Nutrient use by three geographic sources of eastern cottonwood

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Three geographic sources (Louisiana, Mississippi, and southern Illinois) of 11-year-old eastern cottonwood (*Populus deltoides* Bartr.) growing in Mississippi, U.S.A., were studied for differences in biomass and nutrient accumulation. The three sources produced about the same biomass (70–80 *t*/ha (1 short ton = 2000 lb. = 0.907 *t*; 1 long ton = 2240 lb. = 1.016 *t*)), but the Louisiana source contained significantly lower N contents in the stems and lower K contents in both the stems and the total tree. Trees originating in Louisiana produced 640 g of dry matter for each 1 g of N found in the tree, compared with 430 g per gram of N for the Illinois source. The Louisiana source produced 430 g of dry matter per gram of K whereas the Illinois source produced about 200 g of biomass per 1 g of K. Thus, the Louisiana source appears to be more efficient in N and K utilization. Data indicate that if this stand were harvested at age 11, the Illinois source would remove 118 kg of N and 284 kg of K per hectare from the site. The Louisiana source would remove only 73 kg of N and 127 kg of K per hectare.

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Les auteurs ont mesuré les différences d'accumulation de biomasse et d'éléments nutritifs chez *Populus deltoïdes* Bartr. cultivé au Mississippi, U.S.A., originant de trois sources géographiques (Louisiane, Mississippi et Sud de l'Illinois). Les trois sources ont produit environ la même biomasse (70–80 *t*/ha (1 tonne courte = 2000 lb. = 0.907 *t*; 1 tonne forte = 2240 lb. = 1.106 *t*)) mais la source Louisiane renfermait significativement moins de N dans le tronc et moins de K dans le tronc et l'arbre entier. Les arbres originant de Louisiane ont produit 640 g de matière sèche pour chaque gramme de N trouvé dans l'arbre comparativement à 430 g de matière sèche pour les arbres de la source Illinois. La source Louisiane a produit 430 g de matière sèche par gramme de K comparativement à 200 g pour la source Illinois. La source Louisiane apparait donc avoir une meilleure efficacité d'utilisation de N et K. Les données recueillies montrent que si le peuplement était récolté à l'âge de 11 ans, la source Illinois exporterait de la station 118 kg N et 284 kg K par hectare; la source Louisiane n'exporterait que 73 kg N et 127 kg K par hectare.

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Genotype and environment interact to influence the use of different nutrients by eastern cottonwood (*Populus deltoides* Bartr.). Curlin (1967), for example, found large differences in nitrogen response among cottonwood clones. Baker and Randall (1975) found variation in foliar N to be associated primarily with a clone × soil interaction, and Mohn and Randall (1973) reported strong clone × site interactions.

Curlin (1967) pointed out that varietal differences in response to nutrition are of two types: *differential yield response* or the efficiency of biomass production from available nutrients, and *differential nutrient uptake*, indicated by the concentration of an element in plant parts. In this paper, we report on differences in the use of nutrients by three geographic sources of eastern cottonwood to determine if certain sources were more efficient than others in nutrient utilization.

Methods

The study was conducted in an 11-year-old cottonwood plantation located near Stoneville, Mississippi, U.S.A. (33°35′ N latitude). Soil at the study site is Commerce silt loam, a member of the fine-silty, mixed, nonacid, thermic family of Aeric Fluvaquents that developed in alluvial deposits from the Mississippi River.

The plantation was established at a 3 m × 3 m spacing in January 1967, to evaluate growth and development of cottonwood from a range of geographic sources along the Mississippi River. The plantation was thinned at age 3 by removing alternate diagonal rows, thus leaving trees spaced at approximately 4.2 m × 4.2 m. Tree height and diameter

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TABLE 1. Biomass and morphological data: three geographic sources of *Populus deltoides*

Source	Diameter at breast height, cm	Height, m	Crown length, m	Crown width, m	Number of leaves per tree	Dry weight per leaf, g	Trees per hectare	Dry weight, *t*/ha				
								Leaves	Current-year branches	Older branches	Stem	Total tree
Southern Illinois	23a*	22a	5.2a	3.1a	3537a	0.67a	452a	1.1a	0.2a	5.2a	63.0a	69.5a
Mississippi	22a	22a	6.1a	3.4a	4425ab	0.68a	476a	1.3ab	0.2a	4.7a	68.8a	75.1a
Louisiana	23a	22a	7.9a	4.2b	7849b	0.60a	487a	2.0b	0.4a	8.3a	70.8a	81.6a

*Means followed by the same letter (vertically) are not significantly different at the 0.05 probability level as determined by Duncan's new multiple range test.

measurements were taken periodically through age 11.

The present study investigated dry matter and nutrient relationships for three of the geographic sources: southern Illinois (37° N latitude), Mississippi (33–34° N latitude), and Louisiana (31° N latitude).

In July 1977, sample trees were selected by the mean tree technique of Ovington *et al.* (1967). All trees were measured for diameter, height, and crown width and length. Each character was averaged for the trees in a block, and 1 tree approximating the average was selected from each of four blocks for a total of 12 sample trees (3 sources × 4 blocks).

After each sample tree was cut and mensurational data collected, the tree was separated into leaves, current-year branches, older branches, and stem. The stem was cut into 120-cm sections and subsampled by removing a 5-cm-thick disk from the middle of each section. Branch material was cut into 10-cm lengths and subsamples were taken so that diameter distribution in the subsample approximated that of the total branch mass. Leaves were subsampled by quartering after thorough mixing. Roots were not studied.

Total and subsample green weights were taken in the field. Subsamples were then dried in the laboratory at 70°C and reweighed. Fresh weight : dry weight ratios were used to calculate dry weight of components. Estimates of total number of leaves per tree were made by weighing 30 representative leaves and extrapolating the number based on total weight of leaves on a tree.

Ovendry leaf, branch, and stem samples were ground to pass a 40-mesh screen, dry-ashed at 500°C, taken up in 1 *N* HCl, and analyzed for P, K, Ca, and Mg concentrations. Total nitrogen was determined by the standard Kjeldahl procedure, P by colorimetry, and K, Ca, and Mg by atomic absorption spectrophotometry.

Biomass per hectare was calculated by multiplying the biomass of the average tree for each source and block by the number of stems per hectare. Nutrient contents were calculated by multiplying concentrations by the dry weight of the appropriate component.

An expression of nutrient efficiency was derived by dividing tree dry weights by nutrient contents.

Results and Discussion

Biomass and Morphology

For the first 8 years, the southern Illinois source grew faster than the Louisiana and Mississippi sources, but the growth rate of the Louisiana source relative to the others began to increase by age 8 and the Louisiana source appeared to have larger crowns than the other sources by age 10.

At age 11, diameter at breast height, height, crown length, dry weight per leaf, and trees per hectare did not vary by geographic source (Table 1). Trees from the Louisiana source, however, had significantly wider crowns than those from the other two sources. Also, trees from the Louisiana source had over twice the number of leaves as trees from the southern Illinois source.

On an area basis, the aboveground portion of the stand contained 70–80 metric tons (1 short ton = 2000 lb. = 0.907 *t*; 1 long ton = 2240 lb. = 1.016 *t*) of dry matter per hectare, approximately 90% being in the stems (Table 1). Total tree dry weight per hectare did not vary by geographic source, but the Louisiana source had about 2 tons of leaves per hectare and the southern Illinois source had only about 1 ton/ha, a significant difference. Branch mass also tended to be greater for the Louisiana source, but not significantly so.

Nutrient Concentrations

In general, nutrient concentrations followed the trend, southern Illinois > Mississippi > Louisiana (Table 2). Concentrations of N in the foliage, older branches, and stem of Louisiana trees were significantly lower than those of southern Illinois trees.

TABLE 2. Influence of geographic source on N and K concentrations of various components of cottonwood

Source	Leaves	Current-year branches	Older branches	Stem
	Percentage N			
Southern Illinois	1.71a*	0.90a	0.50a	0.19a
Mississippi	1.46ab	0.88a	0.48a	0.14b
Louisiana	1.41b	0.88a	0.30b	0.10c
	Percentage K			
Southern Illinois	1.44a	1.25a	0.50a	0.45a
Mississippi	1.24a	1.14a	0.46a	0.30b
Louisiana	1.32a	1.27a	0.48a	0.18b

*Means followed by the same letter (vertically) are not significantly different at the 0.05 probability level as determined by Duncan's new multiple range test.

TABLE 3. N and K content of cottonwood stands by geographic sources

Source	N content, kg/ha					K content, kg/ha				
	Leaves	Current-year branches	Older branches	Stem	Total tree	Leaves	Current-year branches	Older branches	Stem	Total tree
Southern Illinois	18a*	2a	26a	118a	164a	16a	3a	26a	284a	329a
Mississippi	19a	2a	22a	96ab	140a	16a	3a	21a	195ab	235ab
Louisiana	29a	3a	25a	73b	130a	27b	4a	40a	127b	198b

*Means followed by the same letter (vertically) are not significantly different at the 0.05 probability level as determined by Duncan's new multiple range test.

TABLE 4. Nutrient efficiency of three geographic sources of cottonwood

Source	Nutrient efficiency (grams of dry matter/grams nutrient per tree)				
	N	P	K	Ca	Mg
Southern Illinois	430a*	3110a	220a	180a	2500a
Mississippi	540b	3110a	350ab	170a	3200a
Louisiana	640c	3330a	430b	190a	3790a

*Means followed by the same letter (vertically) are not significantly different at the 0.05 probability level as determined by Duncan's new multiple range test.

Both the Mississippi and Louisiana sources had significantly lower concentrations of K in the stem than Illinois trees. Phosphorus, Ca, and Mg concentrations were not generally influenced by source, except that the Louisiana trees had significantly more Ca in current-year branches and less Mg in older branches than the other sources.

N and K Contents and Efficiency

Inspection of nutrient contents in the cottonwood stands indicates significant differences for only N and K. Southern Illinois sources averaged 164 kg of N per hectare in the stem, whereas Louisiana trees had only 130 kg/ha of N in the stem (Table 3). The Louisiana source had much lower K content in the stems and in the total tree than the southern Illinois source. One might assume that lower N and K contents are the result of dilution of these nutrients in greater biomass. This is not the case, however, because stem biomass did not vary significantly by source (Table 1). It thus appears that a differential yield response as reported by Curlin (1967) exists between the geographic sources in that the Louisiana source may be more efficient in N and K utilization than the southern Illinois source.

The greater efficiency of nutrient utilization by trees from the Louisiana source is further indicated by the fact that they produced 640 g of dry matter per gram of nitrogen (Table 4). Southern Illinois and Mississippi trees produced 430 and 540 g of biomass per gram of N. The Louisiana source also produced 430 g of dry matter per gram of K; southern Illinois trees produced only one-half that amount.

There are not enough data to even speculate as to why the Louisiana source appears to be more efficient in its use of N and K.

Regardless of the reasons for it, efficient use of nutrients has important implications. Sources able to produce as much biomass as other sources but accumulate less nutrients presumably would be better adapted to nutrient-deficient sites, or at least grow acceptably with less nutrients. Also, nutrient losses through harvesting would be less with the more nutrient-efficient sources. For example, if the stand used in this study were harvested at age 11 by removing stems only, 118 kg of N per hectare would be removed in the southern Illinois source, 96 in the Mississippi source, and only 73 in the Louisiana source (Table 3). Losses of K would be 284, 195, and 127 kg/ha for the three sources. Over several rotations, this difference could be important, even on fertile sites.

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