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DEVELOPMENT OF AN ASPEN SUCKER STAND FOLLOWING IRRIGATION AND FERTILIZATION

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ABSTRACT.--A 16-18 year-old aspen stand was harvested in 1969. Aerial biomass components were determined and soils evaluated. Treatments of fertilizer, irrigation, fertilizer + irrigation and control were applied over a seven year period following harvest. Stand measurements were taken periodically over 18 years. Fertilization produced growth increases of 45-55 percent. Height, diameter, and stems per acre were affected by treatments. Guidelines for fertilizer application were developed from leaf tissue analysis.

INTRODUCTION

Interest in the growth potential of aspen led to research focused on the production of maximum growth in natural and improved aspen. The objectives were to demonstrate the biological potential of aspen and aspen hybrids. The program had the goals of: (1) exploiting available genetically improved species of Populus, (2) developing rotation age and harvesting system information, (3) determining the biological feasibility of such forestry practices as fertilization, irrigation, and whole tree harvesting.

Silvicultural Trial V (ST V) imposed treatments on a developing Populus tremuloides sucker stand immediately after harvest. One of the objectives was to demonstrate the growth potential of native aspen stands, the results of which are reported here. Other objectives, not reported in this paper, were to examine the feasibility of short rotation intensive culture for fuel and fiber, and study the impact of whole tree harvesting on nutrient removal.

The subject stand arose from clear cutting a 16-18-year-old sucker stand in the fall of 1969. Yield data from the stand were obtained by whole-tree chipping all trees in the stand, weighing chipped material and roundwood, and determining moisture content. The approach was made possible through the willingness of Owens-Illinois, Inc. to provide the site and harvesting and transportation equipment. Because of the size of the test area, sufficient chips were available for a millrun evaluation of pulping. Additional information from the original stand was obtained from eight 2/25-acre randomly located plots measured prior to harvesting.

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EXPERIMENTAL AREA

The test area is located in northern Wisconsin on Owens-Illinois, Inc. (now Nekoosa Packaging, Inc.) land at a site known as the Willow Flowage (Section 8, T-37-N, R-5-E, Oneida County). The 9.8 acre site is best described as a slightly rolling upland loamy sand about 10 feet above the flowage high water mark.

Soil samples were taken at three locations on the test area; texture and nutrient status information are given in Table 1. The texture of the surface soil was a loamy sand; nutrient analyses indicated N, P, K levels were comparable to and Ca and Mg were lower than those found on good aspen sites[2] (Koerper and Richardson 1980).

PARENT STAND INFORMATION

The study aspen stand originated from a commercial clear-cut made 15-20 years earlier, about 1950. Ring counts of stump disks from 24 trees indicated most were between 15 and 17 years of age with only one tree at age 18. Based on the ring counts, the original stand was considered to be 18 years old, recognizing it was probably a conservative figure. The stand also had few residual stems from the 1950 harvest; most of these were birch, red maple, spruce, and balsam fir.

Additional stand data were acquired by taking eight 2/25 acre circular plots. One of those plots was cut and weighed. Eleven trees were selected as representative of the area and dissected to determine moisture content, percent bark, and specific gravity. The dissected trees had an average of 45.3 percent moisture, 17.0 percent stem bark, and an average green volume specific gravity of 0.37 for wood and 0.44 for stem bark. The information from this plot (124 trees) was used to compute a regression equation which predicted fresh weight from height and diameter measurements. The regression equation was in good agreement with Bella (1968) and was used with the data from all plots to provide an estimate of the wood on the area. Table 2 provides a description of stand composition and wood volume. The stand had an average density of 1700 stems /acre. Aspen accounted for 98 percent of the stems and 95.6 percent of the basal area. Ninety-five percent of the aspen was P. tremuloides and five percent was P. grandidentata.

Table 1.--ST V soil texture and nutrient analyses[1] in 1969.

Location	Sand %	Silt %	Clay %	N	P	K	Ca	Mg	pH
Rep A	93	4	3	373	133	98	333	93	4.4
Rep B	92	5	3	308	135	85	412	110	4.4
Rep C	90	6	4	448	158	93	333	93	4.6

[1]Nutrient levels are pounds/acre; available N,P, K, exchangeable Ca and Mg.

[2]Institute of Paper Science and Technology, Atlanta, Georgia 30318, unpublished data.

Volume estimates (wood plus bark) were made from the eight plots listed in Table 2. Results from another study indicated inclusion of branches would increase the volume by 11 percent. Site index (base age 30) for quaking aspen was determined to be 52 (Graham et al. 1963). Hypoxylon mammatum canker was found on 5.7 percent of the aspen stems.

YIELD

Cutting the parent stand began in mid-October 1969 and was completed by the third week of November. Institute of Paper Chemistry personnel felled and windrowed the trees, and Owens-Illinois personnel skidded, chipped, hauled, weighed, determined moisture content, and pulped the chips. Eight-foot bolts with a minimum top diameter of 2.5 inches were chipped at the mill; smaller material was chipped on site.

All yield data were based on fresh weight and moisture content data. Volume equivalents, using green volume density determinations made on whole tree aspen (wood and bark), averaged 24.0 lb/cubic foot. Ovendry material averaged 21.2 tons per acre with an estimated mean annual increment of 2355 pounds per acre. These results are in close agreement with those obtained from the 2/25 acre plot measurements summarized in Table 2.

Table 2.--ST V original stand composition.

			Percent of Total Basal Area					
Plot Number	Stems/ Acre	Basal Area/A (ft^2)	Aspen	Other Hdwds	Mean Total Ht (ft)	Mean DBH (in)	OD Wt/ Acre (M lb)	Cords/ Acre (79 ft^3)
1	975	68	100	--	31.8	3.2	32.8	17.3
2	2100	102	90.2	9.8	30.1	2.7	48.0	25.3
3	1450	82	100	--	32.3	3.0	39.4	20.8
4	2400	90	94.2	5.6	29.2	2.4	41.3	21.8
5	1140	68	90.8	9.2	30.0	2.6	30.1	15.9
6	2190	100	90.0	10.0	30.4	2.6	46.9	24.8
7	1810	66	100	--	27.7	2.4	30.1	15.9
8	1550	74	100	--	29.5	2.6	34.2	18.1
Av	1700	81	95.6	4.4	30.1	2.7	37.8	20.0
Est. MAI							2.1	1.11

TREATMENTS AND EXPERIMENTAL DESIGN

The area was divided into 12 plots 150 x 200 feet in size with 10-foot lanes between plots and a 20-foot border around the perimeter of the area. Root connections between plots were severed in 1970 and 1971 and maintained annually with a brush disk. An eight-foot deer enclosure was placed around the trial.

Cost restricted irrigation treatments to a single area so the trial was laid out in a three-replicate, randomized block, split-plot design. Treatments consisted of a control, fertilization at 1000 pounds/acre, irrigation, and fertilization plus irrigation. A balanced, custom-made fertilizer with 20 percent N, 5 percent P, 10 percent K, 20 percent Ca, and 4 percent Mg was applied between May 27 and June 3, 1970 and again in June, 1975. Half of the nitrogen was supplied as ammonium nitrate, and the other half as a slow-release urea form. The fertilizer used was selected on the basis of soil nutrient and texture information[3] and earlier greenhouse and nursery studies (Einspahr 1971).

Irrigation treatments used water pumped from the Willow Flowage using a 25 horsepower engine. Water was delivered to plots through aluminum pipe to 11 high volume (40 gallons per minute) nozzles mounted on 10-foot risers that were later increased to 20 feet. Water application was based on soil moisture measurements made using both Bouyoucos blocks and gravimetric determinations. Circular plots for measuring growth were randomly located, and increased in size over time from one mil acre to 1/50 acre. The nutrient status of the trees on the trial was monitored by making leaf collections from all treatments, one sample from each replication of each treatment. Samples were collected in late August for the years 1970 through 1978. Levels of N, P, K, Ca, and Mg were determined for each sample.

RESULTS

Table 3 summarizes the growth information obtained for an eighteen year period from 1970 through 1987. Growth was good the first three growing seasons (1970-1972) with a significant height growth response due to fertilizer treatments. Fertilization also resulted in a significant reduction in number of stems per acre. Irrigation treatments had an increased incidence of Venturia tremulae, a fungal disease causing growing tip dieback. The disease occurs under conditions of high humidity, and causes a reduction in height growth. It was this dieback that produced a lack of growth response to irrigation. The effects of that disease were still evident 18 years later; the irrigation treatment had the lowest average height.

At age four (1973) a major natural thinning began in the control and irrigation treatments; thinning in the fertilization treatments was present from the beginning. Similar thinning effects from fertilization have been reported by other workers (Safford and Czapowskyj, 1986). The natural thinning process continued in all treatments at age 5 (1974) and tended to equalize the number of trees per acre. However, there remained fewer trees per acre in the fertilizer and fertilizer + irrigation treatments, and average height and diameter were significantly different. A volume loss in both 1973 and 1974 was a direct result of the thinning process (Fig. 1).

The fertilized areas received a second application in 1975. Measurements taken the fall of 1976 indicated there was no significant difference in number of stems per acre by treatment, although there appeared to be some reduction due to the reapplication of fertilizer. Average height, average DBH, average diameter growth, and total volume were significantly influenced by treatments seven years (1976) after the start of the trial.

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[3]Institute of Paper Science and Technology, Atlanta, GA 30318, unpublished data.

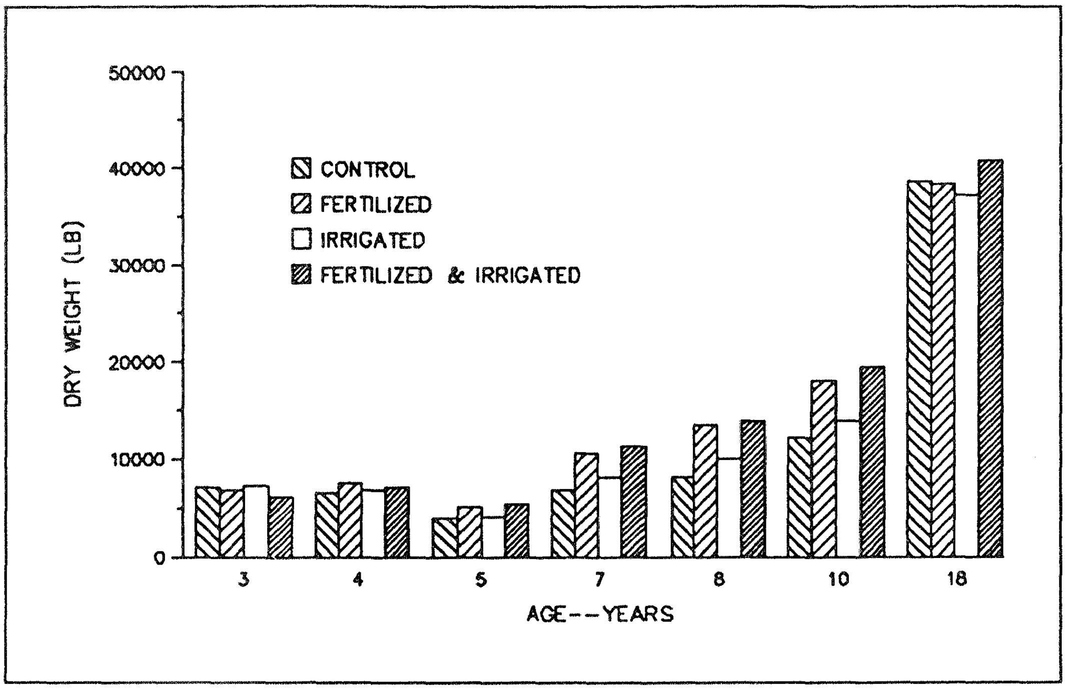

Figure 1.--Dry weight of stem wood produced over an eighteen year period.

Irrigation was discontinued after the 1976 growing season (year 7). The plots were remeasured in 1977 and 1979; at ten years, significantly greater volumes of wood were present on the fertilized (+47%) and the fertilized + irrigated (+55%) areas than on the untreated control areas. Wood volume on the irrigated areas was not significantly different from the control areas although the irrigation treatment supported a significantly greater number of stems than all other treatments.

Leaf nutrient measurements were made on trees from all plots through age nine (Table 4) to monitor soil nutrient uptake and to establish which elements were responsible for the growth increases obtained. Results from leaf analyses indicate nitrogen and, to a lesser extent potassium, are responsible for the growth increases. The data further indicates that response to nitrogen fertilization can be expected when leaf nitrogen levels drop below 2.8 percent and/or potassium levels drop below 0.9 percent, provided that other essential elements are at appropriate levels and soil moisture is not limiting. Based on leaf tissue measurements and upon growth rate comparisons during years 8, 9, and 10, there appeared to be no fertilizer carryover by age 10 on this sandy, well-drained site.

EIGHTEEN YEAR GROWTH

A growth response due to treatment was noted through age 10. The trial was measured at age 18 (1987) to see if those differences were still present. Table 3 summarizes the 18th year measurements. Diameter and stems per acre in the fertilizer treatments continued to be significantly different from the control and irrigation treatments ($p < 0.05$); stem diameters were greater and number of stems per acre were less. Total height and total wood volume were not significantly different.

DISCUSSION

Fertilization and irrigation of hardwoods is an interesting concept because of the high site requirements of hardwoods. Intensive management procedures like irrigation and fertilization may provide a better return on investment when applied to high value hardwoods like walnut and oak. Response of aspen sucker stands to fertilization is more difficult to interpret than evenly spaced hardwood plantations. Typically, irrigation produces height response and fertilization results in diameter growth increases.

Table 3.--ST V eighteen year growth.

Year	Height (ft)	DBH (in)	Aspen Stems/ Acre	Dry Wt. Wood (lb/acre)	Vol/A (ft^3)	Mean Annual Increment
CONTROL						
1970	2.8	--	33200	--	--	--
1971	4.3	--	27700	--	--	--
1972	5.7	0.5	22277	7224	315	105
1973	8.1	0.7	13523	6461	282	94
1974	12.0	0.8	5400	3891	170	57
1976	15.3	1.0	5188	6558	286	41
1977	16.1	1.2	4800	8107	354	44
1979	20.6	1.5	3266	12043	526	53
1987	36.1	3.0	1670	38124	1665	92
FERTILIZED						
1970	3.3	--	22300	--	--	--
1971	5.3	--	18300	--	--	--
1972	7.2	0.6	14814	6637	290	97
1973	9.6	0.8	10830	7549	330	83
1974	12.7	0.9	6222	5077	222	44
1976	17.3	1.2	5540	10403	454	65
1977	18.5	1.3	5115	13302	581	73
1979	22.6	1.8	3422	17717	773	77
1987	36.9	3.2	1425	37861	1653	92
IRRIGATED						
1970	2.7	--	38700	--	--	--
1971	4.2	--	30500	--	--	--
1972	5.3	0.5	24635	7257	317	106
1973	7.8	0.6	14926	6642	290	73
1974	11.9	0.8	5944	4134	180	36
1976	16.3	1.0	5811	8083	353	50
1977	17.3	1.2	5422	9867	431	54
1979	21.0	1.5	3755	13838	604	60
1987	34.7	2.9	1800	36771	1606	89
IRRIGATED & FERTILIZED						
1970	3.3	--	22800	--	--	--
1971	4.8	--	18900	--	--	--
1972	7.0	0.7	13883	5938	259	86
1973	8.8	0.8	11346	6767	295	74
1974	12.4	0.9	6209	5309	232	46
1976	17.7	1.2	5143	11111	484	69
1977	19.8	1.5	4300	13826	603	75
1979	24.0	1.9	3077	19090	833	83
1987	37.9	3.4	1320	40359	1762	98

Table 4.--Leaf nutrient levels.

YEAR	N	P	K	Ca	Mg
CONTROL					
1970	2.69	0.24	0.63	1.52	0.35
1971	2.43	0.18	0.71	1.02	0.24
1972	2.64	0.19	0.64	1.40	0.22
1973	2.83	0.23	0.86	1.38	0.33
1974	2.58	0.20	0.79	1.23	0.23
1975	2.40	0.17	0.74	1.03	0.22
1976	2.62	0.19	0.83	0.88	0.26
1977	2.71	0.25	0.90	1.43	0.32
1978	2.64	0.21	0.66	1.33	0.30
FERTILIZED					
1970	3.07[1]	0.24	0.83	1.23	0.33
1971	2.86[1]	0.20	0.98[1]	1.02	0.19
1972	2.84	0,19	0.80[1]	1.23	0.16
1973	2.81	0.23	1.06	1.44	0.28
1974	2.49	0.19	0.91	1.16	0.20
1975	2.82[1]	0.19	1.01	1.10	0.19
1976	3.16[1]	0.20	1.20[1]	0.77	0.20
1977	2.93	0.24	0.97	1.33	0.27
1978	2.64	0.21	0.80	1.40	0.21
IRRIGATED					
1970	2.76	0.23	0.87	1.52	0.30
1971	2.44	0.18	0.82	1.19	0.22
1972	2.59	0.19	0.74	1.24	0.21
1973	2.85	0.21	0.90	1.53	0.30
1974	2.51	0.17	0.90	1.21	0.19
1975	2.26	0.19	0.73	1.08	0.21
1976	2.64	0.20	0.93	1.23[1]	0.28
1977	2.78	0.23	0.85	1.53	0.35
1978	2.65	0.20	0.64	1.70	0.30
IRRIGATED & FERTILIZED					
1970	3.02[1]	0.23	0.83	1.41	0.27
1971	2.91[1]	0.21	1.03[1]	1.21	0.21
1972	2.98	0.19	0.82[1]	1.06	0.21
1973	2.75	0.19	1.00	1.46	0.29
1974	2.56	0.20	0.99	1.07	0.22
1975	2.87[1]	0.19	0.96	1.04	0.21
1976	3.16[1]	0.21	1.23[1]	0.89	0.23
1977	3.10	0.27	1.05	1.47	0.30
1978	2.60	0.20	0.79	1.40	0.19

[1]Values are significantly different from control ($p<0.05$).

However, competition between stems for moisture and light in sucker stands causes natural thinning and complicates the interpretation of results. In this study, fertilization resulted in improved diameter growth, increased competition between stems, and reduced the number of stems per acre. Irrigation through age seven failed to significantly increase average height after year ten except when combined with fertilization, apparently due to repeated tip dieback caused by the humidity-related disease Venturia tremulae.

The control plots had 33000 stems per acre at age one. Stem numbers decreased rapidly during growing seasons 2, 3, 4, and 5 with the greatest decreases during years 4 and 5 (-8700 and -8100 stems/acre). At age 18, the control areas had 1670 stems per acre which was comparable to the 1700 stems/ acre present when the stand was cut in 1969. Dry weight of wood (bolewood excluding bark and branches to 1/2 inch top) on control plots was estimated to be 38100 lb/acre and was comparable to the estimated 37800 lb/acre in the original stand. Growth for the 18 year period was 1.1 cords/ acre/year (79 ft^3).

The irrigation "only" plots had the greatest number of stems/acre (38700) at age one. Rapid thinning occurred, as with the control, during years 4 and 5. Stem losses were approximately 9300/year. Diameter growth was not improved with irrigation, and height growth was reduced by dieback from Venturia tremulae for the first four years. By age five, the trees had reached heights and stand densities where V. tremulae was not affecting growth. The irrigation "only" plots carried a larger number of stems/acre through the 18 year measurement period, although at the age 18 measurement, the number of stems and their diameter were not significantly different from the control.

Treatment response on the fertilized and the fertilized + irrigated areas was similar; there were equivalent numbers of stems at age one, natural thinning occurred at the same rate, and height growth was similar. Stems/acre at age one were about 22500 and thinning of 4-5000 stems/acre occurred through age 4. Fertilization treatments affected growth through age 10; at age 18, those differences were no longer detected and appear to be due to a lower number of stems/acre.

RECOMMENDATIONS

Silvicultural Trial V is located on an upland loamy sand site with a growing season water table at about 10 feet. Based upon observations of this site for 18 years, irrigation of aspen stands on similar sites is not recommended. Growth increases are low, application costs are high, and disease problems are increased.

Fertilization resulted in ten-year growth increases of 45-55 percent. Based upon leaf tissue analyses it is recommended that fertilizer include both nitrogen and potassium and that part of that nitrogen be a slow release form. An economic analysis undertaken at age 10 indicated that fertilization on upland sandy soils resulted in wood production increases about equivalent in value to application costs. Additional work should be considered to determine if an acceptable economic return may be obtained if higher quality sites are selected and fertilizer is applied 4-6 years prior to harvesting.

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