Wood and Bark Specific Gravity of Small-Diameter Pine-Site Hardwoods in the South

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ABSTRACT. Ten small-diameter trees from each of the 22 species (220 trees) were sampled from throughout the southern United States. Mean SG was determined for stem wood and bark and the whole stem, for branch wood and bark and whole branches (to a minimum diameter of 0.05 in.), and for tree wood and bark and the whole tree. Significant differences were determined a) among the species for each tree part measured and b) among the tree parts of each species. The relationship between both stem-wood SG and stem-bark SG and height above ground is plotted by species. There was a significant inverse linear relationship between green MC and SG; with the exception of bark, the ashes contained lower percent moisture than did species of similar SG. Comparison of stem-wood SG values with *Wood Handbook* values indicates that small-diameter pine-site hardwoods are somewhat denser than larger trees of the same species more typically measured.

As REPORTED previously (1, 2, 3, 8), personnel at the Southern Forest Experiment Station have studied those properties of small-diameter hardwoods deemed important to the forest products industry. The hardwoods studied produce a substantial fraction of the total volume of fiber on sites capable of growing southern pine. However, they generally have not been utilized because they lack a market and because of their small size and poor form. An evaluation of their properties should aid process engineers in devising utilization procedures for this hardwood resource.

Specific gravity (SG) is an important property because it is an indicator of other properties and of fiber yield per unit volume. It is also relatively easy to measure. The objective of the study was to determine, for each of 22 species, mean SG values for the entire tree; i.e., wood plus bark, and for tree wood and bark separately; and for the entire stem, and for stem wood and bark separately; and for the entire branches, and for branch wood and bark separately. A second objective was to determine changes in SG along the length of the stem for each species. The 22 species investigated (Table 1) comprise nearly 90 percent of the hardwood volume growing on sites which support, or are capable of supporting, pine stands.

Procedure

A total of 220 trees, 10 of each species, were cut from widely separated locations throughout that portion of each species range occurring ir the 11 southern states from Virginia to Arkansas and eastern Texas. Sampling was restrictec to trees between 5.5 and 6.5 inches in diameter outside bark, at breast height. Tree age variec from a species mean of 27 years in yellow-popla to 59 years in black tupelo, with an overal average of 39 years.

To sample the stem wood and bark ir proportion to occurrence by volume, 2-inch thick disks were removed at 48-inch interval along the stem. The lowest disk was taken at 2 inches above ground, and the stem was considered to end at a point of branching abov which a main stem could no longer be distinguished. A 45-degree, pith-centered wedg measuring 1/2 inch along the grain wa removed from each disk, and the wood and barl separated at the cambium. SG values wer determined from ovendry (OD) weight an green volume, the latter determined by wate immersion after saturation. An average SG fo stem wood (or for stem bark) was obtained b adding the weights and the volumes of th individual wedges of that stem to yield one OI weight and one green volume. Whole-stem S(was found by combining all the bark and woo weights and the volumes from stem wedges.

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TABLE 1. — *SG (with standard deviation in parentheses) of 6-inch hardwoods growing on pine sites.*[1].

Species	Common name	Code	Stem wood	Stem bark	Stem	Branch wood	Branch bark	Branch	Tree wood	Tree bark	Tree
Acer rubrum L.	Red maple	RM	.496 (.014)	.535 (.027)	.500 (.013)	.507 (.013)	.469 (.034)	.497 (.078)	.495 (.015)	.525 (.023)	.498 (.014)
Carya spp.	Hickory, true	Hi	.643 (.051)	.522 (.053)	.618 (.049)	.607 (.061)	.467 (.059)	.567 (.058)	.641 (.051)	.516 (.052)	.614 (.049)
Celtis spp.	Hackberry	Ha	.525 (.047)	.606 (.056)	.532 (.046)	.551 (.048)	.541 (.049)	.549 (.042)	.527 (.047)	.596 (.053)	.534 (.045)
Fraxinus americana L.	White ash	WA	.582 (.037)	.397 (.040)	.543 (.032)	.559 (.047)	.460 (.060)	.533 (.047)	.580 (.037)	.402 (.040)	.542 (.032)
F. pennsylvanica Marsh.	Green ash	GA	.561 (.041)	.407 (.045)	.536 (.034)	.556 (.035)	.450 (.035)	.532 (.027)	.560 (.040)	.411 (.042)	.535 (.034)
Liquidambar styraciflua L.	Sweetgum	SG	.453 (.018)	.369 (.047)	.439 (.021)	.451 (.028)	.416 (.038)	.442 (.029)	.453 (.017)	.373 (.045)	.439 (.021)
Liriodendron tulipifera L.	Yellow-poplar	YP	.395 (.032)	.390 (.035)	.394 (.028)	.406 (.036)	.335 (.035)	.389 (.028)	.395 (.032)	.385 (.031)	.394 (.027)
Magnolia virginiana L.	Sweetbay	SB	.437 (.037)	.440 (.018)	.437 (.033)	.423 (.039)	.390 (.045)	.415 (.036)	.436 (.037)	.434 (.017)	.435 (.032)
Nyssa sylvatica Marsh.	Black tupelo	BT	.500 (.042)	.428 (.051)	.490 (.040)	.487 (.050)	.433 (.064)	.476 (.040)	.500 (.042)	.428 (.051)	.489 (.039)
Quercus alba L.	White oak	WhO	.665 (.039)	.543 (.055)	.648 (.039)	.637 (.039)	.488 (.027)	.596 (.030)	.664 (.039)	.537 (.051)	.645 (.038)
Q. coccinea Muenchh.	Scarlet oak	ScO	.622 (.030)	.618 (.064)	.620 (.033)	.643 (.024)	.511 (.042)	.615 (.021)	.623 (.029)	.609 (.060)	.620 (.031)
Q. falcata Michx.	Southern red oak	SRO	.609 (.020)	.601 (.039)	.607 (.022)	.621 (.026)	.504 (.033)	.592 (.026)	.610 (.020)	.593 (.036)	.606 (.021)
Q. falcata var. *pagodaefolia* Ell.	Cherrybark oak	ChO	.623 (.034)	.622 (.052)	.623 (.032)	.640 (.024)	.520 (.030)	.617 (.024)	.624 (.033)	.612 (.048)	.622 (.031)
Q. laurifolia Michx.	Laurel oak	LO	.582 (.030)	.630 (.043)	.589 (.028)	.624 (.034)	.521 (.057)	.605 (.029)	.586 (.031)	.618 (.038)	.590 (.028)
Q. marilandica Muenchh.	Blackjack oak	BjO	.638 (.024)	.642 (.033)	.639 (.018)	.706 (.039)	.548 (.031)	.662 (.031)	.645 (.027)	.631 (.031)	.642 (.018)
Q. nigra L.	Water oak	WaO	.587 (.034)	.628 (.052)	.593 (.032)	.604 (.025)	.508 (.046)	.585 (.020)	.588 (.033)	.618 (.049)	.593 (.031)
Q. rubra L.	Northern red oak	NRO	.605 (.034)	.644 (.044)	.611 (.034)	.597 (.034)	.536 (.050)	.583 (.036)	.605 (.034)	.636 (.043)	.610 (.034)
Q. shumardii Buckl.	Shumard oak	ShO	.625 (.040)	.644 (.062)	.627 (.042)	.643 (.027)	.540 (.029)	.622 (.025)	.627 (.038)	.636 (.058)	.627 (.041)
Q. stellata Wangenh.	Post oak	PO	.659 (.037)	.498 (.055)	.626 (.036)	.646 (.048)	.438 (.049)	.580 (.039)	.658 (.036)	.488 (.054)	.622 (.035)
Q. velutina Lam.	Black oak	BO	.620 (.022)	.612 (.044)	.618 (.022)	.648 (.030)	.542 (.042)	.624 (.029)	.622 (.021)	.606 (.041)	.618 (.021)
Ulmus alata Michx.	Winged elm	WE	.623 (.030)	.341 (.030)	.577 (.023)	.610 (.031)	.369 (.031)	.540 (.014)	.622 (.029)	.345 (.029)	.574 (.022)
U. americana L.	American elm	AE	.536 (.020)	.395 (.039)	.515 (.017)	.526 (.035)	.356 (.034)	.484 (.025)	.535 (.020)	.388 (.037)	.512 (.015)

[1]Based on OD unextracted weight and green volume; each value is an average of 10 trees.

A similar procedure was followed in the top: each branch was sampled at 48-inch intervals down to a diameter of 0.5 inch, outside bark. The first disk was taken at 24 inches from the point of branching. For branch material, however, the entire disk, 1/2 inch along the grain, was used rather than a wedge.

Mean SG for tree wood was obtained by combining the branch wood and stem wood weights, and the volumes. Stem wood values were weighted by a factor of eight since they were taken from a 45-degree wedge rather than from the entire disk. The same procedure was followed for tree bark. Finally, whole-tree SG was determined by combining the stem and branch wood and bark weights, and the volumes.

Statistical comparisons were made in two days at the 0.05 significance level by Duncan's multiple range test for: a) within-tree SG for each species, and b) among-species SG by tissue types.

I determined the alcohol-benzene extractive content of OD wood and bark and calculated regression equations to determine whether a linear relationship existed between extractive content and SG. The sampling procedure was as described except that stem wedges and branch disks were 1 inch along the grain. For each part (stem wood, stem bark, branch wood, and branch bark), the samples were combined and ground to pass a 40-mesh screen. Extractives were removed with a 5-hour extraction of one volume 95 percent ethanol to two volumes benzene, an alcohol wash, a 5-hour extraction with 95 percent ethanol, and a water (not hot) wash.

Results

Hardwoods growing on pine sites are apparently somewhat denser than larger trees of the same species more typically measured. The *Wood Handbook* (15) lists wood SG values for 18 of the 22 species sampled. Stem-wood SG (Table 1) of most species was 0.01 to 0.04 above the *Wood Handbook* value, with the mean difference for 18 species being 0.03. Sweetgum averaged 0.01 below, while black oak, post oak, white oak, American elm, and southern red oak averaged 0.06 to 0.09 above *Wood Handbook* values. An increase of 0.03 in SG would represent an additional 1.9 pounds of wood per cubic foot, and a difference of 0.09 would represent an increase of 5.6 pounds.

It is unlikely that the *Wood Handbook* values were obtained by a systematic sampling along the entire length of the stem. However, a difference in sampling is probably not the major reason for the higher values reported here. Variations in SG with height in the stem are plotted in Figure 1 and those species exceeding the *Wood Handbook* values do so at all heights in the stem.

Variation With Height in Stem

The stem-wood and stem-bark SG curves plotted in Figures 1 and 2 are the average for the 10 trees of each species. However, there is a great deal of variability and in many species individual trees often deviated from the average curve. Since not all stems are the same length, each point is the average of 10 trees (90 in red oaks) only up to a height of 22 or 26 feet. Above that height, the number of trees represented decreases to a minimum of either 4 or 5 (20 in the red oaks).

Wood SG tended to remain relatively constant or to decrease with increasing height in the stem (Fig. 1), but the relationship varied considerably among species. In the ring-porous species SG decreased with increasing height in

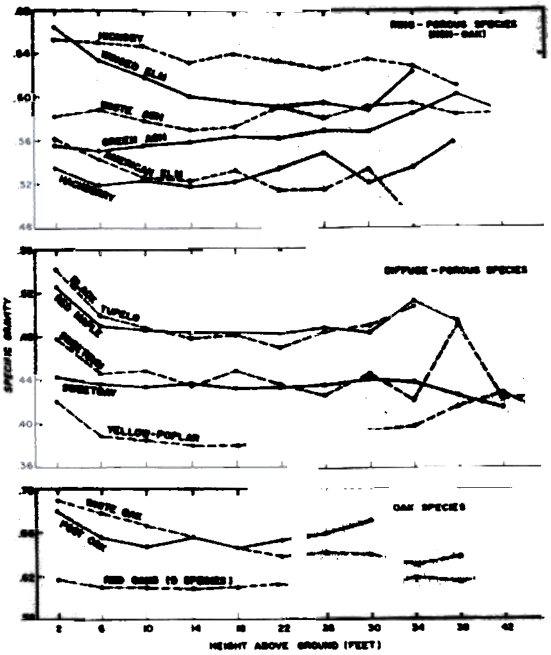

Figure 1. — Relationship between stem-wood SG and height above ground in 6-inch (DBH) hardwoods growing on southern pine sites. The red oak plot is based on data from 90 trees; the other plots represent data from 10 trees each.

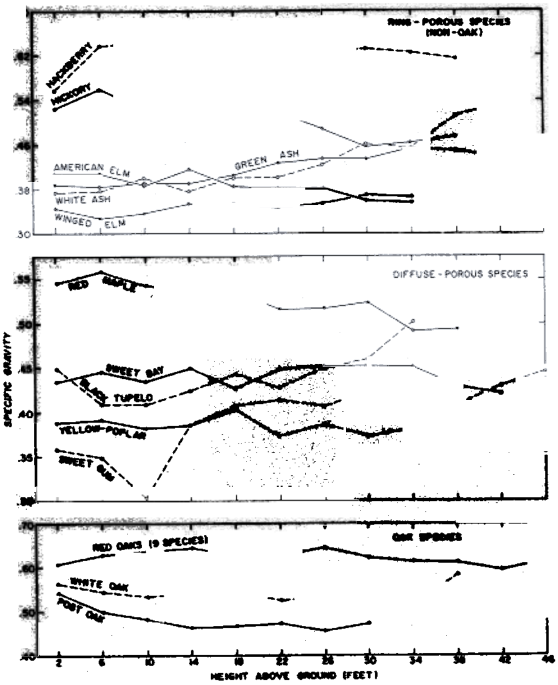

Figure 2. — **Relationship between stem-bark SG and height above ground in 6-inch (DBH) hardwoods growing on southern pine sites. The red oak plot is based on data from 90 trees; the other plots represent data from 10 trees each.**

hickory, remained constant to a height of 30 feet before increasing in the red oaks, and steadily increased in green ash. In the diffuse-porous species, wood SG generally was high near the base of the tree, decreased sharply to a height of 6 feet, then remained relatively constant to a height of about 30 feet. Above that height SG usually increased and then decreased.

There have been some other studies that measured the relationship between SG and height in stem for these species. The relationship reported here for yellow-poplar is very similar to that found by Koch, Brauner, and Kulow (7), Taylor (12), Gilmore (4), and Schroeder and Phillips (11). The relationship observed for sweetgum is similar — but lower at all heights — to the results obtained by both Webb (14) and McElwee, Tobias, and Gregory (10). The curve the latter plotted for white ash falls between those we obtained for white ash and green ash.

The relationship between bark SG and height in the stem (Fig. 2) also varied among species. SG generally increased with height in the ashes and in black tupelo and sweetgum (after an initial decrease) while in other species it decreased or remained relatively constant. Koch (5) found that red maple bark density increased to a height of 10 feet and then remained constant whereas the present results indicate a decrease above 6 feet. In 6- to 8-inch diameter at breast height (DBH) yellow-poplar he found that bark SG increased sharply to breast height, decreased somewhat to a height of 16 feet and then increased again (5). In another stand of 14- to 16-inch trees he found that Bark SG increased steadily with height (6). The curves presented here for the red oaks are similar to those for 8- to 10-inch northern red oak, scarlet oak, and black oak (5). However, his curves for 14- to 16-inch red oak rise sharply to a height of 10 feet and then rise more slowly to a height of 40 feet.

Within-Tree Comparisons

Of the within-tree comparisons possible the following seemed of interest: a) stem wood-branch wood, b) stem wood-stem-branch wood-branch-tree wood-tree, c) stem bark-stem wood, d) branch bark-branch wood, e) stem bark-tree bark, and f) stem bark-branch bark.

In 20 species there was no significant difference in SG between stem wood and branch wood. The two exceptions were laurel oak and blackjack oak, and in both, stem-wood SG was lower than that of branch wood (Table 1). These results agreed in general with those of Taylor (13) who, in comparing stem and branch wood of seven of these species, found that in only one (southern red oak) was there a statistically significant difference between the two.

Because of the preponderance of wood—82 percent of the above-stump green weight when species were averaged—significant differences among stem wood, whole stem, branch wood, whole branch, tree wood, and whole tree occurred in only six species. In post and white oaks and in American and winged elms, branch SG was significantly below that of the other five categories. In addition, winged elm whole stem and whole-tree density, averaging 0.576 was significantly below that of the stem wood, branch wood, and tree wood, averaging 0.618. Laurel oak and blackjack oak were the two species in which branch-wood SG exceeded that of stem wood, by 0.042 and 0.068, respectively. In laurel oak, branch-wood density also exceeded that of the wood; and in blackjack oak branch wood was the densest tissue in the tree.

Stem-bark SG averaged lower than that of stem wood in the two white oaks samples (pos and white), in the ashes, the elms, sweetgum, hickory, and black tupelo; the difference was smallest in black tupelo, 0.072, and largest in winged elm, 0.282. Stem bark was significantly denser than stem wood in hackberry (0.081), laurel oak (0.048), water oak (0.041), and northern red oak (0.039). In the remaining six red oaks, yellow-poplar, sweetbay, and red maple, there was no significant difference between stem wood and stem bark.

Branch-bark SG did not differ significantly from that of branch wood in red maple and hackberry. In the other 20 species, branch bark averaged significantly less, the difference ranging from 0.033 in sweetbay to 0.241 in winged elm. In fact, in those 20 species — the 11 oaks, hickory, yellow-poplar, sweetbay, and American elm—branch bark was lower in density than any other category measured.

There was no significant difference between stem bark and tree bark in any of the 22 species. This observation is to be expected because for all species combined there were about 4.8 times as much stem bark as branch bark, based on green weight. There were significant differences between stem bark an branch bark, however. In the 11 oaks, yellov poplar, sweetbay, hickory, red maple, America elm, and hackberry, stem bark was denser. I sweetgum, the two ashes, and winged eln branch bark was denser. In black tupelo, ther was no difference in density between stem bar and branch bark.

Among-Species Comparisons

For all portions of the tree containing woo (i.e., excluding only stem bark, branch barl and tree bark), species rankings followed similar pattern (Table 2). Yellow-poplar wa consistently low with SG of 0.39 to 0.4 followed by sweetbay and sweetgum (0.42 t 0.45). Intermediate in SG were two group: black tupelo and red maple (averaging 0.48 t 0.50) and American elm, hackberry, and the tw ashes (averaging 0.51 to 0.58). The dense group (0.57 to 0.66), containing 13 of the 2 species, consisted of the oaks, winged elm, an hickory. Of the oaks, water oak and laurel oa were the least dense while blackjack, post, an white oaks were the most dense. The grouping

TABLE 2. — *Among-species comparisons of SG by tissues, using Duncan's multiple range test. SG increases from left to right, and those species underscored by the same line are not significantly different.*

Stem wood	YP	SB	SG	RM	BT	Ha	AE	GA	WA	LO	WaO	NRO	SRO	BO	ScO	ChO	WE	ShO	BjO	Hi	PO	Wh
Stem bark	WE	SG	YP	AE	WA	GA	BT	SB	PO	Hi	RM	WhO	SRO	Ha	BO	ScO	ChO	WaO	LO	BjO	ShO	NR
Stem	YP	SB	SG	BT	RM	AE	Ha	GA	WA	WE	LO	WaO	SRO	NRO	Hi	BO	ScO	ChO	PO	ShO	BjO	Wh
Branch wood	YP	SB	SG	BT	RM	AE	Ha	GA	WA	NRO	WaO	Hi	WE	SRO	LO	WhO	ChO	ScO	ShO	PO	BO	Bj
Branch bark	YP	AE	WE	SB	SG	BT	PO	GA	WA	Hi	RM	WhO	SRO	WaO	ScO	ChO	LO	NRO	ShO	Ha	BO	B
Branch	YP	SB	SG	BT	AE	RM	GA	WA	WE	Ha	Hi	PO	NRO	WaO	SRO	WhO	LO	ScO	ChO	ShO	BO	Bj
Tree wood	YP	SB	SG	RM	BT	Ha	AE	GA	WA	LO	WaO	NRO	SRO	BO	WE	ScO	ChO	ShO	Hi	BjO	PO	Wh
Tree bark	WE	SG	YP	AE	WA	GA	BT	SB	PO	Hi	RM	WhO	SRO	Ha	BO	ScO	ChO	LO	WaO	BjO	ShO	N
Tree	YP	SB	SG	BT	RM	AE	Ha	GA	WA	WE	LO	WaO	SRO	NRO	Hi	BO	ScO	PO	ChO	ShO	BjO	Wh

[1]For species codes and specific gravities, see Table 1.

TABLE 3. — *Weight per cubic foot (green volume) of freshly felled 6-inch hardwoods growing on pine sites.*

Species	Stem wood	Stem bark	Stem	Branch wood	Branch bark	Branch	Tree
		-----	----- Po	nds per cubi	oot ----		------
Red maple	52.6	58.2	53.2	55.0	55.4	55.0	53.3
Hickory, true	60.8	56.3	60.0	56.2	53.8	55.6	59.7
Hackberry	56.6	58.8	56.6	56.4	58.0	56.7	56.6
White ash	53.6	41.7	51.0	51.0	51.1	51.5	51.1
Green ash	51.6	44.7	50.7	51.0	52.2	51.7	50.7
Sweetgum	62.3	43.6	59.2	58.8	53.7	57.5	59.0
Yellow-poplar	52.2	55.0	52.5	52.0	49.0	51.4	52.5
Sweetbay	54.8	55.5	54.9	52.6	48.8	51.8	54.6
Black tupelo	59.3	45.4	56.8	57.7	50.9	56.2	56.8
White oak	67.2	53.6	65.3	62.9	51.7	59.9	65.0
Scarlet oak	65.8	60.0	64.5	61.6	53.3	60.3	64.1
Southern red oak	64.7	57.4	62.9	61.1	52.4	59.0	62.5
Cherrybark oak	64.8	59.8	63.9	62.3	54.6	61.0	63.6
Laurel oak	63.4	61.9	63.2	62.9	57.2	62.0	62.9
Blackjack oak	69.4	57.6	66.1	70.2	53.4	65.2	65.9
Water oak	63.6	60.5	63.0	61.6	55.0	60.4	62.8
Northern red oak	64.1	62.6	63.6	59.3	54.4	58.3	63.2
Shumard oak	66.0	61.2	65.0	62.4	56.0	61.3	64.7
Post oak	68.1	46.3	63.3	64.8	45.1	58.6	62.9
Black oak	65.5	59.7	64.1	63.0	55.0	61.3	63.7
Winged elm	64.4	37.5	58.0	61.3	41.4	55.7	59.7
American elm	58.7	46.1	56.8	54.2	44.0	51.9	56.4

presented here apply only in a general way since groups overlap and since significant differences occur within groups.

Because tree bark is composed primarily of stem bark, species ranking and significant differences are essentially the same for both. Winged elm and sweetgum had the lowest SG (0.34 and 0.37). Yellow-poplar, American elm, the ashes, black tupelo, and sweetbay were next with values ranging from 0.39 to 0.44. In an intermediate position were hickory, red maple, and the two white oaks, ranging from 0.49 to 0.54. The nine red oaks and hackberry were the densest group, ranging from 0.60 to 0.64.

Yellow-poplar branch bark was least dense with SG of 0.34, followed by the two elms averaging 0.36 and by sweetbay and sweetgum averaging 0.40. Intermediate were black tupelo, post oak, the ashes, hickory, and red maple, ranging from 0.43 to 0.47, averaging 0.45. The oaks and hackberry, ranging from 0.49 to 0.55, were densest with an average SG of 0.52.

Specific Gravity-Moisture Content Relationships

In a previous paper (9), moisture content (MC) of the same trees, freshly-felled, was determined for seven of the nine tissues reported here; it was not determined for tree wood and tree bark. Using the SG and MC data, it was possible to calculate the weight per cubic foot of each tree part at the time of felling (Table 3). The inverse relationship between MC and SG was investigated by linear regression. Equations for each of the seven tissues were derived in two ways: using all 220 observations from individual trees, and using the 22 species means. In plotting the data it became evident that, with the exception of stem bark and branch bark, white and green ash contain less moisture (percentage-basis) than do other species of similar SG. When the equations were computed again, with the ashes omitted, the coefficient of determination was significantly improved. The relationships, presented in Table 4, were significant at the 0.01 level. The coefficient of determination was improved using species means since variability was reduced.

Specific gravity-Extractive Content Relationships

The addition of extractives to a given volume of wood increases its SG and it was decided to determine whether there was a linear relationship between extractive percent (unpublished) and SG. Individual tree values were used for stem wood, branch wood, stem bark, and branch bark to determine the four equations for each species. Of the 88 equations obtained, only 8 were significant at the 0.05 significance level and 6 had a negative slope. This indicates that at the concentrations obtained in these species (ranging from 3.0% in

TABLE 4. — *Relationship between MC and SG of 6-inch hardwoods growing on pine sites*[1]

Location in tree	Regression intercept (*a*)	Regression coefficient (*b*)	Coefficient of determination (R^2)
OBSERVATIONS FROM 220 TREES			
Stem wood	170.10	−168.90	0.5231
Stem bark	133.44	−125.89	.4445
Branch wood	159.38	−162.11	.5812
Branch bark	163.78	−179.14	.4756
Stem	168.58	−171.15	.5567
Branch	169.73	−183.10	.6595
Tree	170.06	−175.03	.5809
OBSERVATIONS FROM 200 TREES — ASHES OMITTED			
Stem wood	174.36	−171.78	0.6582
Stem bark	140.93	−137.87	.4783
Branch wood	166.07	−169.79	.6999
Branch bark	166.37	−184.55	.4971
Stem	177.72	−183.18	.7233
Branch	175.74	−190.88	.7474
Tree	178.87	−186.32	.7414
OBSERVATIONS FROM 22 SPECIES MEANS			
Stem wood	177.98	−182.69	0.5767
Stem bark	138.83	−136.20	.5549
Branch wood	172.80	−185.36	.6693
Branch bark	187.58	−229.76	.6759
Stem	177.36	−187.07	.6229
Branch	183.18	−207.53	.7598
Tree	178.52	−190.08	.6438
OBSERVATIONS FROM 20 SPECIES MEANS — ASHES OMITTED			
Stem Wood	181.03	−183.44	0.7394
Stem bark	148.31	−151.65	.6012
Branch wood	179.18	−192.44	.8133
Branch bark	187.71	−229.82	.6765
Stem	186.62	−198.91	.8240
Branch	188.36	−213.74	.8577
Tree	187.33	−201.31	.8337

[1]Model: Moisture content = a + b (specific gravity)

sweetbay stem wood to 21.8% in green ash branch bark) extractives do not systematically influence SG.

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