets.
3. The effect of container type on height showed up at age 6 months in the greenhouse, became significant at age 2 years in the field, and then remained about the same through age 5 -- about 22% in favor of the Tubepaks.
4. Provenance had no effect on height in the greenhouse. In the field, the difference reached about 20% in favor of the Michigan source at age 2 and then gradually decreased to 4% at age 5.
5. Container type and provenance had a greater effect on diameter than on height. At age 5, Tubepak plants had a 24% greater d.b.h. than Jiffy 7 plants, and the Michigan source had a 14% greater d.b.h. than the one from Wisconsin.
6. The greatest effect of the container type and provenance showed up in total biomass, which incorporates both height and d.b.h. differences. At age 5, biomass of the Tubepak plantings was 102% greater than that of Jiffy 7 plantings. Plantings of the Michigan source had 73% more biomass than those of the Wisconsin source.
7. From age 1 to 5, the densest plantings had the greatest biomass. At age 5, the overall averages were 35, 20, and 16 mt/ha in plantings spaced at 1.0 x 0.3, 1.0 x 0.6, and 1.0 x 1.0 m, respectively.
8. The highest aboveground yield of 60.8 mt/ha at age 5 approaches yields reached in hybrid poplar plantations. The advantages of jack pine over hybrid poplars are (1) it can be harvested at any time of the year; (2) it can be harvested with roots; and (3) its heat of combustion is about 8% higher.

4/ H. M. Phipps, unpublished data.

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