Wood Production and Kraft Pulping of Short-Rotation Hardwoods in the Pacific Northwest

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INTRODUCTION

For decades foresters and fiber-using industries throughout the world have been concerned with the problem of future procurement of wood fiber. Research has progressed on several promising approaches to this problem, including fertilization, genetic improvement, better control of competition, and more complete utilization. Recently another alternative has been suggested --- the production of hardwood fiber on very short rotations with coppice regrowth. The concept was first proposed by McAlpine et al. (1966) under the name, "silage sycamore". Since that time, tests of "silage" forestry have been initiated with other hardwood species in many regions of the United States and Canada (Steinbeck, 1973). The use of unmanaged forest weeds (better known as pucker brush) for a source of fiber has been promoted by Young (1972) in the northeastern United States.

Compared with other regions, the Pacific Northwest has a smaller supply of hardwood fiber and costs of hardwood pulpwood are higher. There are also many acres of marginal agricultural lands near major pulp mills on the west-side of the Cascade Mountain Range. Although these lands are now in pasture, they are natural sites for native hardwoods. Because of these factors, in addition to those listed by McAlpine and his associates (1966) Crown Zellerbach Corporation felt that a close look at short-rotation forestry was needed. Two questions were initially of greatest importance: (1) How much wood could be produced by native hardwoods on short rotations ?, and (2) Could wood grown in this manner be used in convéntional pulping processes for manufacture of existing lines of paper products? To obtain answers to these questions, we entered into cooperative studies of hardwood yield production with scientists at Washington State University Experiment Stations. We also conducted kraft pulping evaluations at Crown Zellerbach's Central Research Laboratory in Camas, Washington. This paper describes and discusses our findings.

WOOD PRODUCTION OF NORTHWESTERN HARDWOODS OF SHORT ROTATIONS

Two hardwood species, black cottonwood (Populus trichocarpa Torr. & Gray) and red alder (Alnus rubra Bong.), are of major commercial importance in the Pacific Northwest. Both species grow much more rapidly than coniferous associates during the initial decades of stand formation. Unfortunately, very little effort has been expended on hardwood management or research in the regions. Following cutting, black cottonwood sprouts form on stumps, but seedling regeneration is unlikely unless special measures are taken to provide the bare, moist seedbed required for initial establishment (Fowells, 1965). On the other hand, red alder establishes readily from seed. It is considered a weed species by most Northwestern foresters and much effort is spent to control red alder on sites where conifers (primarily Douglas-fir) are managed on an intensive basis. Red alder has therefore been relegated to sites receiving limited or no conifer management. With this background we began to look at intensive, short-rotation culture of the hardwood species.

Two studies were done to assess the potential yield of native hardwoods under short-rotation management: (1) an experimental planting of black cottonwood, and (2) yield measurements in dense, natural thickets of red alder. The experimental methods and results for these studies were discussed in detail in two previous papers (Heilman et al., 1972; DeBell, 1972). In this paper, we shall present the results in a general way to illustrate the growth potential of these two species.

Yield of Coppiced Black Cottonwood

Experimental plots were planted with black cottonwood cuttings near Mount Vernon, Washington in 1967 (Heilman et al., 1972). Two years later all plots were harvested. Most plots were harvested again in 1971; the remaining plots were harvested in 1973, four years after the first harvest. Wood produced by these harvests is shown on an annual per acre basis below:

TABLE 1

ANNUAL WOOD PRODUCTION OF COPPICED BLACK COTTONWOOD AS RELATED TO SPACING AND CUTTING CYCLE

	Cutting Cycle	Growth Period years	Initial Spacing (feet) 1 x 1	2 x 2	4 x 4
			o.d. tons/acre/year[2/]		
A.	First Harvest	2	3.6	2.4	1.2
B.	Second Harvest	2	4.0	5.2	3.6
C.	Second Harvest[1/]	4	6.0	6.3	5.7

1/ Unpublished data supplied by P. E. Heilman and D. V. Peabody, Jr., Washington State University Research and Extension Units at Puyallup and Mount Vernon, Washington, respectively.

2/ Values include bark which is estimated at 25 percent. To estimate volume in cubic feet, multiply tons by 77.

The data indicate that above-ground yields exceeding 400 cubic feet per acre per year can be produced with coppiced black cottonwood on cutting cycles of 2 to 5 years. Some plots have grown more than 500 cubic feet per acre annually.

Yield of Natural Thickets of Young Red Alder

In the study by DeBell (1972), total above-ground production was measured in 28 natural thickets of high density. Results shown below are averages of small plots (6 feet by 6 feet) measured in each age class:

TABLE 2

STOCKING AND GROWTH OF YOUNG RED ALDER THICKETS IN THE LOWER COLUMBIA RIVER VALLEY AS RELATED TO AGE CLASS

Age Class yrs	Number of Stems M/ac	Av Dom Ht ft	Mean Annual Wood Production: O. D. Weight With Bark tons/ac	O. D. Weight Without Bark tons/ac	Volume Without Bark ft^3/ac
1-2	122	6	1.7	1.4	100
3-4	60	11	1.7	1.4	100
5-7	39	17	3.2	2.6	190
8-11	14	33	8.8	7.2	530
12-14	13	29	4.4	3.6	270

Interpretations should be tempered with recognition of the limitations associated with small plots. Even so, two important findings are probably valid:

1. Wood production in natural thickets increases greatly after age 5, and appears to culminate near age 10. Mean annual wood yields totaled 200 to 500 cubic feet per acre.

2. Mortality is high in dense, young alder stands. Stocking in 1-2 year-old thickets averaged 122 thousand stems per acre whereas 8 to 11 year-old thickets had 14 thousand stems.

It seems probable that under intensive, short-rotation culture, loss of wood through mortality would be minimized. Growth would be concentrated on fewer, larger stems and maximum yields would probably be obtained at younger ages.

KRAFT PULPING OF JUVENILE WOOD OF NORTHWESTERN HARDWOODS

Young stems of black cottonwood and red alder were evaluated for suitability as hardwood pulps, using the kraft process. Hardwood pulps are normally blended with conifer (long-fibered) pulps to improve formation, texture, softness, and printability. These qualities are required for paper products such as tissue and printing grades.

To determine if wood produced by short-rotation management could be utilized either with or without bark, we evaluated two classes of chipped juvenile wood: (1) the whole tree--stems, branches, and bark, and (2) hand-peeled stems. Specific gravity was measured on chips by a water displacement technique. Two replicate cooks were made for each class using a standard laboratory cooking schedule in which the active alkali content was varied to obtain a suitable pulp. After cooking, the pulps were washed, screened, and centrifuged. Determinations of total yield, screenings, and permanganate number were made by standard methods. On the basis of these determinations, pulp samples were selected for tests of fiber fractionation and handsheet properties. The results were compared with values obtained with chips from mature wood of the same species. The comparisons and their implications will be discussed in two categories: (i) factors which affect the kraft cooking process, and (ii) factors which influence paper manufacturing and the quality of paper products.

Factors Related to Cooking Process

Comparative data on specific gravity, alkali requirements, total pulp yields, and dissolved organic solids are presented in Table 3 for juvenile and mature wood of the two species.

TABLE 3

CHARACTERISTICS OF KRAFT COOKS OF BLACK COTTONWOOD AND RED ALDER OF VARIOUS AGES[1]

Species	Age	Class	Specific Gravity	Active Alkali	Tot. Pulp Yield	Diss. Organic Solids	Permanganate Number
	--yrs--		--g/cc--	---% o.d.	wood---		---points---
Bl. Cotton-wood[2]	30-50[2]		.360-.370	13-14	54-56	44-46	10.5-12.9
	2	Whole	.343	16	42	58	11.6
		1/2"+	.356	15.5	49	51	9.9
Red Alder	30-50[3]		.380-.390	14-15	46-50	50-54	11.6-15.0
	2	Whole	.380	18	39	61	16.3
		1/2"+	.374	16.5	46	54	13.7

Legend: 1/ Class refers only to juvenile wood: whole = tree (stems, twigs, and bark) 1/2"+ = debarked stem wood > 1/2" d.o.b. All percentage figures are based on oven-dry wood or wood plus bark weights.

2/ Range of values from 7 cooks of mature wood from various sources--unpublished CZ data.

3/ Range of values from 11 cooks of mature wood from various sources--unpublished CZ data.

Active alkali requirements and dissolved organic solids are higher for juvenile wood than for mature wood. Alkali requirements and dissolved solids are higher also for chips with bark than for debarked chips. Juvenile wood has a lower specific gravity and lower total pulp yield than mature wood; the presence of bark also decreases total pulp yield. These differences are true for both species. Moreover, the differences appear to be related more to the presence of bark and twigs than to the age of the woods.

These differences have important implications in pulp processing. A decrease in specific gravity indicates that digesters filled by volume will contain less wood by weight. A decrease in total pulp yield means that more chips are needed to produce a ton of pulp. Therefore, purchase and storage requirements of wood chips would increase and production per unit of mill operation time would decrease. Because of a higher organic load, production may be further limited in some mills by capacities of kraft recovery equipment. There also is the possibility of limitations associated with a higher alkali requirement as well as definite increase in operating costs. Reduced pulp production capacity obviously will result in higher fixed costs per ton of pulp. The use of juvenile wood with bark therefore presents some problems for conventional kraft mills. However, these problems could be substantially reduced by debarking. However, the total costs of debarking must be compared with the total costs of using chips with bark before a reliable conclusion can be drawn on the merits of debarking.

Factors Related to Manufacture and Quality of Paper Products

Characteristics of pulps produced from juvenile hardwoods differ from pulps of mature hardwood trees. These differences affect the papermaking process and may influence the kinds of paper products which are manufactured from the pulps.

TABLE 4

CHARACTERISTICS OF KRAFT PULPS FROM BLACK COTTONWOOD AND RED ALDER OF VARIOUS AGES

Species	Age	Class	Initial Freeness	Fiber Fines (150 mesh)	Initial Burst Factor	Initial Tear Factor	Initial Sheet Density
	--yrs--		-cc CSF--	-%-			-g/cc-
Bl.Cottonwood	30-50 1/		608-630	5-10	28-37	93-123	.60-.65
	2	Whole	370	19	42	65	.71
		1/2"+	440	12	47	75	.76
Red Alder	30-50 2/		540-631	11-15	26-40	85-114	.64-.70
	2	Whole	434	17	56	70	.73
		1/2"+	498	12	57	72	.74

1/ Range of values from 7 cooks of mature wood from various sources--unpublished CZ data.

2/ Range of values from 11 cooks from various sources--unpublished CZ data.

The differences associated with juvenile wood and wood with bark were similar for both species. Pulps from 2-to-4-year-old trees were lower in initial freeness and initial tear factor, but were higher in burst factor, sheet density, and fine fiber fraction than pulps from 30- to 50-year-old trees. The presence of bark reduced initial freeness and increased the fiber fines but bark had little effect on strength properties and sheet density. This is primarily because fiber yield of cottonwood bark is much lower than yield of wood (Keays 1973).

The changes in strength properties and sheet density are of minor significance in hardwood pulps. In cases where quality of products may be affected, the changes probably can be reduced by varying other components of the pulp furnish (e.g., more or less coniferous pulp in the mixture). The increase in fiber fines, however, is serious because this represents an additional decrease in pulp yield. Freeness also is an important factor; it is related to drainage of water from pulp on the paper machine and would likely decrease rate of paper production. It appears that the latter two problems (freeness and fiber fines) can be improved by debarking.

DISCUSSION AND CONCLUSIONS

Measurements of juvenile black cottonwood and red alder stands indicate that yields exceeding 5 tons or 400 ft^3/ac/yr can be grown on short-rotations of 2 to 10 years. Whether the highest yields (7 tons or $>$500 ft^3/ac/yr) are producible on a large-scale, long-term basis is an open question. Silvicultural information is needed about the interrelationships of spacing, rotation length, and yield. Probably the two most serious obstacles to short-rotation culture are high costs of establishing densely-spaced plantations (Smith and DeBell 1973) and the fact that harvesting methods are still in the developmental stage. Nevertheless, the yields measured in our studies were sufficiently high to warrant a closer look at short-rotation culture of these species.

The kraft pulping tests indicated that juvenile hardwoods can be converted into pulp suitable for use in several paper products. Although there are changes in pulp characteristics which tend to lower product quality, these changes are less serious than problems associated with the kraft cooking process. The latter problems result in higher processing costs per ton of pulp due to the following:

1. Additional wood required (lower sp. gr., lower total pulp yield, higher fine fiber fraction).

2. Additional chemicals required (lower total pulp yield, higher alkali requirement).

3. Additional recovery costs (higher dissolved organic load).

Possibly some of the aded costs could be reduced by designing mills specifically for the processing of juvenile hardwood. Moreover, it appears that chip debarking can lessen many of the problems associated with juvenile trees and thus may lower costs even in conventional mills. Work on compression debarking is in the pilot stage and appears promising (Erickson 1972). In fact, Hillstrom (in press) indicated that red alder was more easily debarked than bigleaf maple, Douglas-fir or western hemlock. Research at Crown Zellerbach suggests that problems related to penetration of cooking liquor into twigs are decreased when the wood is subjected to a compression debarking process. However, it should be remembered that the debarking process would incur added costs and possibly some wood loss. These costs must be weighed against the added costs incurred by using chips with bark.

To conclude, our work indicates that high wood yields can be grown by short-rotation culture of northwestern hardwoods. The wood from these juvenile trees can be converted into pulp suitable for several paper products. However, raw material needs and processing costs will be higher. It is therefore mostly a matter of economics when short-rotation culture will add to our wood supply. To be economical, the costs of producing such wood and delivering it to the mill will have to be less than the price of conventional wood chips on the open market. Whether or not this could be the case under present or future market conditions is unknown.

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