EFFECTS OF MANAGEMENT STRATEGY AND SITE ON SELECTED PROPERTIES OF FIRST ROTATION *POPULUS* HYBRID NE-388[1]

Paul R. Blankenhorn, Todd W. Bowersox, Charles H. Strauss, Gwen L. Stimely, Lee R. Stover, and *Maria L. DiCola*

Professor of Wood Technology, Associate Professor of Silviculture, Associate Professor of Forest Economics, and Research Assistants, School of Forest Resources
The Pennsylvania State University
University Park, PA 16802

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ABSTRACT

The influence of management strategy and site on specific gravity and chemical content (extractive, holocellulose, alpha-cellulose, and Klason lignin) values for 1- to 4-year-old first rotation *Populus* Hybrid NE-388 wood and bark specimens was investigated. Specific gravity, extractive content, and Klason lignin values decreased with increasing age for wood, while extractive content and Klason lignin values decreased with increasing age for bark. All other determinations generally increased with age for wood and bark. Statistical comparisons were made between sites and among management strategies. Management strategies and sites influenced the specific gravity and chemical content properties, with management strategies influencing the specific gravity and chemical content values of wood more than site.

Keywords: Site, specific gravity, chemical composition, age, management, *Populus.*

INTRODUCTION

The use of *Populus* hybrid clones in short rotation intensive culture (SRIC) plantations represents an effort to produce efficiently biomass as a feedstock for energy and chemicals. Research in this area has focused on biomss productivity. Several studies have provided conceptual models for SRIC biomass plantations and SRIC's role in producing wood energy (Fege et al. 1979; Hansen et al. 1983; Howlett and Gamache 1977; Inman et al. 1977; Rose 1977; Rose et al. 1981).

The use of SRIC biomass as a feedstock for energy or chemicals requires data on biomass production and basic physical and chemical properties of the material. Data on the utilization of SRIC biomass are beginning to appear in the literature (Anderson and Zsuffa 1975; Bendtsen 1978; Blankenhorn et al. 1985a, b; Bowersox et al. 1979; Cech et al. 1960; Dawson et al. 1976; Geyer 1981; Holt and Murphey 1978; Murphey et al. 1979). Additional information on the influences of management strategies on fuel and chemical properties will aid the production and conversion decision-making processes.

The purpose of this study was to investigate the effects of management strategies and sites on selected properties of the first rotation *Populus* hybrid NE-388. The properties studied were specific gravity and chemical content (extractives, holo-

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cellulose, Klason lignin, and alpha-cellulose). Wood and bark specimens from 1- to 4-year-old biomass subjected to four different cultural treatments on two sites were analyzed for the effects of management strategies and site.

PROCEDURES

Populus hybrid SRIC plantations were established under four management strategies (control, fertilization, irrigation, and fertilization/irrigation) on two sites representing inherently favorable (Basher silt loam soil) and unfavorable (Morrison sandy loam soil) growth conditions. All management strategies included tillage prior to planting dormant unrooted cuttings and weed control in the first growing season. The control strategy had no additional investments. All fertilization strategy treatment units included annual amendments of a balanced N-P-K-Ca-Mg nutrient set to achieve equal nonlimiting availability of macronutrients at both sites. Amount of nutrients added was based on annual soil tests and recommendations for a high corn silage yield. All irrigation strategy treatment units employed a trickle system to maintain a nonlimiting soil moisture condition at each site. Site specific irrigation was conducted mainly in July and August, depending on soil moisture levels. All fertilization/irrigation strategy treatment units combined the fertilization and irrigation investments.

Each plantation site (1.2 ha) consisted of six replications (0.2 ha each), with three replications planted in 1980 and three replications planted in 1981. Each replication included four treatment units (0.05 ha each for control, fertilization, irrigation, and fertilization/irrigation). Growing space for *Populus* hybrid NE-388 (*P. maximowiczii* × *trichocarpa*) cuttings was 0.48 m^2, with 0.8 meters between rows and 0.6 meters between trees in the rows. In each treatment unit, trees were designated for both continuous inventory and annual destructive sampling over a 4-year period (Blankenhorn et al. 1985c).

Individual sample trees (maximum of 20 trees per treatment unit, and replicated six times per site) were harvested in November–December and returned to the laboratory for analyses. Wood and bark specimens by site, age, and management strategy were separated from the trees. The 1-year-old specimens were collected from growth produced in the first growing season of the rotation. The 2-year-old specimens were a combination of 1- and 2-year-old tissues, 3-year-old specimens were a combination of 1- to 3-year-old tissues, and 4-year-old specimens were a combination of 1- to 4-year-old tissues.

Specific gravity and tissue chemical constituent values for the trees by site, management strategy, age, and tissue were obtained using the following test procedures: 1) specific gravity (maximum moisture content method, Smith 1955), 2) extractive content (ASTM D-1105-79), 3) holocellulose content (acid chlorite method, Browning 1967), 4) alpha-cellulose (ASTM D-1103-77) and 5) Klason lignin content (ASTM D-1106-77) for wood and bark specimens.

Definitive chemical analysis of bark is difficult because of the presence and variability of suberin and other waxlike substances in the bark. In a preliminary study, chemical content data were obtained for untreated bark and bark pretreated with a mild alkali solution used to remove the suberin. The results of this study indicated that the untreated bark containing suberin did not hinder the chemical determinations except for alpha-cellulose. Hence, pretreatment of the bark with a mild alkali solution was not used for the bark chemical content determinations.

Bark alpha-cellulose values were obtained using a standard method (ASTM

TABLE 1. *Average specific gravity values[1] as a function of management strategy, site, age, and tissue.*

Tissue[2]	Age (yr)	Specific gravity[3] Control	Fertilization	Irrigation	Fetilization/ irrigation
		Basher site			
	1	0.458aA	0.439aA	0.436aB	0.444aA
	2	0.436aAB	0.415bBC	0.448aA	0.402aC
Wood	3	0.390aA	0.360bA	0.389aA	0.359aA
	4	0.381aAB	0.349bC	0.397aA	0.370aBC
	1	0.318aA	0.312aA	0.315aA	0.313aA
	2	0.322aA	0.327aA	0.302aB	0.313aAB
Bark	3	0.298aA	0.313aA	0.299bB	0.309aA
	4	0.335aA	0.340aA	0.342aA	0.352aA
		Morrison site			
	1	0.480aA	0.451aA	0.465aA	0.448aA
	2	0.465aA	0.444aAB	0.448aAB	0.430aB
Wood	3	0.427aA	0.398aA	0.432aA	0.388aA
	4	0.397aA	0.387aA	0.406aA	0.391aA
	1	0.299bA	0.331aA	0.322abA	0.323abA
	2	0.306aA	0.317aA	0.310aA	0.310aA
Bark	3	0.315aA	0.320aA	0.315aA	0.310aA
	4	0.328aA	0.336aA	0.339aA	0.343aA

[1] Wood and bark differences among managment strategies for each site, tissue, and age combination are denoted by upper case letters. Wood and bark differences between sites for each tissue, age, and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.05 level as determined by Duncan's mean separation procedure.
[2] Specific gravity values are based on an average of 18 specimens per treatment, except for year one where the specific gravity values are based on an average of 9 specimens per treatment.
[3] Maximum moisture content method. Smith, D. M. 1955. Maximum moisture content method for determining specific gravity of small wood samples, USDA Forest Service, Forest Products Lab., No. 2014. 8 pp.

D-1103-77) developed for wood. Filtration through ground bark specimens was difficult during alpha-cellulose determinations. Numerous tests on 2.0-g and 0.5-g bark specimens yielded comparable results. Therefore, alpha-cellulose determinations of bark were performed on the smaller specimen size because of ease of filtration.

Statistical analyses included analysis of variance (AOV) for treatment effects (site and management strategy). For each tissue/age/site combination (24 total), a model was used to determine whether the property varied significantly with management strategy. Conversely, for each tissue/age/management strategy combination (48 total), a model was used to determine whether a property varied significantly with site. Duncan's mean separation procedure was implemented to denote which means were or were not significantly different. All effects were established at the 0.05 level of significance.

RESULTS AND DISCUSSION

Property means of 1 through 4-year-old wood and bark specimens harvested from the Basher and Morrison sites are summarized in Tables 1–5. Duncan mean separation letters associated with levels of significance are also listed in the tables.

Wood

Average specific gravity values for wood show definite trends. Values for the Morrison trees were higher than those for the Basher trees. This overall difference was consistently, but not significantly, reflected in the age-management strategy

TABLE 2. *Average extractive content values[1] as a function management strategy, site, age, and tissue.*

Tissue[2]	Age (yr)	Extractive content (% of oven dry weight)[3] Control	Fertilization	Irrigation	Fetilization/ irrigation
		Basher site			
	1	9.79aA	8.44bC	8.58bC	9.11aB
	2	7.20aA	6.54aA	6.85aA	6.69aA
Wood	3	5.13aB	5.25aAB	5.53aA	5.56aA
	4	5.59aA	5.52aA	5.29aB	5.30aB
	1	42.94bA	41.30bC	42.22bB	41.13bC
	2	43.40aA	43.61aA	43.09aA	42.94aA
Bark	3	43.89aA	42.95bB	43.16aAB	43.81aA
	4	41.78aA	41.79aA	42.64aA	42.33aA
		Morrison site			
	1	7.69bB	9.73aA	9.81aA	7.92bB
	2	6.43aA	6.77aA	7.23aA	6.98aA
Wood	3	5.18aA	4.98aA	4.78bA	5.24aA
	4	5.64aA	5.19bB	5.48aA	5.17aB
	1	46.08aA	44.50aC	45.21aB	42.85aD
	2	42.94aA	43.38aA	43.99aA	43.44aA
Bark	3	43.46aA	43.46aA	42.26bB	43.25bA
	4	40.53bA	40.85bA	40.56bA	40.84bA

[1] Wood and bark differences among managment strategies for each site, tissue, and age combination are denoted by upper case letters. Wood and bark differences between sites for each tissue, age, and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.05 level as determined by Duncan's mean separation procedure.
[2] Extractive content values are based on an average of 12 specimens per treatment, except for year one, where the extractive content values are based on an average of 6 specimens per treatment.
[3] ASTM D-1105-56.

comparisons between the two sites (Table 1). The site difference in specific gravity may be related to tree growth rates. The Basher site trees consistently had greater age-management strategy diameter values than the Morrison site trees (Blankenhorn et al. 1985c). Management strategy had the greatest effect on the 2- to 4-year-old wood specific gravity average values (Table 1). In general, the fertilization and fertilization/irrigation strategies had lower specific gravity values than the control and irrigation strategies. This trend may also be related to the management strategy growth rates. The fertilization and fertilization/irrigation strategies had greater diameter values than trees from the control and irrigation strategies. In addition, specific gravity for the older ages was lower than those found in the younger age trees. Accumulated and annual diameter tree values for all strategies increased with increasing age. The site, management strategy, and age differences in specific gravity appear to be related more to growth rate than treatment. The suggestion that increased diameter growth rate lowers the juvenile specific gravity of short rotation *Populus* needs further analyses.

Chemical constituent content values (Tables 2, 3, 4, and 5) were similar to previously reported results (Blankenhorn et al. 1985a, b; Holt and Murphey 1978). Trends in the chemical content values for wood were evident. The holocellulose and alpha-cellulose contents increased with age, while the Klason lignin and extractive contents generally decreased with age. Trends among management strategies for the chemical content values were not as evident across both sites as they were in the specific gravity data. Comparisons between sites indicated that

TABLE 3. *Average holocellulose content values[1] as a function of management strategy, site, age, and tissue.*

Tissue[2]	Age (yr)	Holocellulose content (% of oven dry weight)[3] Control	Fertilization	Irrigation	Fertilization/irrigation
		Basher site			
Wood	1	75.47bB	75.04bB	79.47aA	75.27aB
	2	82.61aA	79.87aA	82.94aA	80.72aA
	3	84.00aA	80.90aB	83.35aA	82.52aAB
	4	84.47aA	82.07aA	83.43aA	82.71aA
Bark	1	39.43bB	41.76aA	41.12aA	41.69aA
	2	42.85aA	41.50aA	41.40bA	41.93aA
	3	41.55aA	40.78aA	41.22bA	42.12aA
	4	42.88aA	43.77aA	43.43aA	43.79aA
		Morrison site			
Wood	1	80.61aA	76.91aB	79.94bB	77.08aB
	2	80.99aA	78.73aA	78.90aA	81.09aA
	3	83.62aA	80.96aA	83.07aA	83.05aA
	4	83.31aA	83.48aA	84.66aA	82.92aA
Bark	1	41.80aAB	42.17aA	40.77aB	41.74aAB
	2	38.41bC	41.28aB	42.84aA	41.20aB
	3	42.03aB	39.82aC	43.72aA	41.14aBC
	4	43.80aA	44.21aA	44.77aA	44.07aA

[1] Wood and bark differences among managment strategies for each site, tissue, and age combination are denoted by upper case letters. Wood and bark differences between sites for each tissue, age, and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.05 level as determined by Duncan's mean separation procedure.

[2] Holocellulose values are based on an average of 6 specimens per treatment, except for year one, where the holocellulose values are based on an average of 3 specimens per treatment.

[3] Acid chlorite method, Browning, B. L. 1967. Methods of wood chemistry, Vol. II, Interscience Publishers, New York. 882 pp.

there are a few significant differences in the 2- to 4-year-old material, but for the most part chemical constituent values were not significantly different. Statistical analysis among management strategies indicated that management strategies can influence chemical contents, particularly in the 1- to 3-year-old material. It appears that management strategy can influence the chemical contents of the trees more than site.

Bark

Trends in the specific gravity values for bark were not as evident as those for wood. While bark specific gravity increased with age, there were no trends for the two sites or among the management strategies. Within a management strategy at both sites, most of the specific gravity values were not significantly different. Comparisons among management strategies indicated that some significant differences existed in 2- and 3-year-Basher values, but for the most part the values were not significantly different. Hence, management strategies seemed to influence the specific gravity values of wood more than they did bark.

Holocellulose and alpha-cellulose values increased with age for bark, while the Klason lignin and extractive contents generally decreased or remained relatively the same with increasing age. Comparisons between sites indicated that significant differences were present, particularly in the 1- to 3-year-old values. These significant differences in the chemical contents of the bark, except for extractive content,

TABLE 4. *Average alpha-cellulose content values*[1] *as a function of management strategy, site, age, and tissue.*

Tissue[2]	Age (yr)	Alpha-cellulose content (% of oven dry extractive free weight)[3]			
		Control	Fertilization	Irrigation	Fertilization/ irrigation
		Basher site			
	1	42.28bAB	40.88bB	42.83bA	38.55bC
	2	43.47aA	42.52aA	43.15aA	43.32bA
Wood	3	44.44aB	43.31bC	44.60aAB	45.14aA
	4	46.63aA	46.39aA	46.06aA	45.99aA
	1	39.80bA	37.95bB	38.03aB	36.76bC
	2	43.28aA	41.43aB	41.56aB	40.76aB
Bark	3	42.48aAB	42.24aB	42.38aAB	43.72aA
	4	44.29aA	46.66aA	44.81aA	45.06aA
		Morrison site			
	1	43.58aA	43.42aA	43.12aC	43.28aB
	2	44.13aA	42.68aC	43.43aB	44.27aA
Wood	3	44.78aAB	44.14aB	44.34aB	45.08aA
	4	46.56aA	46.96aA	46.99aA	46.46aA
	1	43.33aA	41.60aA	41.79aA	40.25aA
	2	43.40aA	41.46aA	42.46aA	41.47aA
Bark	3	43.19aA	40.04bB	43.94aA	42.36bA
	4	44.47aA	44.01aA	44.52aA	44.46aA

[1] Wood and bark differences among managment strategies for each site, tissue, and age combination are denoted by upper case letters. Wood and bark differences between sites for each tissue, age, and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.05 level as determined by Duncan's mean separation procedure.
[2] Alpha-cellulose values are based on an average of 6 specimens per treatment, except for year one, where the alpha-cellulose values are based on an average of 3 specimens per treatment.
[3] ASTM D-1103-60.

seemed to decrease at 4 years of age. Statistical comparisons among management strategies indicated significant differences in the first rotation biomass.

SUMMARY

Specific gravity and chemical content values obtained for first rotation biomass for *Populus* Hybrid Clone NE-388 were analyzed for differences between sites and among management strategies. Specific gravity, extractive content, and Klason lignin values decreased with increasing age for wood, while holocellulose and alpha-cellulose values increased. For bark, specific gravity, holocellulose, and alpha-cellulose values increased with age, while extractive content and Klason lignin values decreased. Within a management strategy, tissue and age comparisons between sites indicated that, for the most part, the values were not significantly different. Statistical comparisons among management strategies indicated that management strategies influenced the specific gravity values of wood more than bark. Management strategies also influenced the chemical content values for wood and bark, particularly in the 1- to 3-year-old material.

Hence, it appears that age, management strategy, and site can influence the properties of first rotation *Populus* Hybrid Clone NE-338 biomass. Shorter rotations (1 or 2 years) would result in biomass having proportionally higher extractive contents. Longer rotations (3 or 4 years) would result in biomass having proportionally higher holocellulose and alpha-cellulose values. No consistent

TABLE 5. *Average Klason lignin content values[1] as a function of management strategy, site, age, and tissue.*

Tissue[2]	Age (yr)	Klason lignin content (% of oven dry weight)[3] Control	Fertilization	Irrigation	Fertilization/ irrigation
		Basher site			
	1	17.62aA	16.90aA	15.71aA	17.31aA
	2	17.71aA	16.67aAB	15.84aB	16.31aB
Wood	3	16.56aB	17.84aA	18.03aA	16.59aB
	4	16.73aA	16.63aA	16.39aA	15.52aA
	1	16.31aA	16.28aA	15.30aB	16.58aA
	2	15.01aA	14.55aA	15.01aA	14.62aA
Bark	3	15.05aA	13.91aA	14.68aA	14.68aA
	4	14.08bAB	13.66aB	14.71bA	14.10aAB
		Morrison site			
	1	16.26bA	16.24aA	16.01aA	17.36aA
	2	16.19aA	17.40aA	16.72aA	16.27aA
Wood	3	15.87aA	17.03aA	16.80aA	15.60bA
	4	15.91aA	16.30aA	15.49aA	15.00aA
	1	16.25aB	16.18aB	15.26aC	16.60aA
	2	14.80aA	15.07aA	14.16aA	14.20aA
Bark	3	14.83aAB	14.05aAB	15.65aA	13.29bB
	4	15.10aB	14.23aB	16.87aA	14.67aB

[1] Wood and bark differences among managment strategies for each site, tissue, and age combination are denoted by upper case letters. Wood and bark differences between sites for each tissue, age, and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.05 level as determined by Duncan's mean separation procedure.
[2] Klason lignin values are based on an average of 6 specimens per treatment, except for year one, where the Klason lignin values are based on an average of 3 specimens per treatment.
[3] ASTM D-1106-56.

chemical content trends were measured for either site or management strategy. Site, management strategy, and age appear to have influenced specific gravity but it is uncertain as to whether the changing specific gravity values were due to management strategy or an indirect effect of diameter growth associated with management strategy.

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