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VOLUME COMPARISON OF PINE, SPRUCE, AND ASPEN GROWING SIDE BY SIDE

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Abstract.--Red pine produced significantly more volume than the other species on all five sites in the Lake States. By age 40 to 50 white spruce was second to red pine and beyond this age it is expected that these two species will increase their lead over the other species even more.

KEY WORDS: Species comparison, *Picea glauca, Picea mariana, Pinus banksiana, Pinus resinosa, Populus tremuloides.*

Knowledge of the growth rates of different species on a site is essential for rational forest management. Yields can often be increased dramatically by conversion to a species better adapted to a specific site (Carmean 1975). In the Lake States red pine (*Pinus resinosa* Ait.) has been found to yield more volume than alternative species in several studies. Red pine plantations from 28- to 42-years-old outproduced adjacent stands of jack pine (*Pinus banksiana* Lamb.) over a wide range of site conditions in the northern Lake States (Alban 1978). Two red pine plantations in upper Michigan were found to have about double the volume of adjacent stands of sugar maple (*Acer saccharum* Marsh.) (Frederick and Coffman 1978). And in northern Minnesota Schlaegel (1975) found a 40-year-old pine stand to have produced more volume than adjacent stands of jack pine, white spruce (*Picea glauca* (Moench.) Voss), black spruce (*Picea mariana* (Mill.) BSP), or quaking aspen (*Populus tremuloides* Michx.).

In the 1930's the North Central Forest Experiment Station established several adjacent plantations of red pine, jack pine, white spruce, black spruce, and aspen to determine their relative yield over a wide range of site conditions. Such plantations offer a unique opportunity to study comparative growth rates under conditions where stand age, climate, soils, and past land treatment are relatively constant and the major factor determining differential stand yields are the species themselves. In this paper, results are presented from plantations in Minnesota and Michigan. The objectives were to compare the volume yields of each species and more specifically to verify the high yields of red pine compared with other species.

THE STUDY SITES

The soils on the study sites range from sandy to sandy loams and from well-drained to somewhat poorly drained (table 1). Site D has a water table at about 9 feet and is the kind of soil on which Wilde (1965) found exceptionally fast red pine growth. Site index for red and jack pines ranged from about average for Lake States plantations to excellent (Alban 1978). White spruce ranged from poor to average (Erickson and Rauscher[1]), the aspen and black spruce sites were good (Johnston 1977, Perala 1977). The Michigan sites have greater precipitation and temperatures than the Minnesota site (table 1). At the time of sampling the stands of site C were 30 years old, and the others ranged from 39 to 57 years.

[1]*Erickson, G.; Raushcer, H. M. The status of white spruce plantations on Lake States National Forests. Unpublished manuscript proposed as North Central Forest Experiment Station Research Note.*

Table 1.--*Location and site characteristics of the study stands*

Property	Site A	Site B	Site C	Site D	Site E
Location	N. Minn. 47° 20'N 94° 30'W	N. Minn. 47° 20'N 94° 30'W	M. Minn. 48° 31'N 93° 36'W	Lower Mich. 44° 15'N 85° 43'W	Lower Mich. 43° 23'N 85° 42'W
Soil series	Warba very fine sandy loam	Cutaway loamy fine sand	Redby loamy fine sand	Kalkaska sand	Graftan sand
Drainage	well	well	somewhat poor	moderately well	well
Special soil features	calcareous at 41 in.	--	--	subirrigated at 9 ft	--
Annual ppt (in.)	24	24	25	31	32
Avg ann temp (F)	38	38	36	43	46
Site index (ht-age 50 (ft))[1]					
Red pine	69	63	74	70	62
Jack pine	73	68	71	63	61
White spruce	61	60	61	47	40
Aspen	74	69	--	--	--
Black spruce	55	--	44	--	--
Stand age at time of sampling					
Red pine	39, 49	41, 49	30	46	46
Jack pine	39, 49	41, 49	30	46	46
White spruce	39, 49	41, 49	30	46	46
Aspen	40, 50	49, 57	--	--	--
Black spruce	39, 49	--	30	--	--

[1]Site index for white spruce from the equation of Carmean and Hahn (1981); for other species from the equations of Lundgren and Dolid (1970).

The stands of sites C and D were established on abandoned fields; the others were established after logging. Sites A and B were planted after hand scalping; site C was disked, and sites D and E were furrowed. Two pure stands of each conifer species (1 acre each) were established on sites A and B and one or two 1-acre aspen stands (sites B and A respectively) were established by suckering. At site C six stands of 2 acres each per species were established. At sites D and E about 20 stands of 0.1 acre each per species were established. Most planting stock was 2- to 3-years-old, was from "local seed sources," and was planted at spacings of from 4 x 4 feet to 8 x 8 feet. None of the plantations have been thinned, and this, coupled with the high initial density, means that the volumes reported here should be near maximum for these sites under unmanaged conditions.

METHODS

Measurement plot size and numbers varied slightly from stand to stand (table 2) because of different stand sizes, and because the stands were part of several studies conducted by different researchers with somewhat different objectives. On each plot the diameter of every tree greater than 1.5 inch d.b.h. was measured to the

Table 2.--*Sampling characteristics*

	Site						
	A		B		C	D	E
Years sampled	1973	1982	1975	1984	1980	1982	1982
Plot size (ft^2)	860	1,180	4,360	4,360	4,360	2,180	2,180
No. of plots/species	5-10	10	3	5	6	5	5

nearest 0.1 inch. The heights of 20 to 40 trees per species were measured with an abney or clinometer for construction of height-diameter curves and to determine site index. Five to 20 trees of each species in each stand were felled, the boles sectioned into 3 or 4 ft bolts, and a disk cut from each bolt. On each disk rings were counted and diameter was measured. These data were used to calculate bolewood volume for each tree by Smalians formula. Stand volume was calculated by determining the volume of each tree on a plot based on regression equations of the form Vol = BO + B1 (BH) where B is tree basal area and H is total tree height. Tree height was estimated from a second order polynomial equation relating height to d.b.h. for each species in each stand. The bolewood volume (from 6-inch stump to tip) equations used were:

Vol = 0.106 + 0.427 (BH) red and jack pine, $R^2 = 0.985$
Vol = 0.124 + 0.417 (BH) white spruce, $R^2 = 0.988$
Vol = 0.088 + 0.413 (BH) black spruce, $R^2 = 0.992$
Vol = 0 + 0.42 (BH) aspen, R^2 not available

The red and jack pine equations were reported previously (Alban 1978). The equations for white and black spruce were developed from the 87 white spruce and 79 black spruce trees felled as part of this study. Too few aspen were felled to construct reliable volume equations, so the generalized equation of Olsen and Gevorkiantz (1955) was used. The equations are suitable for estimating tree volumes for trees 3 inches d.b.h. or greater. The equations become very inaccurate for smaller trees, but in this study very few trees were smaller than 3 inches d.b.h., so errors involved in the use of the equations are unimportant.

For sites D and E ring width of felled trees for the last five years was measured which allowed an estimation of the bolewood volume growth. Stands A and B were remeasured 10 and 8 growing seasons, respectively, after the first measurement to estimate net periodic annual increment (PAI).

Statistical testing for bolewood volume between species on each site was done using Duncan's multiple range test (Steel and Torrie 1960) at the 5 percent confidence level.

RESULTS AND DISCUSSION

Yields

Red pine significantly outyielded all other species at each site and for each measurement period (table 3). Black spruce yielded significantly less than the pines or aspen at sites A and C, and less than white spruce for the 49-year-old stands at site A. The yields of white spruce, aspen, and jack pine tended to be similar on a site with the jack pine and aspen yielding relatively more at the younger ages and white spruce more at the older ages. White spruce was second in volume behind red pine for all of the stands older than 40 years except for site E (table 3). White spruce did particularly poorly at site E, both in terms of volume (table 3) and site index (table 1) which may be related to this site being south of the natural range of white spruce (Rudolph and Andresen 1965).

The reason for the good showing of white spruce at the older ages is apparent from the PAI (table 4). White spruce PAI is as high as red pine for three of the four sites, and these two species are considerably higher than for the other species, even though not always significantly so, because of the large experimental variability involved. The large amount of mortality in jack pine, black spruce, and aspen (table 5) at sites A and B has caused a decrease in stand basal area from the first to the second measurement (table 6).

Site Index as Indicator of Volume Growth

For red pine, site index of stands A and D are similar as are stands B and E (table 1). But for jack pine and white spruce, site index at stands D and E are much less than at stands A and B. Evidently, the soils and climate at A and D (and at B and E) are equivalent for red pine height growth, but not so for the other species. This raises the question of the adequacy of site index (height growth) as an indicator of volume

Table 3.--*Stand bolewood volumes*

	Site									
	A		B			C			D	E
Initial spacing	4 x 4	4 x 4	4 x 4	4 x 4	4 x 4	4 x 4	6 x 6	8 x 8	?	?
Stand age	39	49	41	49	57	30	30	30	46	46
	Ft³/acre									
Red pine	5,740a[1]	7,340a	5,130a	5,940a	--	4,820a	4,510a	3,190a	7,470a	6,130a
Jack pine	4,040b	4,110b	3,600b	3,410b	--	--	3,370b	--	3,370b	2,610b
White spruce	3,590bc	5,040b	3,970b	4,710ab	--	1,540b	1,240c	770b	3,690b	1,440b
Aspen[2]	4,140b	4,060b	--	3,510b	2,330	--	--	--	--	--
Black spruce	2,590c	2,940c	--	--	--	1,790b	1,100c	1,130b	--	--

[1]Values in a column with the same letter do not differ significantly at the 0.05 level.
[2]The aspen at Site A are 1 year older than the conifers.

Table 4.--*Net periodic annual increment*[1]

	Stand					
	A		B		D	E
Stand age	39-49	40-50	41-49	49-57	41-46	41-46
	Ft³/acre/yr					
Red pine	*160a*	--	*101a*		*194a*	*204a*
Jack pine	*7b*	--	*-24b*		*80b*	*43b*
White spruce	*145a*	--	*92a*		*143ab*	*71b*
Aspen[2]	--	*-8*	--	*-148*		
Black spruce[2]	*35*	--				

[1]For stands A and B increment was the difference in stand volume (live trees) between the two measurement years divided by the number of years between measurements. For stands D and E increment was calculated as the difference between volume measured at age 46 and estimated volume at age 41 based on stem analysis of trees sampled at age 46. Values in a column with the same letter do not differ significantly at the 0.05 confidence level.
[2]Because of so few samples, aspen and black spruce were not included in the analysis of variance.

Table 5.--*Number of trees per acre on study sites*

	Site									
	A		B			C			D	E
Initial spacing	4 x 4	4 x 4	4 x 4	4 x 4	4 x 4	4 x 4	6 x 6	8 x 8	?	?
Stand age	39	49	41	49	57	30	30	30	46	46
Red pine	720	658	957	775	--	1,115	835	460	1,075	1,103
Jack pine	639	410	500	350	--	--	910	--	560	471
White spruce	885	651	1,127	750	--	1,480	485	425	1,272	982
Aspen	540	297	--	283	146	--	--	--	--	--
Black spruce	737	584	--	--	--	1,220	850	500	--	--

Table 6.--*Stand basal area on the study sites (ft²/acre)*

	Site									
	A		B			C			D	E
Initial spacing	4 x 4	4 x 4	4 x 4	4 x 4	4 x 4	4 x 4	6 x 6	8 x 8		
Stand age	39	49	41	49	57	30	30	30	46	46
Red pine	226	255	214	233	--	231	218	158	268	249
Jack pine	153	134	132	123	--	--	162	--	132	110
White spruce	179	201	196	199	--	116	95	64	202	93
Aspen	151	133	--	134	80	--	--	--	--	--
Black spruce	144	135	--	--	--	146	93	88	--	--

growth throughout the entire range of soils and climate in the Lake States. Mader and Owen (1961) showed that height growth and volume growth of red pine respond differently to varying levels of soil moisture and nutrients. Assmann (1970) showed that two stands of Norway spruce with the same site index and under the same management regime, could have volume growth differences as great as 20 percent.

In the current study, the PAI of jack pine in stand D is about double that of stand E (table 4) even though their site index, basal area, and ages are similar. Based on site index, age, and stand basal area, the estimated PAI for stand D would be 76 ft³/acre/yr and for stand E 74 ft³/acre/yr (Benzie 1977a, table 5). Thus the PAI of stand D is very close to that predicted from the best current information on jack pine growth in the Lake States, while the PAI of stand E is considerably lower than predicted. The white spruce PAI of stand A is about 58 percent greater than for stand B (table 4) even though the site index, basal area, age, and macroclimate are nearly identical. Similarly, the PAI of red pine of stand A is 58 percent greater than for stand B which is a much greater difference than anticipated from the most current growth and yield information (Benzie 1977b).

The limited data presented here suggest that a considerable amount of variance remains in volume growth prediction after site index, age, and basal area have been accounted for. The possibility that this variance could be reduced by incorporating soils and/or climatic data into the growth projections needs to be explored. For example, the much higher PAI of jack pine on site D than on site E may be related to the subirrigation of the soil at site D. Early growth on these sites may have differed little, but as the tree roots at site D reached the water table growth might have accelerated.

SUMMARY AND CONCLUSIONS

This study adds support to the earlier finding that red pine outyields jack pine over the entire range of site quality in the Lake States (Alban 1978). Red pine in this study also produced more volume (at ages 30-50) than white spruce or aspen but the number of comparisons was small. Based on tabular yields (Perala 1977, Stiell and Berry 1973), there appear to be some sites where aspen and white spruce at ages 30-50 will produce about the same volume as red pine on the best sites of this study. Whether red pine grows as well on the sites best for white spruce or aspen is unknown but the identification of such sites is clearly important for their establishment.

Red pine in these closely spaced stands is producing more volume than any of the species with which it has been compared on all five sites. Wood specific gravity of these five species are similar enough (Alban 1978, Schlaegel 1975) that weight yields would follow the same ranking as volumes. The higher yields of red pine and white spruce compared with the other species would be expected to increase even more with time because for both red pine (Lundgren 1981) and white spruce (Love and Williams 1968) mean annual increment does not peak until at least age 50; whereas for jack pine and aspen MAI peaks earlier (Benzie 1977a, Perala 1977). The genetic diversity of white spruce and jack pine (Jeffers and Jensen 1980, Nienstaedt 1982) offers further opportunity to increase the yield of these species relative to the more genetically uniform red pine. I am aware of no published growth and yield information for black spruce on upland soils in the Lake States, but the limited information presented here give no indication that black spruce yields will ever approach those of red pine or white spruce at ages of commercial harvest.

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