CHEMICAL COMPOSITION OF SECOND ROTATION *POPULUS* HYBRID NE-388[1]

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ABSTRACT

The influence of management strategy and rotation on specific gravity and chemical content (extractive, holocellulose, alpha-cellulose, and Klason lignin) values for second rotation 4-year-old *Populus* Hybrid NE-388 wood and bark specimens were investigated. Specific gravity values for wood were lowest for fertilization and fertilization/irrigation strategies and for bark were highest for fertilization and fertilization/irrigation strategies compared to control and irrigation strategies. Management strategies had little effect on the holocellulose and alpha-cellulose values for the second rotation. Management strategy and rotation had significant effects on extractive and Klason lignin contents for bark and the extractive content for wood. Second rotation average specific gravity values for wood were similar to or higher than first rotation values and average Klason lignin content values for bark were higher than first rotation values.

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

INTRODUCTION

A future use of forest biomass from short rotation intensive culture (SRIC) plantations may be as a feedstock for chemicals. The majority of the research effort in the area of SRIC plantations has centered around biomass pro-

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ductivity, conceptual models for the plantations, and the use of SRIC biomass for energy (Fege et al. 1979; Howlett and Gamache 1977; Inman et al. 1977; Rose 1977; Rose et al. 1981; Strauss et al. 1988).

The use of SRIC biomass as a feedstock for chemicals depends on the plantation productivity and the basic properties of the biomass. Information on the basic properties of SRIC biomass has been published (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). As these research plantations mature and new coppice rotations are permitted to grow, additional information on the properties of the biomass in coppice rotation will aid in the determination of SRIC biomass usefulness as a source of chemicals.

The purpose of this study was to characterize the chemical composition of second rotation *Populus* hybrid NE-388. Wood and bark specimens from 4-year-old second rotation biomass grown under four cultural treatments on two sites were analyzed. The properties studied included specific gravity and chemical content (extractives, holocellulose, Klason lignin, and alpha-cellulose).

PROCEDURES

Populus hybrid SRIC plantations were established under four management strategies (control, fertilization, irrigation, and fertilization/irrigation) on two central Pennsylvania sites. The Basher site was located on a nearly level floodplain derived from red shale and sandstone and the soil was Basher silt loam (Fluvaquentic Dystrochrept; coarse-loamy, mixed, mesic). The Morrison site was a gently sloping upland area where sandstone and dolmite had weathered to a Morrison sandy loam (Ultic Hapludalf; fine-loamy, mixed, mesic). 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 (Blankenhorn et al. 1985c).

Sample stems (maximum of 20 dominant stems 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 and management strategy were separated from the stems. The 4-year-old specimens were a combination of 1- to 4-year-old tissues from a single disk of each stem.

Specific gravity and tissue chemical constituent values for the stems by site, management strategy, and tissue (wood and bark) 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. First rotation component 4-year-old average values were published by Blankenhorn, et al. (1988) and are included in Tables 1–5 for convenience.

TABLE 1. *Average specific gravity values as a function of management strategy, site, rotation, and component.*

Component	Rotation	Specific gravity[1] Control	Fertilization	Irrigation	Fertilization/irrigation
		Basher Site			
Wood	1	0.381 Ba[2]	0.349 Ac	0.397 Aa	0.370 Ba
	2	0.402 Ab	0.364 Bb	0.402 Aa	0.370 Ba
Bark	1	0.335 Aa	0.340 Aa	0.342 Aa	0.352 Aa
	2	0.312 Bb	0.329 Aa	0.327 Ab	0.334 Ab
		Morrison Site			
Wood	1	0.397 ABa	0.387 Ba	0.406 Aa	0.391 Ba
	2	0.424 Bb	0.395 Ca	0.436 Ab	0.391 Ca
Bark	1	0.328 Aa	0.336 Aa	0.339 Aa	0.343 Aa
	2	0.331 Ba	0.343 Aa	0.329 Ba	0.341 Aa

[1] Average specific gravity values (maximum moisture content method) are based on an average of 18 specimens per site/treatment/component/rotation combination.

[2] Differences among management strategies for each site, rotation and component combination are denoted by upper case letters. Differences between rotations for each component, site and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.1 level of significance as determined by Duncan's mean separation procedure.

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 and bark alpha-cellulose values should be used only for comparative purposes within this study.

Bark alpha-cellulose values were obtained using a standard method (ASTM 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 significantly different. All effects were established at the 0.1 level of significance.

RESULTS AND DISCUSSION

Property means of 4-year-old first and second rotation wood and bark specimens for both sites are summarized in Tables 1–5. The first rotation values have been presented in Blankenhorn et al. (1988) and are included for convenience. Duncan's mean separation letters associated with levels of significance are listed in the tables.

Wood

Significant differences in the second rotation average specific gravity values (Table 1) for both sites were evident. The control and irrigation management strategies had consistently higher average specific gravity values than the fertilization and fertilization/irrigation management strategies. These differences in specific gravity may be related to management strategy growth rates. The fertilization and fertilization/irrigation strategies produced stems with greater diameter values than stems from

TABLE 2. *Average extractive content values as a function of management strategy, site, rotation, and component.*

Component	Rotation	Extractive content (% of oven dry weight)[1] Control	Fertilization	Irrigation	Fertilization/irrigation
		Basher Site			
Wood	1	5.59 Aa[2]	5.52 Aa	5.29 Ba	5.30 Ba
	2	4.39 Ab	4.45 Ab	4.62 Ab	5.16 Ba
Bark	1	41.78 Aa	41.79 Aa	42.64 Aa	42.33 Aa
	2	41.61 Aa	40.80 Bb	39.50 Cb	41.28 Ab
		Morrison Site			
Wood	1	5.64 Aa	5.19 Ba	5.48 Aa	5.17 Ba
	2	4.11 Ab	4.61 Bb	4.23 Ab	4.42 Cb
Bark	1	40.53 Aa	40.85 Aa	40.56 Aa	40.84 Aa
	2	40.94 Aa	41.61 Bb	41.14 Aa	40.33 Ca

[1] Extractive content values (ASTM D-1105-79) are based on an average of 12 specimens per site/treatment/component/rotation combination.
[2] Differences among management strategies for each site, rotation and component combination are denoted by upper case letters. Differences between rotations for each component, site and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.1 level of significance as determined by Duncan's mean separation procedure.

the control and irrigation strategies Bowersox et al. (1992a and 1992b). A significant difference between the first and second rotation at both sites was evident in the control strategy. Fertilization/irrigation management strategy produced similar average specific gravity values for both sites at both rotations. Irrigation and fertilization strategies produced some significant differences but no trends between sites for both rotations. The second rotation average specific gravity values for each management strategy at each site were similar to or higher than the first rotation values.

Chemical constituent values (Tables 2, 3, 4, and 5) were similar to previously reported results (Blankenhorn et al. 1985a, b, 1988; Holt and Murphey 1978). Management strategy effects on second rotation 4-year-old average chemical constituent values for both sites were not generally significant except for extractive content. However, the range in wood extractive content values was not large (4.2 to 5.2%) for the second rotation material. A comparison of the first rotation average chemical constituent values with the second rotation values produced, in general, nonsignificant results, except for the extractive content. It is interesting to note that the second rotation average

TABLE 3. *Average holocellulose content values as a function of management strategy, site, rotation, and component.*

Component	Rotation	Holocellulose content (% of oven dry weight)[1] Control	Fertilization	Irrigation	Fertilization/irrigation
		Basher Site			
Wood	1	84.47 Aa[2]	82.07 Aa	83.43 Aa	82.71 Aa
	2	86.01 Aa	82.79 Aa	84.78 Aa	82.34 Aa
Bark	1	42.88 Aa	43.77 Aa	43.43 Aa	43.79 Aa
	2	44.91 Aa	44.26 Aa	45.79 Ab	43.61 Aa
		Morrison Site			
Wood	1	83.31 Aa	83.48 Aa	84.66 Aa	82.92 Aa
	2	83.34 Aa	81.46 Ab	83.63 Aa	81.73 Aa
Bark	1	43.80 Aa	44.21 Aa	44.77 Aa	44.07 Aa
	2	44.53 Aa	44.35 Aa	43.53 Aa	44.91 Aa

[1] Holocellulose values (acid chlorite method) are based on an average of 6 specimens per site/treatment/component/rotation combination.
[2] Differences among management strategies for each site, rotation and component combination are denoted by upper case letters. Differences between rotations for each component, site and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.1 level of significance as determined by Duncan's mean separation procedure.

TABLE 4. *Average alpha-cellulose values as a function of management strategy, site, rotation, and component.*

Component	Rotation	Alpha-cellulose content[1] (% of oven dry extractive free weight) Control	Fertilization	Irrigation	Fertilization/irrigation
		Basher Site			
Wood	1	46.63 Aa[2]	46.39 Aa	46.06 Aa	45.99 Aa
	2	45.78 Aa	45.35 Ab	46.23 Aa	45.80 Aa
Bark	1	44.29 Aa	44.67 Aa	44.81 Aa	45.05 Aa
	2	44.66 Aa	44.21 Aa	43.51 Aa	43.68 Aa
		Morrison Site			
Wood	1	46.56 Aa	46.96 Aa	46.99 Aa	46.46 Aa
	2	46.38 Aa	46.14 Aa	46.17 Aa	45.95 Aa
Bark	1	44.47 Aa	44.01 Aa	44.52 Aa	44.46 Aa
	2	44.64 Aa	44.98 Aa	42.40 Bb	44.53 Aa

[1] Alpha-cellulose values (ASTM D-1103-77) are based on an average of 6 specimens per site/treatment/component/rotation combination.
[2] Differences among management strategies for each site, rotation and component combination are denoted by upper case letters. Differences between rotations for each component, site and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.1 level of significance as determined by Duncan's mean separation procedure.

extractive content values were, for the most part, significantly different from the first rotation values and were consistently lower than the first rotation values for each management strategy and each site. This is in contrast to extractive content results reported by Blankenhorn et al. (1985b). In that study, using the same clone as in this study but on different sites than this study, the second rotation extractive content was higher than first rotation. The extractive contents (Table 2) and holocellulose content (Table 3) were lower and higher than previous results for the same clone (Blankenhorn et al. 1985b) indicating the apparent influence of site.

Bark

Management strategy significantly influenced second rotation 4-year-old bark average specific gravity (Table 1). At both sites the average specific gravity values for the control and irrigation management strategies were lower than the average values for the fertilization and fertilization/irrigation strategies. This was inverse to the results for the wood. Comparing the first with the second rotation values re-

TABLE 5. *Average Klason lignin values as a function of management strategy, site, rotation, and component.*

Component	Rotation	Klason lignin content[1] (% oven dry weight) Control	Fertilization	Irrigation	Fertilization/irrigation
		Basher Site			
Wood	1	16.73 Aa[2]	16.63 Aa	16.39 Aa	15.52 Aa
	2	17.18 Aa	14.87 Bb	14.43 Bb	15.64 Ba
Bark	1	14.08 ABa	13.66 Ba	14.71 Aa	14.10 AB
	2	15.88 BCb	15.20 Cb	16.87 Ab	16.03 Bb
		Morrison Site			
Wood	1	15.91 Aa	16.30 Aa	15.49 Aa	15.00 Aa
	2	15.81 Aa	15.91 Aa	15.11 Aa	15.48 Aa
Bark	1	15.10 Ba	14.23 Ba	16.87 Aa	14.67 Ba
	2	18.02 Ab	15.43 Ba	19.30 Ab	16.20 Bb

[1] Klason lignin values (ASTM D 1106-77) are based on an average of 6 specimens per site/treatment/component/rotation combination.
[2] Differences among management strategies for each site, rotation and component combination are denoted by upper case letters. Differences between rotations for each component, site and management strategy combination are denoted by lower case letters. Means with common letters are not significantly different at the 0.1 level of significance as determined by Duncan's mean separation procedure.

sulted in no significant difference for the Morrison site. However, three out of the four strategies were significantly different on the Basher site. For practical purposes, these results may not be important because the range in 4-year-old bark average specific gravity values across both sites, four management strategies, and two rotations was 0.312 to 0.352.

Trends in chemical content values (Tables 2, 3, 4, and 5) for 4-year-old second rotation bark were different from the results for the wood. Management strategy effects were significant in the extractive and Klason lignin content values. The overall range in values was about 3% and 4% for the extractive content and Klason lignin, respectively. There were significant differences between the first and second rotation average chemical content values for each management strategy. Holocellulose and alpha-cellulose had the smaller number of significant differences between rotations. Trends were difficult to detect, except for the Klason lignin content average values. Second rotation average Klason lignin content values for bark were higher than the first rotation average values for each management strategy on each site.

SUMMARY

Wood and bark average specific gravity and chemical content values obtained for second rotation 4-year-old *Populus* hybrid clone NE-388 were analyzed for differences between management strategies and rotations. Specific gravity results for wood indicated that fertilization and fertilization/irrigation management strategies produced lower values than control and irrigation. The reverse result was obtained for bark where the fertilization and fertilization/irrigation strategies produced values that were higher than control and irrigation. There were significant differences in the average specific gravity values for the wood and bark specimens between rotations. However, the magnitude of the difference in the average values was less than 10%. Management strategy or rotation generally produced no significant differences in holocellulose and alpha-cellulose values for the wood and bark specimens. Most of the significant differences for wood were in extractive content for management strategy and rotation. Bark had significant management strategies and rotation differences in extractive content and Klason lignin content. Trends were difficult to detect, but the rotation average Klason lignin content values for bark were higher than the first rotation values for each management strategy on each site.

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