BIOMASS AND WOOD PROPERTIES OF YOUNG SILVER MAPLE CLONES

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ABSTRACT

Biomass properties were determined to characterize the differences between young silver maple clones as an energy source or fiber source feedstock. Size varied significantly among 25 maple sources evaluated, but larger trees generally had the better survival, which is highly important in clonal comparisons. Characteristics of the wood were similar to those of soft hardwoods; the mean value of gross heat of combustion was 19.6 kJ/g; the fiber length was relatively short (0.74 mm); the ash content was 0.291; and the specific gravity was 0.43. Clonal differences were significant.

Keywords: *Acer*, fiber length, gross heat of combustion, specific gravity, tree growth, wood energy.

INTRODUCTION

Woody biomass as an energy resource is well known and has increased over the past few decades (Haynes 1990). Today annual production of over 1.3 billion tons of biomass is potentially possible from agricultural and forest lands in the United States (Perlack et al. 2005). Short rotation woody crops (SRF) have been researched extensively since the 1960s (Mitchell and Ford-Robertson 1992). Several fast-growing hardwood tree species managed intensively for biomass production could be utilized for energy use. Silver maple (*Acer saccharinum* L.) is fast growing, coppices readily, has resistance to pests, and is easily managed on good sites. Some earlier research has documented biomass property variation in silver maple (Geyer and Walawender 1997). Research has shown that certain clones grow well under SRF management schemes (Kopp et al. 1988). Both growth and wood quality characteristics are important. Whole-tree and clonal wood quality differences may influence the viability of the production system.

The objective of this report is to evaluate differences between selected young silver maple clones grown at close spacing under a SRF cultural regime by comparing biomass and wood property differences.

MATERIALS AND METHODS

Planting site and measurements

This study was conducted in eastern Kansas on a level, alluvial, old-field site that was cultivated prior to planting near Manhattan, Kansas at 39.62° N and 96.62° W and 366 m above sea level. Precipitation averages about 82 cm per year, with 75% coming during the growing season. The soil was classified in the Eudora silt loam series (coarse-silty, mixed, mesic, Flueventic Hapudols) and consisted of 25-cm silt loams underlain by very fine sandy loam. Soil characteristics are a pH of 7.5, 2.0% organic matter, 146 kg, available phosphorous (P), and 560 kg exchangeable potassium (K) per hectare.

Twenty-four silver maple clones selected for good growth in the greenhouse, plus one general seeding nursery source from eastern Kansas were planted during the spring of 1988 in a randomized complete-block design with 10 trees from each source for a total of 250 trees. A one-row border was planted on all four sides. The materials were selected from a larger distribution-wide provenance study from Southern Illinois University, Carbondale, Illinois (Preece et al. 1991). Clonal material was propagated from nodal explant tissue culture and rooted microshoots, then grown in greenhouse plugs and sent to Kansas. Each individual within a clone is an exact genetic duplicate of the other.

Biomass measurements

Survival, total height, and ground diameter were recorded at the end of six growing seasons. An index of volume based upon D^2H where D is base diameter and H is total height was calculated. The data were analyzed using analysis of variance at $P = 0.05$ and simple correlation procedures using the General Linear Model (fixed) by SAS (SAS Inst. Inc. 1999). Mean contrasts were determined with Duncan's Multiple Range test for ash, gross heat of combustion, mass, and number of stems, while the Ryan-Einot-Gabriel-Welsch test was used for specific gravity, fiber length, diameters, height, and D^2H.

Wood characteristics

Trees were cut after six growing seasons, and 5-cm-thick disks from four largest trees of each clone were collected for characterization at the stem base, for a total of 100 samples. The fourth growing ring from the pith was sampled to provide a standard comparison for analysis as there is a large difference in length across growth rings (Panshin and de Zeeuw 1980). All wood properties, except the chemical characteristics, were derived from these disks. Wood properties were run in the laboratory for ash content, fiber length, gross heat of combustion, and specific gravity (SG).

Ash content.—Samples of each clone from disks taken at the stem base were oven-dried, ground, and ashed in a muffle furnace. Ash contents of the wood were determined pursuant to the ashing procedure described in ASTM D 1102-84 (1995).

Fiber length.—Fiber length was determined from the disks as described above using the Summa Digitizing board and Fisher Microprojector, a method similar to that of Tsoumis (1968). Matchstick-size slivers taken from chips were macerated, and separate fibers were projected with a Mark VII micro-projector for measurement. The mean fiber length of five fibers on each of 20 slides for a total of 100 values were measured for each of the four ramets separately and recorded.

Gross heat of combustion.—This was determined from ground, oven-dried disk samples according to ASTM D 2015-77 (1981). The material used for the evaluation was ground to pass through a 20-mesh screen to achieve complete combustion and good pellet cohesion (Neenan and Steinbeck 1979). Samples from four trees per ramet, each consisting of approximately one gram of milled material, were pressed into pellets and combusted in a Parr 1341 adiabatic calorimeter. Correction factors for the formation of acids were not included in the calculations of gross heat of combustion (Murphey and Cutter 1974; Barnes and Sinclair 1984). However, heating values were corrected for moisture regained during storage.

Specific gravity.—The specific gravity was determined on the basis of oven-dried weight/green volume of four individual disk segments from four ramets of each of the 25 sources (¼ section void of branch traces) for a total of 100 trees. To reduce laboratory effort, only two of the four sections were used from each disk for measurement. Green volumes were obtained by soaking disk segments for maximum moisture content for 10 days in water until constant volume was achieved. Excess moisture was removed from the surface of the segment with a damp cloth, and each segment's water displacement (volume) was measured. Then segments were oven-dried at 104°C for 3 to 4 days to constant weight to determine the dry sample weight.

RESULTS AND DISCUSSION

Biomass characteristics

Total biomass, using D^2H as an indicator of yield for SRF evaluation, had a range of 159 to 1303 and a mean value of 630. This characteristic varied between clones and was highly significant (Table 1). The fastest growing clone was from the common Kansas nursery stock, #999. A clear geographic pattern was not discernible, although those clones from the central part of the selection range, Indiana and Pennsyl-

TABLE 1. *Biomass characteristics where ranking is based on D^2H (volume index) where D is base diameter and H is total height of Acer clones.*[1]

Clone (#)	Origin	Surv. (%)	Mean stems (#)	Mean height (m)	Mean base diam. (cm)	Volume index (D^2H)
999	Kansas seedling nursery stock	**100**[2]	**3.8 a**	7.7 a–e	**14.0 a**	**1303 a**
112	Northeastern Pennsylvania	**100**	2.8 a–d	**8.6 a**	**14.8 a**	**1197 ab**
121	South-central Ontario	**100**	2.5 b–e	**8.5 a**	**13.0 a–d**	**1099 a–c**
116	Northeastern Pennsylvania	**100**	**3.0 ac**	**8.6 a**	**13.4 a–c**	**1052 a–c**
111	Northeastern Pennsylvania	**100**	**3.3 ab**	**8.2 ab**	**12.6 a–e**	**989 a–d**
054	South-central Indiana	90	**3.8 a**	**8.1 ab**	**13.0 a–d**	**938 a–e**
053	South-central Indiana	90	1.2 f	**8.1 ab**	12.1 a–e	918 a–f
056	South-central Indiana	**100**	3.0 ac	8.0 a–d	11.6 a–e	820 a–g
061	Central Iowa	**100**	2.0 c–f	8.0 a–d	11.0 a–h	797 a–h
084	South-central Wisconsin	90	2.5 b – e	7.5 a – f	9.6 c–j	644 b–i
193	Southeastern Minnesota	**100**	**3.3 ab**	7.6 a – e	10.7 a–i	617 c–j
156	Central New Hampshire	**100**	**3.8 a**	6.7 d – i	9.7 b–j	589 d–k
042	Southern Illinois	70	1.8 d – f	7.6 a – f	8.6 e–k	562 d–l
192	Southeastern Minnesota	**100**	2.8 a – d	7.2 a – g	10.9 a–i	521 g–l
206	North Kansas	90	1.8 d–f	7.8 a – d	9.5 c–k	491 g–l
045	Southern Illinois	90	1.8 d–f	7.1 b – h	7.7 g–k	491 g–l
064	Central Iowa	90	2.5 b – e	7.0 a – h	8.5 e–k	384 g–l
011	East-central Mississippi	90	2.0 c – f	6.5 e – i	7.6 h–k	339 g–l
163	Northwestern Vermont	80	1.8 d – f	6.3 e – j	6.4 i–k	335 g–l
072	South-central West Virginia	70	2.5 b – e	5.2 i – k	7.7 g–k	227 h–l
173	South-central New York	**100**	2.2 b – f	5.8 g – k	9.0 d–k	211 i–l
134	Central Ontario	60	1.5 e – f	6.0 f – j	6.2 jk	211 j–l
016	East-central Mississippi	80	2.0 c – f	5.4 i – k	6.8 h–k	192 l
013	East-central Mississippi	90	2.8 a – d	5.0 j – k	7.7 g–k	158 l
015	East-central Mississippi	40	2.0 c – f	4.1 k	4.7 k	133 l
Mean	—	**85**	**2.5**	**7.3**	**10.1**	**631**
Sign.[3]	—	—	**	**	**	**

[1] Column values with the same letter not significantly different at the 0.05 level.
[2] Bold type indicates upper 1/4.
[3] * = significant at the 0.05 level; **significant at the 0.01 level; NS = not significantly different.

vania, tended to be larger than those from the northern and southern provenances. Base diameter and total height followed a similar pattern and survival was high (70 to 100%) for all clones except one from east central Mississippi (#115), which exhibited only a 40% rate of survival. The overall mean base diameter, height, and survival for the six-year-old trees were 10.1 cm, 7.3 m, and 85%, respectively.

Wood characteristics

Juvenile wood properties of other several deciduous tree species have been published by the senior author (Geyer et al. 1987, 2000; Geyer and Walawender 1994, 1997, 1999). All of the wood properties in this study and statistical analyses are summarized in Table 2.

The ash content of the silver maple clones had a mean value of 0.291% ranging from 0.185 to 0.379% based upon oven-dry weight. In our previous study we found ash had a mean value of 0.40% for whole-tree chips (Geyer and Walawender 1997). Normally, ash content of tree species ranges from 0.1 to 0.5% for wood (Panshin and de Zeeuw 1980). This characteristic varied between clones and was highly significant in this study (Table 2).

The average fiber length of 0.74 mm (range of 0.66 to 0.83) in this study was the same as what we found in our previous study for young silver maple (Geyer and Walawender 1997). Panshin and de Zeeuw (1980) report silver maple fiber length to be 0.76 mm and to be among the shorter lengths found in hardwoods. We found

TABLE 2. *Wood properties where rankings based on D^2H (volume index) where D is base diameter and H is total height of Acer clones.*[1]

Clone (#)	Origin	Ash (%)	Fiber length (mm)	Heat (kJ/g)	Specific gravity (SG)	Mass index (D^2H*SG)
999	Kansas seedling nursery stock	0.265 d–h	0.74 b–i	19.33 i	**0.45 b–d**	**410 a**
112	Northeastern Pennsylvania	0.279 c–g	**0.83 a**	19.54 d–i	0.43 d–f	**297 b–d**
121	South-central Ontario	0.212 hi	0.70 h–k	19.48 f–j	**0.45 b–d**	**276 b–d**
116	Northeastern Pennsylvania	0.226 g–i	0.73 d–i	19.51 e–j	**0.49 a**	**326 b**
111	Northeastern Pennsylvania	0.281 c–g	0.76 b–g	19.60 c–h	**0.47 ab**	**331 b**
054	South-central Indiana	0.312 b–e	0.72 f–j	19.62 c–g	**0.47 ab**	**267 b–e**
053	South-central Indiana	0.298 b–f	**0.78 a–c**	19.58 c–h	**0.45 b–d**	260 c–e
056	South-central Indiana	**0.342 ab**	**0.77 a–e**	19.69 b–f	0.42 e–g	231 e–g
061	Central Iowa	0.185 i	0.71 g–j	**19.72 b–e**	0.43 d–f	164 f–i
084	South-central Wisconsin	0.241 f–h	0.69 ij	**19.79 a–c**	0.43 c–f	206 d–g
193	Southeastern Minnesota	0.271 d–h	0.66 k	19.33 i	0.44 d–f	165 f–i
156	Central New Hampshire	0.298 b–f	0.73 d–i	19.65 g	**0.45 b–e**	197 e–h
042	Southern Illinois	**0.379 a**	0.73 d–i	**19.87 ab**	0.43 c–f	157 g–i
192	Southeastern Minnesota	**0.348 ab**	0.66 jk	19.586 c–h	0.40 gh	137 g–i
206	North Kansas	0.276 d–g	0.72 e–i	19.43 g–i	0.43 c–f	124 i–kl
045	Southern Illinois	0.268 d–h	**0.79 ab**	**20.32 a**	0.41 fg	102 i–m
064	Central Iowa	0.310 b–e	0.75 b–h	19.65 b–g	**0.45 b–d**	126 h–k
011	East-central Mississippi	**0.339 a–c**	**0.77 a–e**	19.38 hi	0.38 h	107 i–m
163	Northwestern Vermont	0.248 f–h	**0.77 a–e**	19.70 b–e	0.42 e–g	78 j–m
072	South-central West Virginia	**0.378 a**	0.76 b–g	19.53 e–i	0.42 e–g	62 k–m
173	South-central New York	0.315 b–d	0.73 d–i	19.70 b–f	0.43 d–f	66 j–m
134	Central Ontario	**0.349 ab**	0.66 k	**19.73 b–e**	0.44 c–f	51 lm
016	East-central Mississippi	0.290 b–f	0.74 d–i	19.63 e–i	0.42 e–g	74 j–m
013	East-central Mississippi	0.251 e–h	0.75 b–i	19.35 i	0.42 fg	50 i–m
015	East-central Mississippi	0.300 b–f	0.76 b–h	**19.76 a–d**	0.40 gh	44 m
Mean	—	**0.291**	**0.74**	**19.60**	**0.43**	**172**
Sign.[3]	—	**	**	**	**	**

[1] Column values with the same letter not significantly different at the 0.05 level.
[2] Bold type indicates upper 1/4.
[3] * = significant at the 0.05 level; **significant at the 0.01 level; NS = not significantly different.

this characteristic to have a highly significant variation between clones (Table 2).

Silver maple's average heating value was 19.60 kJ/g (19.33 to 20.32) and nearly the same as the average of 19.76 kJ/g reported for hardwoods (Panshin and de Zeeuw 1980). In a previous study we found ash had a mean value of 18.26 kJ/g for whole-tree chips (Geyer and Walawender 1997). This characteristic varied between clones and was highly significant (Table 2).

Silver maple wood is moderately heavy, with a specific gravity (SG) of 0.43 (range 0.38 to 0.49) in our current study based upon oven-dry weight and green volume. In a previous study we found wood SG to have a mean value of 0.45 for samples collected from the base of 7-year-old trees (Geyer and Walawender 1997). This is less than the range reported by Panshin and de Zeeuw (1980) for soft maple of 0.51-0.55**.** We found this characteristic varied between clones and was highly significant (Table 2). Some of the larger trees had the greatest SG.

Correlations of wood properties with tree size (volume D^2H) at 6 years were not significant except for SG. Base diameter, total height, and number of stems were significantly related to SG at the 1% level, with r^2 values ranging from 0.43 to 0.63. Young *Populus* clones were also reported (Geyer et al. 2000) to have a similar relationship.

CONCLUSIONS

Our results suggest that biomass growth and wood properties should be considered when selecting silver maple clones for SRF. Comparisons indicate that some significant clonal effects were present.

1) Clonal differences in growth were readily apparent: the tallest one-third was significantly greater in D^2H (4 1/2 times) than the smallest one-third.
2) After harvesting, silver maple stumps often produce many stems. Coppicing is prolific and should be considered in SRF production. Clonal differences exist, but are not recorded in this study.
3) Wood properties were similar to those of other soft hardwoods, such as, catalpa, cottonwood, and willow. These results suggest that for the 25 sources included in this study, parentage affected ash, fiber length, gross heat of combustion, and specific gravity.

REFERENCES

American Society for Testing Materials (ASTM). 1981. Standard test method for gross-calorific value of solid fuel by the adiabatic bomb calorimeter. ATSM D 2015-77. Philadelphia, PA

————. 1995. Standard test for ash in wood. ASTM D 1102-84.

Barnes, D. A. and S. A. Sinclair. 1984. Gross heat of combustion of living and spruce budworm-killed balsam fir. Wood Fiber Sci. 16(4): 518–522.

Geyer, W. A. and W. P. Walawender. 1997. Biomass properties and gasification behavior of young silver maple trees. Wood Fiber Sci. 29(1):85–90.

———, and ———. 1994. Biomass and gasification properties of young black locust. Wood Fiber Sci. 26(3):354–359.

——— and ———. 1999. Biomass properties and gasification behavior of young catalpa trees. Wood Fiber Sci. 29(1):95–100.

———, R. M. Argent, and W. P. Walawender. 1987. Biomass and gasification properties of 7-year-old Siberian elm. Wood Fiber Sci. 19(2):176–182.

———, J. Deyke, and ———. 2000. Biomass and gasification properties of young *Populus* clones. Wood Fiber Sci. 32(3):375–384.

Haynes, R. W. 1990. An analysis of the timber situation in the United States: 1989–2040. USDA Forest Serv. Gen. Tech. Pub. RM 199. Ft. Collins CO. 267 pp.

Kopp, R. F, W. A. Geyer, and W. R. Lovett. 1988. Silver maple seed sources for increased biomass production. North. J. Applied Forestry. 5(3)180–184.

Mitchell, C. P., and J. B. Ford-Robertson. 1992. Introduction to ecophysiology of short rotation forest crops. Elsevier Applied Science, London and New York. 30 pp.

Murphey, W. K. and B. E. Cutter. 1974. Gross heat of combustion of five hardwood species at different moisture contents. Forest Prod. J. 24(2)44–45.

Neenan, M. and K. Steinbeck. 1979. Calorific values for young sprouts of nine hardwood species. Forest Sci. 25(3):455–461.

PANSHIN, A. J., AND C. DE ZEEUW. 1980. Textbook of wood technology, 4th ed. McGraw-Hill, Inc., New York, NY. 722 pp.

PERLACK, R. D., L. L. WRIGHT, A. F. TURHOLLOW, R. L. GRAHAM, B. J. STOKES, AND D. C. EERBACH. 2005. Biomass as feedstock for a bioenergy and bioproducts industry: The technical feasibility of a billion-ton annual supply. USDOE and USDA. Oak Ridge, TN. 59 pp.

PREECE, J. E., ASHBY, W. C., AND R. L. ROTH. 1991. Micro- and cutting propagation of silver maple-II genotype and provenance affect performance. J. A. Soc. Hort. Sci. 116(1):149–155.

SAS INSTITUTE INC. 1999. SAS proprietary software Version 8. SAS Institute, Cary, NC.

TSOUMIS, G. 1968. Wood as raw material. London, England. 275 pp.