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Processing and Wood Factors Influence Medium Density Fiberboard Production from Young *Eucalyptus grandis*, *E. amplifolia*, *Corymbia torelliana*, and Cottonwood Grown in Florida USA

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Abstract: Fast growing *Eucalyptus grandis* W. Hill ex Maiden (*EG*), *E. amplifolia* Naudin (*EA*), *Corymbia torelliana* (F.Muell.) K.D.Hill & L.A.S.Johnson (*CT*), and *Populus deltoides* W.Bartram ex Marshall (*PD*) may be deployed in Short Rotation Woody Crop (SRWC) systems in the lower Southeastern USA, especially in Florida. To evaluate these species for possible use as medium density fiberboard (MDF) and other composites, 2.5 m logs of three *EG* clones, three *PD* clones, six *EA* progenies, four *CT* trees, and one *P. tremuloides* Michx. (*PT*) tree from northern Wisconsin as a control were characterized for basic wood properties before being chipped, pulped, and pressed into MDF. The chips were thermomechanically pulped (TMP) for a two-phase study of the factors expected to influence suitability for MDF production: wood characteristics, refining system, resin system, and MDF formation. Phase I used TMP and 4% phenol-formaldehyde (PF) resin to produce 17 MDF species/genotype batches (S/GB). Thickness Swell (TS), Water Absorption (WA), Internal Bonding (IB), Modulus of Elasticity (MOE), and Modulus of Rupture (MOR) were evaluated to: (1) assess within species and within tree variation, (2) relate basic wood properties to MDF potential, and (3) examine repeatability of MDF-making. There was considerable variation among and within species, but only minor within tree variation. Six of the seventeen S/GBs had superior physical and mechanical MDF properties. In Phase II, two of the six better performing Phase I S/GBs were evaluated, along with three average Phase I S/GBs. Phase II compared the effects on IB from using tube and drum blenders for resin application, the influence of using unscreened versus screened fibers, and the differences of using PF resin at 4% or 6% versus urea-formaldehyde (UF) resin at 8% or 12%. Overall, genetic variation among species, and particularly within these species, affected their potential for commercial MDF. Log specific gravity (SG), fines, MDF SG, and fiber length influenced MDF properties, as did refining and MDF-processing variables. Further study of specific processing requirements can optimize the potential of young *EG*, *EA*, *PD*, and *CT* genotypes for MDF and other composites.

Keywords: *Eucalyptus grandis*; *Eucalyptus amplifolia*; *Corymbia torelliana*; *Populus deltoides*; *Populus tremuloides*; cottonwood; aspen; genetic variation; MDF; wood composites

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1. Introduction

SRWC systems involving the fast-growing hardwoods *EG*, *EA*, *CT*, and *PD* may be implemented in appropriate portions of Florida and the lower Southeast. *EG*, *CT*, and *PD* are also important plantation species worldwide. On suitable southeastern USA sites and/or with intensive culture, *EG*, *EA*, and *PD* may reach harvestable size in as few as three years [1,2]. *EG* is the most productive of the three, largely because of a tree improvement program conducted by the US Forest Service from the late 1960s to 1984 [3]. *EG* is now grown and sold commercially in southern Florida for landscape mulch. *EA* may be grown from central Florida into the lower southeastern USA, while *PD* can be grown across much of the US. *CT* is used as a windbreak for vegetable crops and citrus in central and southern Florida. While these SRWCs have been shown to be suitable for some traditional products and for energy wood [4], little is known about their suitability for a wider range of value-added products.

Accordingly, our general objective was to determine the potential for using these SRWCs as wood-composite products. Previous research on wood-based composites and other similar hybrid composites has laid a foundation for this study. The properties of wood-based composites are known to be a function of wood fiber species, source, and quality [5–11]. They are also related to composite processing parameters [12–16]. The age of the woody fiber source, especially related to wood juvenility, is also well recognized as being important, which could definitely be an issue with SWRC fiber [11,17–20]. Many of these same issues would also likely be a concern in the use of SRWCs as a fiber source for inorganic bonded wood composites [21,22].

Recognizing these critical issues, the specific objectives of our investigations were to evaluate and compare the broad suitability of young *EG*, *EA*, *CT*, and *PD* for making MDF by evaluating the basic wood properties of MDF produced from defibrillated SRWCs. Then, within- and between-tree variation influencing MDF production was evaluated to assess their potential for use for other wood-composite products.

2. Materials and Methods

EA, *EG*, *CT*, and *PD* from Florida were assessed for their MDF suitability. The *EG*, *EA*, and *PD* genotypes included three superior *EG* and three superior *PD* clones and six top *EA* progenies, based on statewide genetic tests (Table 1). The 30.5 cm, diameter at breast height (DBH) *EG* 2805 was harvested from a clonal test near Haines City, FL; the 20.3 cm *EG* 2814 and 30.5 cm *EG* 2817 came from a study at Tampa, FL; each provided 2.5 m long basal logs. The nine *PD* trees harvested from a study near Sumterville, FL, averaged 10.2 cm in DBH, and each provided one to three logs per tree. Six *EA* trees in a study near Old Town, FL, averaging 15.2 cm in DBH, provided basal logs. Five logs from an *EA* 4836 progeny were used to estimate within tree variability. Four approximately 15-year-old *CT* trees harvested from a windbreak near Clewiston, FL, averaged 25.4 cm in DBH and also contributed basal logs. For comparison to known species commonly used commercially for MDF, one 20.4 cm *PT* log provided by LP in Hayward, WI, was included.

Table 1. S/GB IDs, age, number of trees, and number of logs per tree of *PT*, *PD*, *EG*, *EA*, and *CT* in this study.

Species	Genotype	S/GB	Age (Years)	# of Trees	# of Logs
PT	unknown	Pt1	unknown	1	1
PD	94-1	Pd2-3	3.2	3	2-3
PD	Ken-8	Pd4	3.2	2	1-3
PD	S13C20	Pd5	3.2	2	2-3
EG	2805	Eg1	11.8	1	1
EG	2814	Eg2	6.7	1	1
EG	2817	Eg3	13.3	1	1
EA	4853	Ea1	8.3	1	1
EA	-	Ea2/3	8.3	-	-
EA	4875	Ea4	8.3	1	1
EA	4836	Ea5	8.3	1	5
EA	4543	Ea6	8.3	1	1
CT	unknown	Ct1	15	1	1
CT	unknown	Ct2	15	1	1
CT	unknown	Ct3	15	1	1
CT	unknown	Ct4	15	1	1

The 2.5 m long logs were harvested and shipped to FPL, where they were cut into 1.2 m lengths with a 50-mm thick mid-log disk removed for anatomical study. The 1.2 m lengths were then debarked, sectioned to chippable sizes, and stored at 4.5 °C. The mid-log disks were then saturated in water, weighed green, and dried at 103 °C to determine wood moisture content (MC) and SG. Each of the resulting 17 MDF S/GBs was chipped (usually the day before being defibrillated by TMP) by presteaming for 10 min and then steaming at 167 °C with 0.621 MPa for ~6 min using a 1 kg/min feed rate at 3000 rpm in a Sprout-Bauer Model 121CP (Andritz, Inc., Muncy, PA, USA), a 305-mm thermal mechanical single-disk refiner operated with a digester at 620 Pa and an energy consumption of 200–250 watts/kg when using a 0.152 mm separation between refiner plates (Sprout-Bauer D2B503). The resulting fiber was then immediately dried in a tray drier for approximately 24 h at 104 °C.

For each S/GB, the MC of the dried fiber was determined to assess how much fiber was needed for a 4% blend with PF resin (Dynea/Arclin 13CO85, 50.3% non-volatiles, typical of those used at the FPL [23]) in a tube blender. After blending, the MC was again estimated to derive the amount of the blend necessary to hand-form a 1810 g, 406 × 406 × 12.5 mm MDF board with a target SG of 0.72. The board was then hot-pressed at a constant 180 °C for two minutes; the maximum panel pressure during closing was set at 6.0 MPa and was reduced to 0.11 MPa after the 12.5 mm thickness was reached. The first board of each S/GB was cut-up and inspected to assure the hot-press and blending processes were appropriate for that S/GB. Then, another five MDF boards for each S/GB (nine for PD2/PD3) were subsequently made. Each of the second through to the sixth MDF boards of each S/GB (8–12 for PD2/PD3) were hot-stacked and cooled. They were then included in subsequent physical and mechanical testing in Phase I.

In Phase I, the flexural properties, internal bond strength, and dimensional stability were determined according to ASTM Standard D1037-12 [24] using seven samples cut from each board. All seven test samples were conditioned at 27 °C and 65% relative humidity (RH) for 7 days. MOR, MOE, and board SG and MC were evaluated for two 76.5 × 356 mm samples. IB was derived from three 51 × 51 mm samples. TS and WA were evaluated by immersion of two 152 × 152 mm samples horizontally in a soak tank and weighed after 2 and 24 h at ambient temperature.

Phase II involved studying two of the "best" Phase I S/GBs (Eg2, Pd4) and three nearly average Phase I S/GBs (Ea4, Ct3, Pt1). Using TMP fiber from the earlier pulping process, another three new MDF boards were made using the same methods and processes as Phase I to hand-form and hot press a 1810 g, 406 × 406 × 12.5 mm MDF board with a target SG of 0.72. These Phase II evaluations specifically compared the use of tube or drum blenders, determined the effect of using unscreened or screened fiber, and compared the use of PF resin at 4% or 6% with UF resin (GP789D16, 47% solids, typical of those used at the FPL [25,26]) at 8% or 12%. The various effects of these different MDF processes were determined using from one to five IB samples per S/GB (Table 2).

Table 2. Number of 254 × 254 mm MDF boards by S/GB and blender/screening/resin treatments in Phase II.

S/GB	Tube Blender						Drum Blender	
	PF Unscreened		PF Screened		UF Unscreened		UF Unscreened	
	4%	6%	4%	6%	8%	12%	8%	12%
Pt1	5	1	1	1	1	1		
Pd4	5	1	1	1	1	1	1	1
Eg2	5	2	2	2	2	2	1	1
Ea4	5	1	2	1	1	1		
Ct3	5	1	1	1	1	1	1	1
Total	25	6	7	6	6	6	3	3

Analyses of variance and covariance examined differences in MOR, MOE, IB, TS, and WA, with panel density as a covariate. MOR, MOE, IB, LE, TS, and WA of MDF panels were related to wood and fiber characteristics such as wood density, pH and base buffering capacity, and fiber coarseness. The analyses also examined the effects of species, genotype, and/or log on MDF panel properties, with a significance level of 5%. Species and S/GB means were tested using Duncan's multiple range test. Finally, a series of progressive weighted-rank analyses of physical and mechanical properties sorted the 17 S/GBs for the MDF properties evaluated in Phase I and the five S/GBs of Phase II.

3. Results and Discussion

3.1. Phase I

A number of differences were noted for certain wood properties among and within the Florida-grown *EG*, *EA*, *PD*, and *CT* S/GBs (Table 3). The *EG* clones were generally the denser *Eucalyptus*, while *EA* was generally less dense based on the limited genotypes and ages represented in this study. Considerable within-species variation for wood properties was evident in each species, suggesting that the deployment of favorable clones would be advantageous in producing currently-used energy products. Similar variation in the characteristics of refined fibers also emphasized the importance of genetic variation in making other products such as value-added wood composites.

Table 3. Age and various physical MDF properties of Florida-grown *EG*, *EA*, *CT*, and *PD*, and a Wisconsin-grown *PT* control (adapted from [27]).

Species S/GB	Genotype	Age (Years)	No. of Trees	Density (kg/m^3)	Moisture Content (%)	Fines (%)	pH	Fiber Length (mm)
EG	**3 clones**	**10.6**	**3**	**544**	**107**	**38.9**	**4.05**	**0.673**
Eg1	2805	11.8	1	522	104	30.3	3.96	-
Eg2	2814	6.7	1	470	129	32.1	4.30	-
Eg3	2817	13.3	1	640	89	54.1	3.92	-
EA	**4 progenies**	**8.3**	**4**	**508**	**108**	**59.5**	**3.97**	**0.502**
Ea1	4853	8.3	1	506	109	70.7	-	-
Ea4	4875	8.3	1	529	88	60.5	4.11	-
Ea5	4836	8.3	1	527	107	53.1	3.89	-
Ea6	4843	8.3	1	469	115	53.5	3.89	-
CT	**4 trees**	**15**	**4**	**526**	**101**	**50.0**	**4.20**	**0.472**
Ct1	unknown	15	1	526	80	48.6	4.17	-
Ct2	unknown	15	1	610	98	52.6	4.20	-
Ct3	unknown	15	1	555	94	37.1	4.23	-
Ct4	unknown	15	1	411	131	61.5	4.21	-
PD	**3 clones**	**3.2**	**4**	**367**				**0.670**
Pd2-3	94-1	3.2	1	369			4.54	-
Pd4	Ken8	3.2	1	381			4.51	-
Pd5	S13C20	3.2	1	351			4.41	-
P Pt1	unknown	**~55**	**1**	**360**			**4.17**	**0.754**

At the S/GB level, relatively few log fiber and MDF variables were correlated. Log SG was only correlated with MDF TS and WA (Table 4). MDF TS was strongly correlated with WA, MOE with MOR, and both MOE and MOR were correlated with IB (Table 5).

The strength properties and dimensional stability of the MDF panels made from the five species varied at many levels (Table 6). Species differed significantly for TS and WA but not IB, MOE, and MOR. Differences between genotypes/species were significant for IB, MOE, and MOR. The boards/batch were typically highly significant for each property.

At the S/GB level, the strength properties and dimensional stability of the MDF panels varied considerably (Table 7). For example, some of the 17 S/GBs were clearly consistently better than others for the MOR–MOE relationship (Figure 1). Similar separations were noted between the 17 S/GBs for the other properties, too.

Table 4. Correlations of log fiber variables with MDF variables for 17 S/GBs in Phase I.

	TS	WA	MOE	MOR	IB
Log SG	0.77	0.78	0.13	0.04	0.06
kW	0.50	0.51	−0.10	−0.12	−0.09
Fines	−0.44	−0.36	−0.38	−0.33	−0.30
pH	−0.54	−0.56	−0.21	−0.18	−0.36
Buff	0.35	0.42	−0.24	−0.23	0.00

Table 5. Correlations among MDF variables for 17 S/GBs in Phase I.

	TS	WA	MOE	MOR	IB
TS		0.96	0.19	0.19	0.20
WA			0.07	0.05	0.06
MOE				0.97	0.76
MOR					0.81

Table 6. Variation in various physical and mechanical properties of MDF from four Florida-grown species and a *PT* control in Phase I.

Species	TS_{24} (%)		WA_{24} (%)		IB (kPa)		MOE (GPa)		MOR (MPa)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Pt	60.7 bc	-	156.6 bc	-	296	-	1.47	-	7.72	-
Pd	48.7 c	41.8–58.8	137.6 c	130.5–145.7	445	0.0–445	1.17	0.88–1.70	5.01	3.37–9.52
Eg	77.1 a	73.6–81.6	186.4 a	179.1–186.0	226	169–272	1.59	1.42–1.84	8.01	6.64–10.27
Ea	71.0 ab	62.8–77.9	173.9 ab	160.5–189.2	294	193–483	1.47	1.20–1.71	7.74	5.82–9.41
Ct	80.5 a	64.5–88.9	192.2 a	177.8–205.6	196	138–263	1.24	0.93–1.45	5.90	4.43–7.74
Ave.	68.1		170.7		264		1.35		6.76	
					Significance of Source of Variation					
Species	0.0004		0.0002		0.4025		0.3429		0.4270	
Geno	0.0150		0.0909		<0.0001		<0.0001		<0.0001	
Batch	0.0412		0.1772		0.5240		0.4877		0.8014	
Board	<0.0001		<0.0001		<0.0001		0.0095		<0.0001	

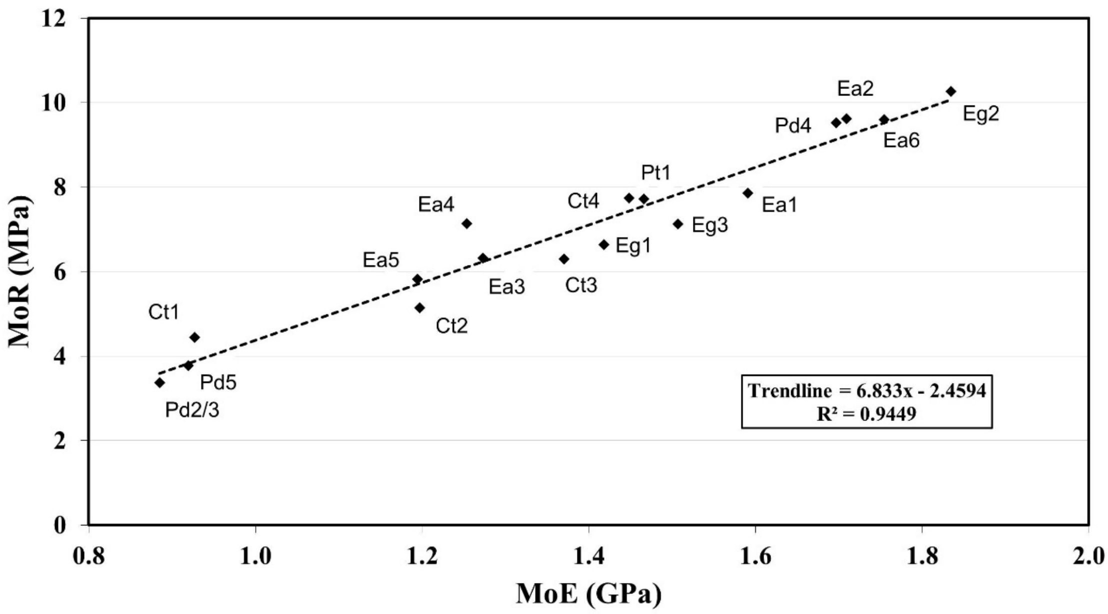


Figure 1. Relationship between average MOE and MOR of 17 S/GBs.

Table 7. Means and significance (S/GBs not sharing the same letter are significantly different) for 17 S/GBs for 6 MDF properties tested in Phase I.

S/GB	Density (kg/m^3)	TS_{24} (%)	WA_{24} (%)	MOE (GPa)	MOR (MPa)	IB (kPa)
Pt1	360	60.7	156.6	1.466 bcdef	7.72 bc	269.9 b
Pd2-3	369	45.4	137.1	0.885 bcdef	3.37 h	-
Pd4	381	58.8	145.7	1.697 abc	9.52 a	445 a
Pd5	351	41.8	130.5	0.919 gh	3.77 gh	-
Eg1	11.8	73.6	179.1	1.418 cdef	6.64 bcde	-
Eg2	6.7	76.2	186.0	1.835 a	10.27 a	272 bcd
Eg3	13.3	81.6	194.1	1.507 bcde	7.12 bcd	169 bcd
Ea1	506	70.4	168.4	1.591 abcd	7.86 b	301 b
Ea2	-	69.6	170.3	1.754 ab	9.59 a	237 bcd
Ea3	-	72.7	184.9	1.273 ef	6.32 cde	193 bcd
Ea4	529	77.9	177.2	1.254 ef	7.14 bcd	265 bcd
Ea5	527	73.0	189.2	1.195 fg	5.82 def	281 bc
Ea6	469	62.8	160.5	1.709 abc	9.62 a	488 a
Ct1	526	88.9	205.6	0.927 gh	4.44 fgh	138 d
Ct2	610	80.0	198.4	1.197 fg	5.14 efg	159 cd
Ct3	555	74.5	177.8	1.370 def	6.30 cde	263 bcd
Ct4	411	78.5	187.0	1.448 cdef	7.74 bc	225 bcd

A rank order analysis compiling ranked performance data from five properties (TS_{24}, WA_{24}, IB, MOE and MOR) ranked the 5 species and 17 S/GBs from best to poorest performance (Table 8). In Table 8, all five sets of the tested properties are evenly weighted using an "Importance Factor" (IF) of 1.0 for each of the five properties. We then repeated the ranking three additional times by first applying weights for TS and WA = 0.5, IB = 0.75, and MOE and MOR = 1.0, then ranking by weights for TS and WA = 0.6, IB = 0.8, and MOE and MOR = 1.0, and finally weights for TS and WA = 0.75, IB = 1.0, and MOE and MOR = 1.25. All four rank ordered analyses of the ranked scores for all five MDF properties consistently ranked the 6 S/GBs higher than the other 11 groups. Ea6, Pd4, Ea1, Pt1, Ea2, and Eg2 were consistently from 29% to 40% better than the next batch (overall ranked as 7th) and even much better than the others ranked from #8 to #17.

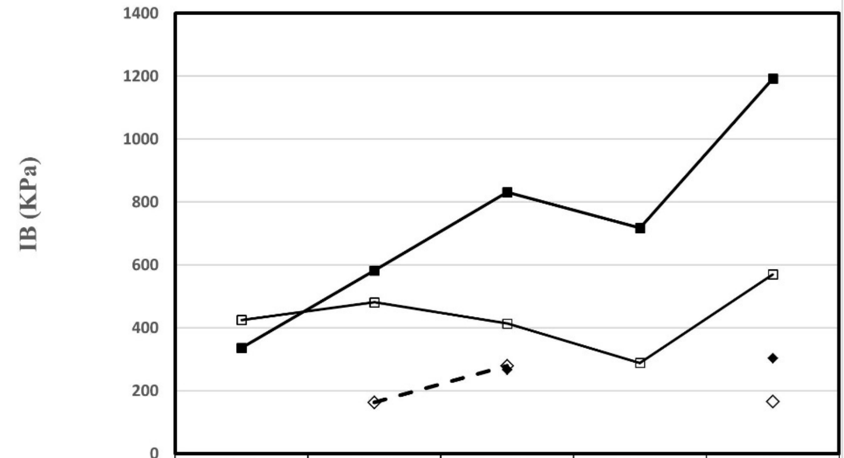
The various minimum property requirements for the evaluation of MDF panels for interior applications are listed in ANSI Standard A208.2-2016 [28]. For MDF, three grade levels are given. None of the 17 S/GBs of MDF panels tested in Phase I met the minimum requirements for MOR of interior-use MDF panels. For MOE, 12 of the 17 groups of MDF panels met the ANSI requirements of the lowest Grade 115 MDF panels, but none met the requirements for the intermediate Grade 130. Only 1 of the 17 S/GBs (Ea6) met the ANSI minimum requirement of IB. We did not compare the WA and TS requirements because no wax nor other water-repellant additives were used in the manufacture of these Phase I MDF panels. While the general results of these comparisons of MOR, MOE, and IB did not generally meet the minimum requirements for commercial MDF, these results are not entirely negative. Recalling that these initial test results are based on first-run fiber and manufacturing processes, it is quite reasonable to assume that future evaluations will have considerably higher material properties, as fiber and manufacturing processes are optimized for fiber prep, resin type, concentration and blender application, and as hot-pressing parameters are improved, more desirable panel density profiles are achieved, and performance enhancing additives are developed and used.

3.2. Phase II

Phase II involved comparisons of the two better-performing and three average-performing S/GBs, as determined in Phase I. Phase II IB testing suggests that G/SBs behave differently to the various MDF resin systems and application rates. MDF made using a tube blender for resin application was better than that made using a rotary drum blender (Figure 2). The percentage of fines when using unscreened fiber clearly negatively influenced MDF properties (Figure 3). It was also clear that the use of UF resin was far more suitable for making better MDF than PF resin (Figures 4 and 5). It is not unreasonable to think that these higher UF resin rates may be needed with these low SG woods, as such fiber density-to-MDF performance ratios are commonly used in commercial MDF manufacture.

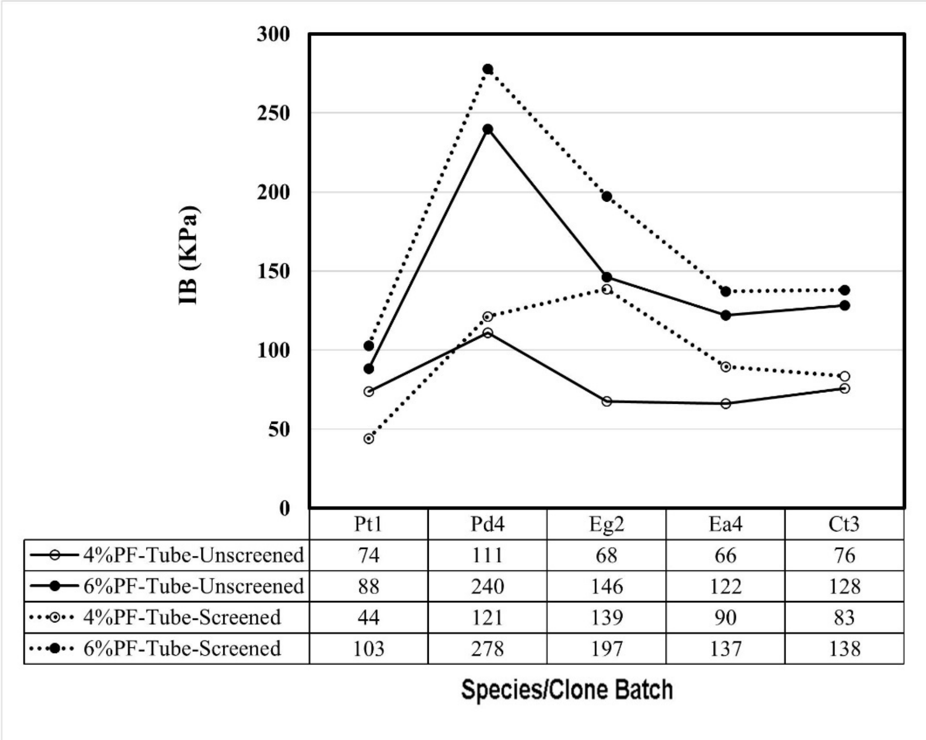
Table 8. Relative weighted rank-order analysis of five species and 17 S/GBs using TS24, WA24, IB, MOE and MOR and Importance Ranking Factors of: TS, WA, IB, MOE, and MOR = 1.0.

Species S/GB	TS24	WA24	IB	MOE	MOR	Average Rank & Factored Score	Combined Rank
Ct	**5**	**5**	**5**	**4**	**4**		
Ct1	17	17	15	15	15	15.80	15
Ct2	15	16	14	13	14	14.40	14
Ct3	11	9	8	10	12	10.00	10
Ct4	14	13	11	8	6	10.40	9
Ea	**3**	**3**	**3**	**2**	**2**		
Ea1	7	6	3	5	5	5.20	3
Ea2	6	7	10	2	3	5.60	5
Ea3	8	11	12	11	11	10.60	11
Ea4	13	8	5.5	12	8	9.30	7
Ea5	9	14	5.5	14	13	11.10	13
Ea6	5	5	1	3	2	3.20	1
Eg	**4**	**4**	**4**	**1**	**1**		
Eg1	10	10	9	9	10	9.60	8
Eg2	12	12	7	1	1	6.60	6
Eg3	16	15	13	6	9	11.80	12
Pd	**1**	**1**		**5**	**5**		
Pd2	2	2	-	17	17	-	
Pd4	3	3	2	4	4	3.20	2
Pd5	1	1	-	16	16	-	
Pt	**2**	**2**	**2**	**3**	**3**		
Pt1	4	4	4	7	7	5.20	4



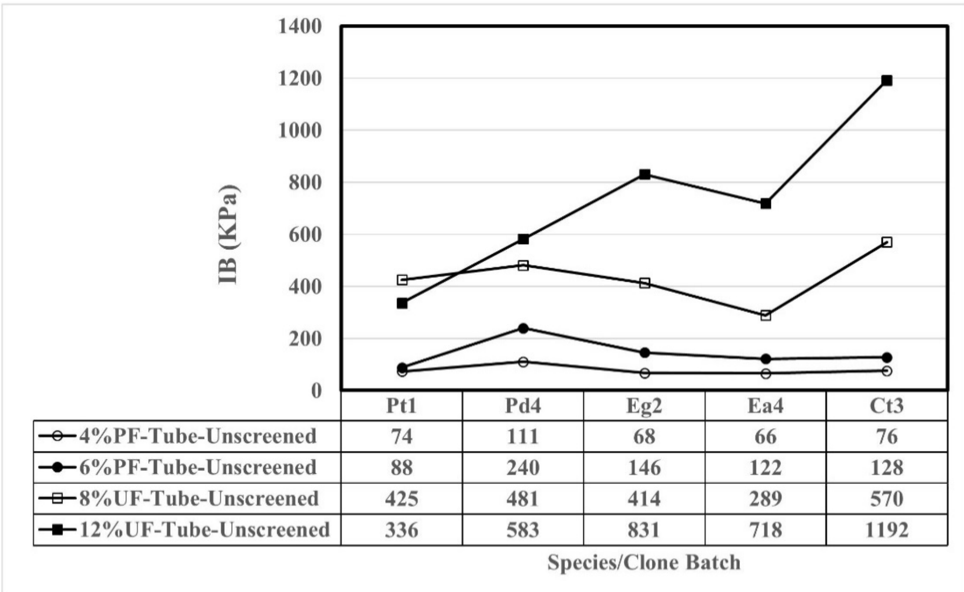
	Pt1	Pd4	Eg2	Ea4	Ct3
8%UF-Tube-Unscreened	425	481	414	289	570
12%UF-Tube-Unscreened	336	583	831	718	1192
8%UF-Drum-Unscreened		163	279		166
12%UF-Drum-Unscreened			267		304

Figure 2. Influence of UF resin at 8% or 12%, two blender types, and five S/GBs on IB in Phase II.



	Pt1	Pd4	Eg2	Ea4	Ct3
4%PF-Tube-Unscreened	74	111	68	66	76
6%PF-Tube-Unscreened	88	240	146	122	128
4%PF-Tube-Screened	44	121	139	90	83
6%PF-Tube-Screened	103	278	197	137	138

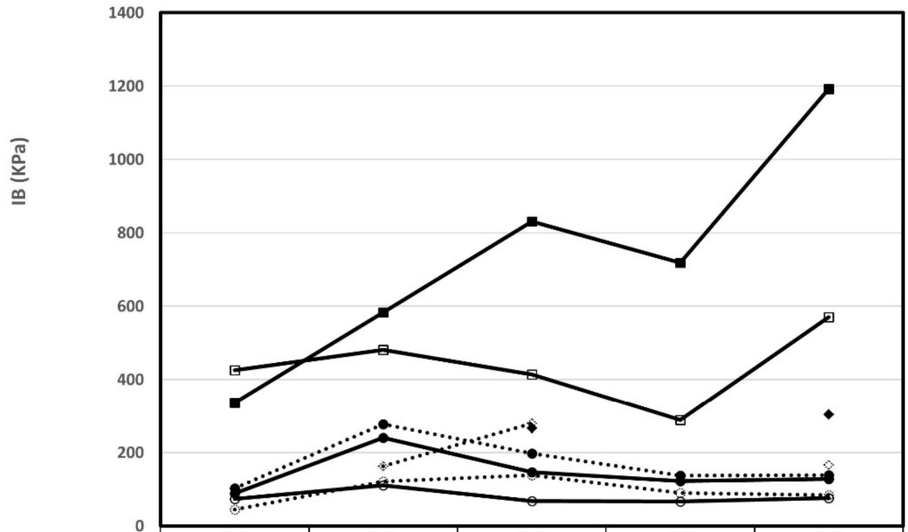
Figure 3. Unscreened vs. screened TMP fiber and S/GB influences on IB for tube-blender applied PF resin 4% or 6% in Phase II.



	Pt1	Pd4	Eg2	Ea4	Ct3
4%PF-Tube-Unscreened	74	111	68	66	76
6%PF-Tube-Unscreened	88	240	146	122	128
8%UF-Tube-Unscreened	425	481	414	289	570
12%UF-Tube-Unscreened	336	583	831	718	1192

Figure 4. Resin and S/GB influences on IB for tube-blender applied PF resin of 4% or 6% or UF resin at 8% or 12% in Phase II.

The ANSI A208.2-2016 Standard was used to assess the potential of these experimental MDF panels for commercial interior applications. The IB of Phase II panels were clearly a function of the selection of fiber- and composite-processing variables (Figures 2–5). Only 12 of 17 S/GBs met the ANSI A208.2 requirements for the lowest 115-grade of MDF; none met the next higher 130-grade for MOE. No Phase II S/GB MDF met the MOR requirements, and only 1 of the 17 S/GBs met the ANSI A208.2 requirements for the lowest 115-grade of MDF for IB. It is highly likely that many of these differences can be compensated for by optimizing refining parameters to reduce fines in the fiber content in the pulp and then improving the hot-pressing parameters, resin selection and application rates, and fiber preparation processes so that more desirable panel density profiles and in-service performance properties can be achieved.



	Pt1	Pd4	Eg2	Ea4	Ct3
4%PF-Tube Blender	74	111	68	66	76
6%PF-Tube Blender	88	240	146	122	128
4%PF-Tube-Screened	44	121	139	90	83
4%PF-Tube-Screened	103	278	197	137	138
8%UF-Tube Blender	425	481	414	289	570
12%UF-Tube Blender	336	583	831	718	1192
8%UF-Tube-Screened		163	279		166
12%UF-Tube-Screened			267		304

Species/Clone Group

Figure 5. Influences of S/GB and all processing factors on IB in Phase II.

These preliminary Phase I and II examinations of the potential for 17 S/GBs clearly showed that some have a high potential for further studies to examine their potential for commercial MDF use and possibly other fiber-based composites. More *EG*, *EA*, *PD*, and *CT* genotypes should be considered. Additional study is needed on thermal pretreatment of the wood [29] and the MDF pressing schedule [30]; especially evaluating the incorporation of nanoclay, zeolite, or cationic starch which could provide distinct benefits for OSB, MDF, and PB board production [31]. Enhancements in IB, WA, and TS and in achieving lower press energy requirements by 10–25%, depending on product specifications, are potentially possible. These additives are commercially available and are amenable to commercial applications. Finally, all additives can be readily incorporated into modern composite board production facilities. These results provide board producers new additive technologies and treatments to enhance board products while reducing energy requirements.

Based on these combined Phase I and II results, it is reasonable to assume that with future work on improving fiber and fiberboard processing, certain *EG*, *EA*, and *CT* genotypes may be suitable for use as a primary or supplement fiber source for commercial MDF and probably other commercial interior-use composite products [32,33], such as particleboard or other types of fiberboards and energy products [27].

4. Conclusions

This two-phase study of a limited number of genotypes suggests that appropriate young *EG*, *EA*, *CT*, and *PD* genotypes, with additional fiber and processes experience and improvements in refining, resin, and formation, may be used for wood composites such as MDF:

1. In Phase I, using 4% PF resin in a tube blender, there was some variation among species, considerable variation within species, minor within-tree variation, some influence of basic wood characteristics on MDF properties TS, W, IB, MOE, and MOR, and a large sampling variation for some MDF properties;
2. The top 6 of the 17 S/GB genotypes were three of the six 8.3-year-old *EA* progenies (Ea1, Ea2, and Ea6), one of the three 7- to 13-year-old *EG* clones (Eg2), one of three 3.2-year-old *PD* clones (Pd4), and the one ~55-year-old *PT* tree (Pt1);
3. Phase II, involving the six top S/GBs, provided valuable insight into the needed fiber and processes improvements. For example, MDF made with UF resin at 8% or 12% had generally better performance properties than PF resin at 4% or 6%;
4. Screened TMP fiber produced better MDF than unscreened fiber, and resin application by tube blenders made better MDF than by drum blenders;
5. Overall, genetic variation among and, particularly, within these species affected MDF performance properties;
6. Refining and MDF-making aspects have such major impacts on MDF properties that specific processing requirements are needed and must be optimized for future commercial MDF options for appropriate *EG*, *EA*, *PD*, and/or *CT* genotypes;
7. *EG* and *EA* utilization may, thus, expand from the current mulchwood market to various interior-use wood composites such as MDF and cement board;
8. These results are encouraging for the development and use of wood composites from SRWCs in Florida and the southeastern USA.

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